Lancaster University

Mixed Reality Commercial Design: Designing the Space and Interface Between Digital and Physical Environments of Purchase

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Dedicated to Mama and Maternal Grandma

Declaration

This thesis has not been submitted in support of an application for another degree at this or any other University. It is the result of my own work and includes nothing that is the outcome of work done in collaboration, except where specifically indicated. Unless otherwise stated, all images, figures, tables, and other visual content included in this thesis are the author's own work. Excerpts of this thesis have been published in the following conference manuscripts and academic publications.

Jin, L., 2025. Adopting Mixed Reality Product Customisation in Brick-and-Mortar Retail: Stakeholder Insights for Commercialisation Challenge, in: Proceedings of the 2025 ACM Designing Interactive Systems Conference. Association for Computing Machinery, New York, USA, pp. 1886–1899.

Jin, L., 2025. Comparison of Customer Experience in Traditional and Mixed Reality Fashion Shops, in: Proceedings of the 2025 Academy of Marketing Science Annual Conference. Springer Nature Switzerland. In press.

Jin, L., Fagan, D., 2024. MRPaperPro: Mixed Reality Interdisciplinary Design Prototyping Technique, in: Proceedings of the 2024 ACM International Conference on Interactive Media Experiences. Association for Computing Machinery, New York, NY, USA, pp. 268–275.

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Jin, L., Dalton, R., Fagan, D., 2023. Extended Reality (XR) Survey: A Consumer Technology Acceptance Preference Study on Retail, in: Proceedings of the 8th Colloquium on European Research in Retailing 2023. University of Portsmouth, Portsmouth, UK, pp. 207–218.

Abstract

With omnichannel retail and increasingly competitive markets, technology and digital marketing are penetrating the market to improve retailer profitability and brand image. To enhance the attractiveness of brick-and-mortar stores, retailers and brands are increasingly adopting mass customisation and immersive technologies to create unique experiences, such as Mixed Reality (MR) technology. However, MR retail is an emerging field, and the lack of empirical, theoretical, and practical guidance for its design and strategies for customer experience, store environment, and user interface leads to low market adoption and has yet to be successful in commercialisation. In response to this phenomenon, this thesis explores the requirements and challenges of the market to guide the MR retail commercial design to provide value for stakeholders.

The research indicates that the current retail market remains unprepared for MR implementation. These challenges relate to multiple issues, such as customer experience quality, market environment accessibility barriers, unavailability of open-source applications, equipment barriers, ethics and policies. However, the findings also revealed that implementing MR with brick-and-mortar stores can address customer experience challenges and obstacles observed in online or offline shopping channels. In order to create a seamless MR customer experience, this thesis proposes an MR commercial design framework – "DIDPOE": define, ideate, design, prototype, onboarding, and evaluate. It suggests that MR-based retail should enhance the practical functionality of the commercial application with ergonomic MR user interfaces, design an MR store environment, and refine MR retail assistant services to improve customer experience inclusiveness in stores. An MR Product Configurator (MRPC) prototype system and MR user interface design principles were developed to fulfil the demands of mass customisation, combined with an MR store interior environment design guideline for adopting the MRPC in commercial space. Through designing a holistic experience, consumers can obtain an efficient and enjoyable shopping experience from MR that other retail channels cannot deliver. This helps retailers promise MR retail long-term success and future MR mass retail implementation.

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Glossary of Terms

Terms/Abbreviations	Definition
Abduction	A combination of deductive and inductive reasoning is a type of inference.
Application (App)	A software program that runs on a computer to help people perform an activity.
Application programming interface (API)	It is a way for two or more computers or software to communicate with each other, a software interface that provides services to other software.
Artificial intelligence (AI)	Computer systems perform tasks by mimicking the human mind's problem-solving and decision-making abilities, usually processing vast amounts of data for predictive purposes.
Augmented reality (AR)	It refers to an immersive technology that integrates real-world and virtual information to enhance reality.
Avatar	A virtual character or creature that represents an individual on the Internet or in online games.
Between-subjects design	Each participant experiences only one condition, and group differences between participants in the different conditions are compared.
Brick-and-mortar store/shop	Refers to stores with actual physical stores where customers can shop in person.
Business-to-consumer (B2C)	It refers to a model in which businesses sell products and services directly to consumers, often online through the Internet.
Co-design	An approach to developing products with stakeholders, that is, individuals, groups, or organisations, by designing with people rather than for people.
Configurator/Toolkits	A computer program that enables a customer of an e-commerce site to configure a particular product from several choices.
Costume (fashion) jewellery	It refers to fashion accessories or decorative items, usually made from inexpensive materials such as non-precious metals, plastics, and glass, but it can also be made from pearls and metals such as aluminium and brass.
Cronbach's alpha (α)	A coefficient of internal consistency is commonly used to assess the reliability of a set of scales or test items that have been constructed or adopted.
Customer experience management (CEM)	It refers to systematic marketing strategies and technologies focusing on customer engagement, satisfaction, and experience.

Customer retention	It refers to a business's ability to keep customers making repeat purchases of its products and from switching to competitors.
Dwell time	The length of time a person gazes at a display or remains in a particular area.
Electronic commerce (e-commerce)	It is a broader concept encompassing all online transactions, referring to buying and selling merchandise and services over the Internet electronically.
Electronic retailing (e-tailing)	It refers to specific activities related to selling retail goods and services via the Internet.
Extended reality (XR)	Computer technology and wearable devices, including VR, AR, and MR, generate combinations of real and virtual environments and human-computer interactions.
Fine Jewellery	Characterised by using precious metals and stones, such as gold, silver, and diamonds.
Focus group	A research technique in which a researcher gathers a group of people to discuss a particular topic to elicit information from the participants' experiences and perspectives through moderated interaction.
Gamification	Adding and using game elements in a non-game environment, such as a website or management system, to increase participation.
Grounded theory	Grounded theory is a systematic methodology applied to qualitative research to discover new theories based on real-world data analysis.
Hawthorne effect (Observer bias)	Individuals modify or improve their behaviour in response to an awareness of being observed.
Head-mounted display (HMD)	A visual display unit mounted on the head includes a headset and a pair of goggles with a liquid crystal display.
High street	It refers to the central business street of a town or city, which has a mix of large stores and smaller shops.
Holography	A technique with a wide range of applications here refers to 3D images.
Human-computer interaction (HCI)	It refers to a design method that creates compatibility between the user, the machine, and the desired service to achieve a certain level of performance in service and optimisation.
Key performance indices (KPIs) in customer experience	The metrics of using data to improve customer experience and company financial results.
Latin square design	It is a partially counterbalanced design that helps to control for sequencing effects in within-subjects designs.
Learning effect	It refers to an effect that participants improve performance as learning occurs and become familiar with procedures and tasks.

Mass customisation (MC)	A production process or strategy that can provide personalised products and services from the large-scale provisioning of customer needs.
Metaverse	The Metaverse is an interconnected web of ubiquitous virtual worlds partly overlapping with and enhancing the physical world.
Mixed methods approach	It refers to a combination of both qualitative and quantitative methods.
Mixed reality (MR)	It refers to an existing display system that displays real environments and virtual objects.
Mixed reality (MR) store/shop	It refers to a retail environment offering MR headsets, MR technology experiences, and purchase applications as a means of shopping.
Mixed reality toolkits (MRTK)	The Microsoft-driven project provides components and features to accelerate cross-platform MR app development in Unity.
Naturalistic observation	A qualitative research method where the observer records the behaviours of research subjects in real-world settings. Observers avoid interfering with or influencing anything in a naturalistic observation.
NVivo 12	It is a software used for qualitative data analysis.
Omnichannel retail	It refers to the integration of store, online, and mobile retail into a unified whole.
Optical transmissive/see-through HMD (OST-HMD)	Optical combiners that superimpose computer-generated images on reality, displaying virtual information and real-world scenes simultaneously.
Order effects	Differences in participant responses as a result of the order in which treatments are presented to them refer to how the positioning of tasks influences the outcome.
Pain point	It refers to problems, frustration, or troublesome issues, especially those experienced by consumers, customers, or employees.
Parametric design	Could specify the key parameters of the project and make changes interactively, with the model updating automatically.
Participant observation	It refers to a research method in which the researcher immerses in a specific social setting or group, observing the behaviours, interactions and practices of the participants.
Participatory design	An approach to design that attempts to involve all stakeholders in the design process actively.
Pilot study	It refers to a small-scale test of the methods and procedures to be used on a larger scale.
Pop-up stores	Temporary stores that open for a limited period of time.

Positive affect	The internal feeling state occurs when an individual subjectively experiences a level of positive emotion while feeling satisfied.
Pragmatism	A philosophical movement or system has various forms but generally stresses practical consequences as constituting the essential criterion in determining meaning, truth, or value.
Prototypes	Prototypes are early models of a user interface or product that simulate its design and functionality to test concepts and iterate design.
Qualitative research	A research strategy includes collecting, analysing, and interpreting non-numerical data, such as language.
Qualtrics survey software	A tool used to design, send, and analyse surveys online.
Quantitative research	A research strategy involves objectively collecting and analysing numerical data to describe, predict, or control variables of interest.
Retail	Sell merchandise and services to consumers.
Return on investment (ROI)	It is a performance measure used to evaluate the efficiency or profitability of investments and calculate the monetary value of an investment versus its cost.
Reward system	The brain's reward system is a network of structures responsible for pleasure, motivation, and reinforcement learning — a collection of brain structures and neural pathways responsible for reward-related cognition.
Sales conversion	Turning potential customers into purchasing customers.
Sales turnover	It refers to the total amount of products sold during a specific period of time.
Semi-structured interview	A data collection method with a relatively detailed interview guide or schedule in which participants answer open-ended questions.
Semi-structured questionnaire	A data collection method that incorporates both closed-ended and open-ended questions.
Small and medium-sized enterprise (SEM)	Non-subsidiary, independent firms that maintain revenues, assets, or a number of employees below a certain threshold.
SPSS (IBM SPSS)	It is a structural equation modelling software that supports statistical analytical operations, predictive analytics, and decision support.
Storyboards	Deliver a story through images displayed in a series of panels, mapping the principal events of the story in chronological order.
Structured questionnaire	A document consists of a set of standardised questions with a fixed scheme specifying the

	exact wording and order of the questions for gathering information from respondents.
Tangible user interface (TUI)	It refers to user interfaces where a person interacts with digital information through the physical environment.
The People's Republic of China (China)	China is a communist nation that covers a vast territory in eastern Asia.
Touchpoint	It refers to the various modalities through which consumers interact with a brand, including verbal (e.g., advertising) and nonverbal (e.g., product use) events.
United Kingdom (UK)	The United Kingdom of Great Britain and Northern Ireland is an island country located northwest of mainland Europe.
Unity	A 3D development creative platform gives content creators the tools to create 2D, 3D experiences.
Usability testing	Refers to performing meaningful task activities for the user while observing them using the product.
User experience (UX)	It refers to all aspects of the end-user's interaction with companies, services, and products.
User interface (UI)	Refers to the visual layout of a website when the user interacts with the computer.
User-centred design	User problems are solved by prioritising the needs of users.
Virtual reality (VR)	It refers to a suite of technologies that allow people to experience a world beyond reality in a fully immersive manner.
Within-subjects design	The same participant tests all the conditions corresponding to the variable.

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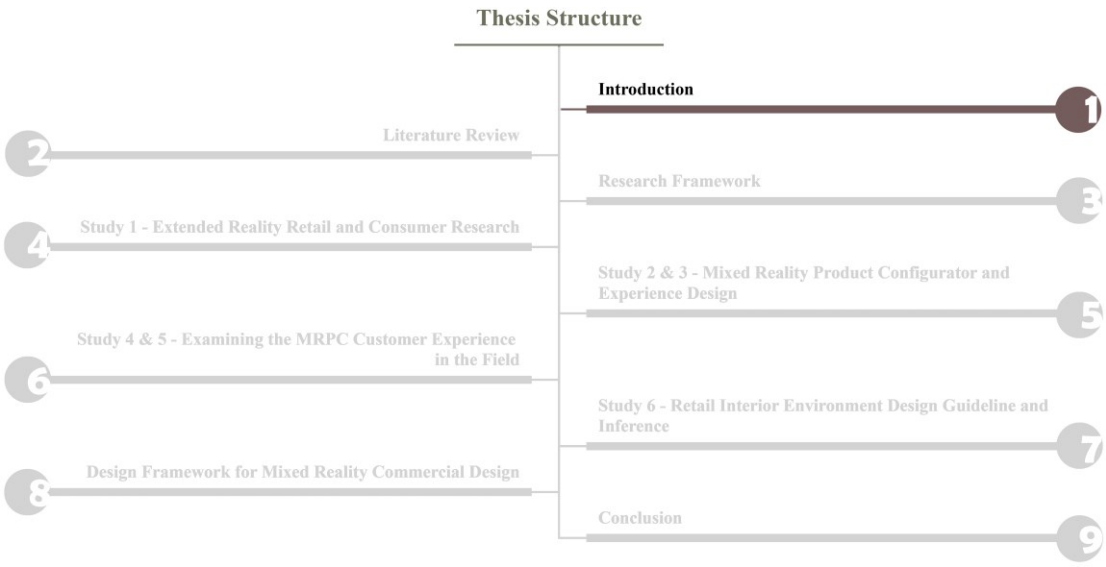
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1 Introduction



1.1 Background

Retail high streets play a vital role in the economy and social infrastructure of cities. Nevertheless, since 2009, retail shopping streets have been severely damaged, in the United Kingdom (UK), the United States (US), and Europe. Since 2013, town centre footfall has been declining and has fallen by 17% over the last decade (Grimsey *et al.*, 2018, p. 16). In particular, in 2020, 54 companies closed down, 5,214 stores were affected by these closures, and 109,407 employees were affected by the pandemic (Centre for Retail Research, 2022). The fashion industry has been particularly impacted; sales were 15% lower in 2021 than in 2019, even though they increased by 15.1% in 2021. McKinsey & Company, a global management consulting company, indicates that global luxury fashion sales were set to grow from 5% to 10% in 2023, while other industries were set to grow from minus 2% to plus 3%. Consequently, nearly 75% of the executives surveyed planned to simplify their inventories by reducing the number and variety of products (McKinsey & Company and Business of Fashion, 2022). The global fashion industry was due to achieve revenue growth of 2% to 4% in 2024, and the outlook for 2025 is likely to continue the downturn of 2024 (McKinsey & Company and Business of Fashion, 2024). This highlights the continuing challenges facing the fashion retail industry and the limited optimism with regard to recovery.

Conversely, sales in hardware, DIY (that is doing it yourself rather than buying services or ready-made products), paint and glass stores increased by 14.3% in 2020 and 13.6% in 2021, with sales in the DIY and hardware sector increasing by 29.9% compared to 2019 (Centre for Retail Research, 2022). Furthermore, the total retail sales in the UK are expected to reach £599.07 billion by 2025, with nearly one-third (30.7%) of purchases taking place online (eMarketer, 2025). These reflect the rise of convenience culture (refers to fast and convenient lifestyles such as automated services and self-service) and an increase in e-commerce (the trading of goods and services online), indicating a shift in consumer behaviour (Wrigley et al., 2015). As suggested in a report by McKinsey and Business of Fashion (2021), digitalisation, sustainability and customer engagement are the three most promising factors for growth in the future (McKinsey & Company and The Business of Fashion, 2021a). This highlights the

ongoing digitalisation of the retail industry and enhances customer engagement to remain competitive.

To remain competitive, many medium to large-scale stores are seeking innovative experiences, such as investing in immersive technology – eXtended reality to stimulate the industry (Hagtvedt and Chandukala, 2023). Brick-and-mortar stores – physical locations where customers shop in person – must adopt innovative strategies to enhance the consumer experience and reignite interest in in-person retail. The development of immersive technology – *eXtended Reality (XR)*, which includes *Virtual Reality, Mixed Reality and Augmented Reality,* has played a significant role in the future retail industry (Hagtvedt and Chandukala, 2023).

- **Virtual Reality (VR):** This presents digital content that is either simulated or based on real-world content. Users are isolated from the real world through Head-Mounted Displays (HMDs) and can only interact with the presented digital content (Cruz-Neira, 1998).
- **Augmented Reality (AR):** Users are able to see digital information superimposed on the real-world environment (Flavián et al., 2019). Through the operation of smart devices, users interact with digital content and view an augmented world that is near physical reality. In this thesis, it refers to mobile AR (Rauschnabel et al., 2024).
- **Mixed Reality (MR):** MR refers to immersive AR (iAR) or wearable AR in this thesis. It presents visual effects by overlaying digital information in the real world (Rauschnabel et al., 2024). The main distinction lies in deeper immersion than mobile AR, as it directly interacts with virtual content using HMDs in reality and reacting to constantly changing virtual environments. The fusion and overlay of real and virtual worlds create a new environment in which physical and digital objects interact and coexist in real-time (Speicher et al., 2019).

Immersive technology has helped the retail industry address challenges such as retail returns through innovation, such as the creation of virtual try-on shopping, virtually previewing interior furniture and furnishings, and bespoke products. XR technology, as one of omnichannel retail, has made shopping more efficient and enjoyable and improves consumer conversion by pushing retailers to engage consumers through a diverse, multi-channel approach (Xi and Hamari, 2021). Omnichannel retailing is a

highly integrative retail approach that responds to consumers across multiple channels, such as brick-and-mortar stores and online (Wilding, 2013). Adopting XR interactive technology promises to heighten the physical impact of brick-and-mortar retail by enhancing the in-store experience, satisfaction, shopping enjoyment, and product information (Burke, 2002; Erensoy et al., 2022).

Some industries have adopted AR. IKEA Studio allows users to view the effects of virtual interior furnishings via their smartphones through an AR app. Retail brand ASOS used AR to try clothes on models virtually, tackled the problem of stock accounting, and helped reduce the number of returns. Its revenue grew by 24% in the six months until 2021 as a result of this innovation (Gilliland, 2021). There was a 20.7% increase in browsing time of customers using AR in the cosmetics category; 1.28 times more products were viewed, and there was a 19.8% higher purchase rate than among those who did not use AR (Tan et al., 2022a). However, product design is sometimes more in line with designers' tastes than the demands of the users (Hsu, 2012). Therefore, many brands involve customers in the product design process using product configurators to mass customise, increasing customer satisfaction with the product and thus saving on time and cost consumption (Bachvarov et al., 2009). For example, a car brand, BMW, provides an AR modular configurator to enable consumers to personalise their products. Mass customisation can provide a module method, allowing customers to participate in the design process, launch a wider variety of products by personalising certain features, shorten product lifecycles, and accelerate product development times (Alford et al., 2000).

As an innovative form of interaction, MR provides customers with a multisensory immersive experience and encourages the rethinking and redefining of the future omnichannel retail development (Alexander, 2024). However, this purchasing and experiential approach is still a relatively new concept for retail. The adoption of MR technologies in brick-and-mortar stores still remains in many undeveloped areas, such as the design of mass customisation-based user interfaces, store environments that can implement MR, and inclusive customer experiences. Therefore, this thesis aims to provide a design framework for a more accessible customer experience in an integrated store environment and MR application to support broader public adoption.

This thesis suggests a design framework and a series of practical methods for the integration of MR technology in actual retail settings by using the jewellery industry as a pilot. It focuses on: *a) the design guidelines for MR retail store interior design*; *b) the design of ergonomic MR interfaces for mass customisation in physical environments for retail purchases*; and *c) a commercial design framework for MR customer experience implementation in brick-and-mortar stores.* The thesis integrates the knowledge of the fields of retail, design, and human-computer interaction (HCI), and uses MR technology to design and research that helps retailers better understand the needs of consumers and helps consumers become more engaging, thus moving retail stores into the future.

1.2 Research Problem Statement

The trend of omnichannel retail implies the growing integration of online and offline retail. As one of the retail channels, brick-and-mortar retail needs to adopt immersive technology such as mixed reality to enhance in-store experiential stimuli and activate the vitality of brick-and-mortar store purchasing. Therefore, it is necessary to explore the future role of MR retail channels and to recommend holistic MR commercial design frameworks to direct design implementation. Current research on MR and retail lacks data on user markets, mass customisation applications, physical environment design and MR commercial strategy. These are all significant reasons for the lack of large-scale adoption in the market.

1.3 Research Aim

This research aims to provide value for designers, retailers, consumers, and researchers from a design perspective by adopting MR to enhance the customers' in-store shopping experience, purchasing power, and retailers' market competitiveness. It explores an effective framework to implement large-scale MR brick-and-mortar store commerce design by developing an MR commercial user interface and store environment design, assisting retailers in planning management strategies and services.

1.4 Research Questions

According to the aims of this research, this thesis answers and addresses the following research questions (see also Section 3.2):

Meta Question (Chapter 8): How is it possible to design accessible customer experiences in mixed reality retail environments for brick-and-mortar stores?

Research Question 1 (Chapter 4): What is the feasibility of, and user preference for, mixed reality adoption in the retail industry?

Research Question 2 (Chapter 5): How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments?

Research Question 3 (Chapter 6): What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops?

Research Question 4 (Chapter 7): How is it possible to design inclusive mixed reality retail interior design guidelines for diverse demographics?

1.5 Significance of the Study

The field of MR research is highly fragmented, with most studies examining niche topics from a single disciplinary perspective (Rauschnabel et al., 2024). A comprehensive MR commercial design framework to help plan and develop future research would be beneficial in guiding the development of realistic MR retail projects, brand planning and its effectiveness. The framework encompasses contextual scenarios and methods that can benefit individuals regardless of their background and experience. It will benefit the following groups of the community:

DESIGN: Interior, User Interface, User Experience, and Product Designers. Based on the design recommendations, interior designers will be able to design less accessible and more inclusive MR interior spaces. UI and UX designers can understand MR headset user behaviours and requirements to design better MR interaction and interface

content. Product designers will be able to understand their responsibilities during application design development better and employ the proposed MR paper prototype toolkit to co-design with the customers' and UI designers' participation.

RETAIL MANAGEMENT: Retailers, Companies, Customer Experience Managers, and Product Managers. Retailers will be able to determine the types of retail and consumer genres suitable for implementing mixed reality technology to target the market and potentially achieve maximum profits. Additionally, they will be able to plan marketing strategies in advance based on user feedback on product development and technology acceptance predictions. The suggested framework will allow them to evaluate investments, plan their brand strategy and services, and manage the work of design and software development teams.

SOFTWARE DEVELOPMENT: Mixed Reality Developers and Software Engineers. The product configurator design recommendations provide developers with insights into current consumer market demands, foundational development documentation, and case studies for reference. They equip developers with an approach and requirements for effectively developing a relevant MR commercial system.

FACTORY: Manufacturers and Producers. Brands will achieve higher product satisfaction through product configurators, potentially reducing return and exchange rates. Manufacturers and producers will be able to understand MR-based business procedures and carry out robust product manufacturing and assembly business planning.

POLICY AND ACADEMIA: Policy planners and Researchers. Through comprehensive research reports, policymakers and urban planners will be able to use these contexts as reference guidance for planning city business centres and economic development areas. Researchers will be able to use these research directions and experimental procedures to construct and replicate relevant study experiments.

1.6 Thesis Structure

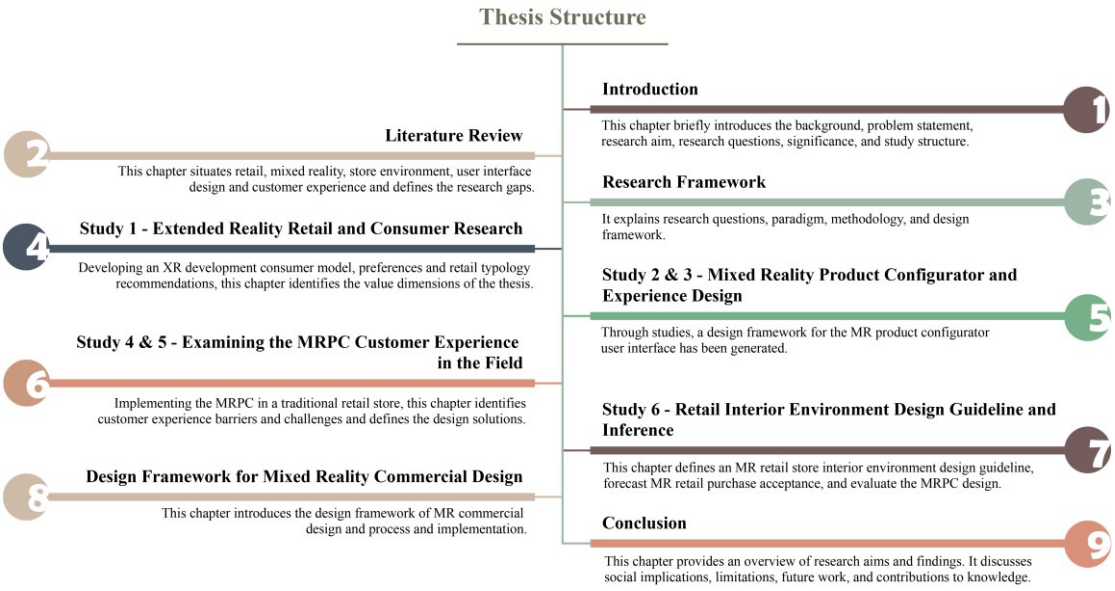


Figure 1.1 Thesis structure

Figure 1.1 illustrates the thesis structure, and a brief overview of each chapter is provided below. The thesis consists of nine chapters, and the research questions are addressed by conducting six studies.

Chapter 1 Introduction. The chapter briefly outlines the research context, problem statement, research aims and significance of the study.

Chapter 2 Literature Review. This chapter examines the adoption of immersive technology in the retail market, integrating empirical evidence from practice with interpretive insights from research literature. The review highlights that MR retail purchases and a well-designed MR store environment are effective commercial strategies for enhancing the customer experience in brick-and-mortar stores. Through a comprehensive literature review, this chapter identifies ten research gaps in order to achieve this research aim.

Chapter 3 Research Framework. This chapter elaborates on the philosophical perspectives, research paradigm, methodology, and research methods utilised to achieve the thesis aims. A research framework is proposed to address how to convert the mixed

reality brick-and-mortar purchase experience into workable research strategies. Design research methods are then applied to underpin and instruct the thesis research.

Chapter 4 Study 1 – Extended Reality Retail and Consumer Research. This chapter employs quantitative research by conducting a consumer market survey (n=807) to collect consumer demographics, preferences, and intentions to determine the feasibility of mixed reality technology for retail. It identifies the demand, dimensions of value, and design development directions for MR, AR, and VR in retail. It also defines the research motivation and scope of this study, which provides the knowledge and data support for the subsequent experimentation sections of the research.

Chapter 5 Study 2 & 3 – Mixed Reality Product Configurator and Experience Design. The chapter includes two studies. The first study engages consumers to iterate the user interface and product configurator design through three participatory 2D prototype tests (n=15). Then, through semi-structured interviews to involve related stakeholders (retailers, consumers, UI and UX designers, and XR experts), it investigates the considerations and customer and retail genres of MR retail experience for mass adoption in the market (n=26). It highlights the significance of store environments and holistic design and iterates the 3D MRPC design. Finally, this chapter proposes the Mixed Reality Product Configuration (MRPC) application design specification for mass customisation in brick-and-mortar stores.

Chapter 6 Study 4 & 5 – Examining the MRPC Customer Experience in the Field. This chapter conducted two fieldwork studies in a contemporary fashion retail store in London, UK. Study 4 employs a naturalistic observation approach to compare the consumer experience journey in a traditional retail store and the MR in-store experience. Study 5 used a triangulation observation approach (observations, questionnaires, an interview) (n=68) to observe customer behaviours through customer engagement with the MRPC experience in-store. The finding identifies adopting MR in current traditional brick-and-mortar stores' lack of user experience quality, which means the MR experience is less accessible to use in stores. The design factors that influence MR retail experience quality include three aspects: interior atmosphere (8 factors), retail MR system design (4 factors) and space users (MR HMD users, retail assistants, user companions, and third-party customers). As a result, this chapter suggests designing an

inclusive and accessible interior environment for MR retail stores based on the above factors and improving the service quality of MR retail assistants.

Chapter 7 Study 6 – Retail Interior Environment Design Guideline and Inference. This chapter uses a quantitative research methodology to conduct an empirical field-built study through a within-subjects experimentation approach (n=64). The chapter identifies MR store interior environment design guidelines for implementing MR in retail stores, including seven design factors for colour, light illuminance, colour temperature, merchandise display, privacy, spatial ratio, and spatial dimensions. Guidelines are provided for interior designers to design inclusive MR retail spaces, considering technology accessibility, customer preferences, and demographics.

Furthermore, through experimentation, this study proposes an MR customer retail purchase acceptance model that interprets the influence of UI design, perceived usefulness and ease of use, and attitude on consumer technology use behaviour and purchase intent. It emphasises the importance of utility and hedonic nature in the MR experience. This chapter provides designers, practitioners, and companies with instructions on design guidelines, investment practicability, and interpretability.

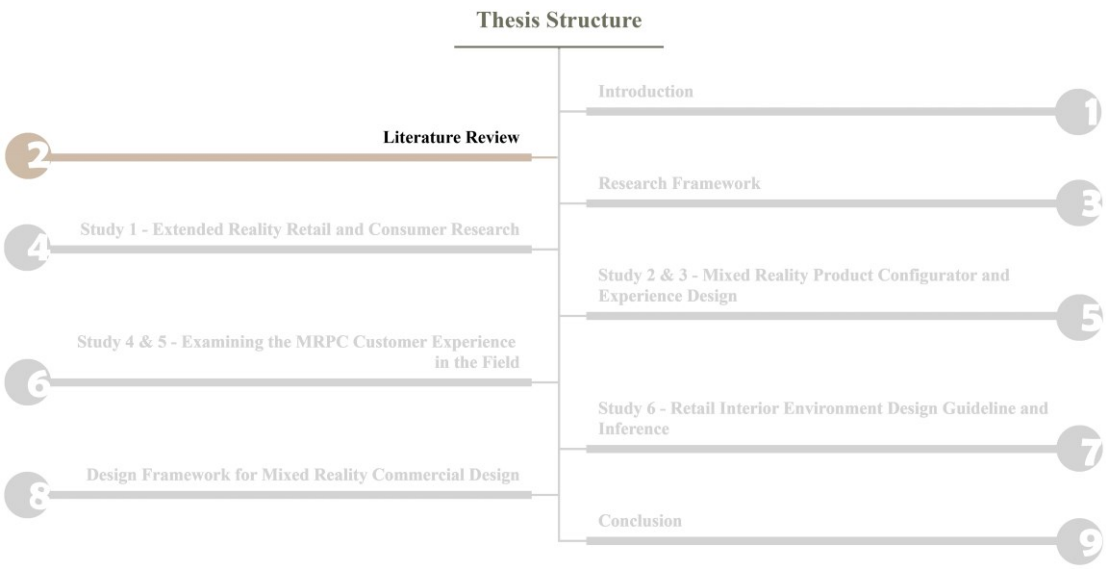
Chapter 8 Design Framework for Mixed Reality Commercial Design. This chapter integrates the findings of the six studies and generates the research output – *Mixed Reality Commercial Design Brochure: Design the Space and Interface for Commerce Mixed Reality in Brick and Mortar Stores* (see Appendix F). This MR commercial design framework is proposed as "DIDPOE": Define, Ideate, Design, Prototype, Onboarding, and Evaluate. It delivers a holistic design loop and aims to achieve an accessible MR customer experience in brick-and-mortar stores. This chapter elaborates on what this design brochure is, how it can be applied, and relevant readerships of practitioners (a retail manager, interior designer, product (jewellery) designer, MR software engineer, and product manufacturer) insights for the design brochure.

Chapter 9 Conclusion. The concluding chapter recaps the research objectives, answers research questions, summarises the social implications, limitations and directions for future work, and discusses knowledge and practical contributions.

1.7 Chapter Summary

This chapter introduced the relevant background, research scope, research purpose and significance of the study. Thematic concepts used in this thesis are explained as ***store interior environment design, retail product configurator, participatory customer experience,*** and the adoption of ***mixed reality*** to improve them. It introduced the need for an MR commercial design framework that facilitates the implementation and mass market adoption of MR brick-and-mortar stores. It stated the problems, summarised the aims of the thesis, and raised the research questions, which guided research throughout the remaining chapters. The next chapter will provide insights into these key concepts through a literature review and identify research gaps that should be addressed.

2 Literature Review



2.1 Introduction

This chapter presents a literature review of the scope of the thesis based on concepts of *mixed reality*, *retail configurator design*, *store interior environment design*, and *customer experience*. It also discusses current challenges facing the fields, including design practices, theories, and measures that can undertaken to address social issues. By addressing the issues, this chapter introduces the context of the thesis research and identifies research gaps.

2.2 Extended Reality in Omnichannel Innovative Retail

2.2.1 Innovation Channels of Omnichannel Retail: Extended Reality

With the synergy of online and offline retail, traditional and online retail have evolved towards omnichannel (Verhoef et al., 2015). Online shopping is defined as the transaction stage where purchases and logistics are performed over an internet shop (Perea y Monsuwé et al., 2004). Offline shopping refers to visits to brick-and-mortar stores (actual physical stores where customers can shop in person) to purchase products and physical experience methods. Omnichannel retail refers to the integration of store, online, and mobile retail into a unified whole (von Briel, 2018), and it encompasses all channels of retailing.

A large majority of people shop online, and even though stores have reopened post COVID-19, online demand remains robust (Mintel Reports, 2020). Electronic commerce (e-commerce) is the trading of goods and services online and has influenced consumer shopping habits, moving consumers from physical retail to online retail. This shift has had a significant impact on high street retail (Thakur, 2018), particularly, the impact of COVID-19 on the global economy has forced consumers to rely on e-commerce retail even more.

In contrast to the downturn in physical retail, online retail sales have grown significantly. Global electronic retail revenues will grow to $8,034 billion by 2027, up from $3,351 billion in 2019 (eMarketer, 2023) (Figure 2.1). While global online retail growth has

outpaced offline retail, interactive technologies (AR, VR) in physical stores are expected to drive physical retail growth, projected to grow by 5.1% by 2024 (GlobalData, 2024). A report showed that 71 per cent of customers typically spend more than $50 when shopping in-store and 54 per cent when shopping online (First Insight, 2019). 34 per cent of customers reported spending more than $100 during a typical in-store shopping trip, compared to only 21 per cent, who reported spending more than $100 when shopping online (First Insight, 2019). This indicates that customers are willing to pay more in physical stores while spending less online.

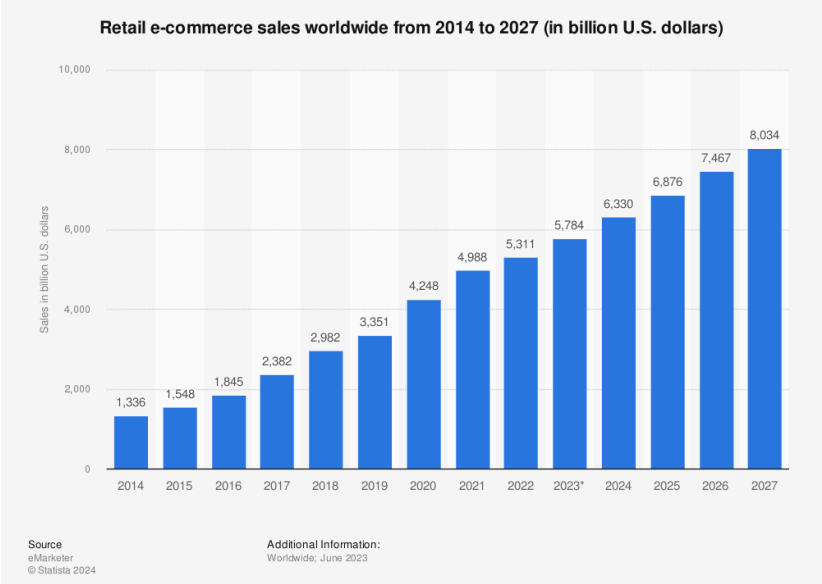


Figure 2.1 Retail e-commerce sales worldwide from 2014 to 2027 (in billion U.S. dollars), eMarketer (2023)

A study conducted in the United States (US) proved that consumer dissatisfaction with the shopping experience in existing brick-and-mortar retail stores originates from shopping speed, quality of service, availability of product information, enjoyment of shopping, security and privacy (Burke, 2002). Customer satisfaction, which means the difference between customer needs and expectations, has been considered a measure of customer retention to gauge the potential for repeat purchases (Jones and Sasser, 1995). Customer retention refers to a business's ability to keep customers making repeat purchases of its products and from switching to competitors (Sashi, 2012). The relationship between satisfaction and retention depends on the consumer type, and consumer demographics (education, gender and age) will directly affect the

transformation of satisfaction to retention (Mittal and Kamakura, 2001; Rao et al., 2011). For the same satisfaction rating, females are the group with the higher intrinsic retention rate, valuing service quality 33% more than males and consistently having a higher probability of repurchase than males; higher educated consumers (college and above) tend to have lower retention rates than high school or less educated groups; and older customers (60 years or older) may have a higher probability of repurchase than younger consumers due to more stable preferences (Mittal and Kamakura, 2001). Therefore, customer satisfaction is one of the considerations for store sustainability to attract customers to purchase.

Dwell time, the length of time a consumer effectively stays in a store, has been found to have a significant positive correlation with sales, with a 1% increase in dwell time associated with a 1.3% increase in sales (McAdams and Biggar, 2007). However, dwell time also needs to be interpreted in relation to the level of crowdedness in the store; delayed or waiting dwell time does not lead to customer satisfaction (Hui and Bateson, 1991). Effective dwell time means that consumers are highly engaged with the space. For example, the time and distance consumers travelled inside a store were validated to correlate with unplanned purchases, and in-store technology usage prolonged their journey duration (Hui et al., 2013). Ultimately, the way brands leverage technology to enhance consumption values will shape their market's potential (Pantano et al., 2018).

Alongside this, advances in technology have significantly contributed to the transformation of the retail market in another direction, namely, immersive, innovative retail. Researchers who study the future development of retail believe that virtual reality will be the next disruptive innovation in the retail market (Wang, 2016), as it gives people the opportunity to experience a world beyond reality in a fully immersive environment (Berg and Vance, 2017). However, some established retailers calculate factors including return on investment (the profit for a period compared with the amount invested), payback period (the minimum time taken to recover investment costs), net present value (sum of the present value of cash inflows and outflows over a period), internal rate of return (a metric used to estimate the return on investment), and impact on profitability before deciding to invest in new technology (Inman and Nikolova, 2017). Upfront market research on technology selection and evaluation will be essential to investment considerations.

Some pioneering industries and enterprises have embarked on an exploration of the development of the XR channel. A worldwide report forecasts a growing trend in industry spending on XR in the global retail market (Accenture, 2019) (Figure 2.2). 98.6% of enterprise users reported that they are considering investing more in XR in the next few years, 65.7% are confident that they will invest in the future, 22.9% reported that it is possible but is still in the testing stage, and 10% reported that they are unsure (VR Intelligence, 2019). Consumer and enterprise AR (including MR) headset hardware and software revenues reached $3.8 billion in 2022 and are estimated to increase to $35.1 billion by 2026 worldwide (ARtillery Intelligence, 2022) (Figure 2.3). Global revenues for the AR hardware Business and Consumer (B2C) market are forecast to grow between 2024 and 2029, totalling $5.4 billion (+85.31%) and reaching a new peak of $11.75 billion in 2029 (Statista, 2024) (Figure 2.4). These statistics indicate a steady to positive trend in retail AR/MR hardware and software development and research.

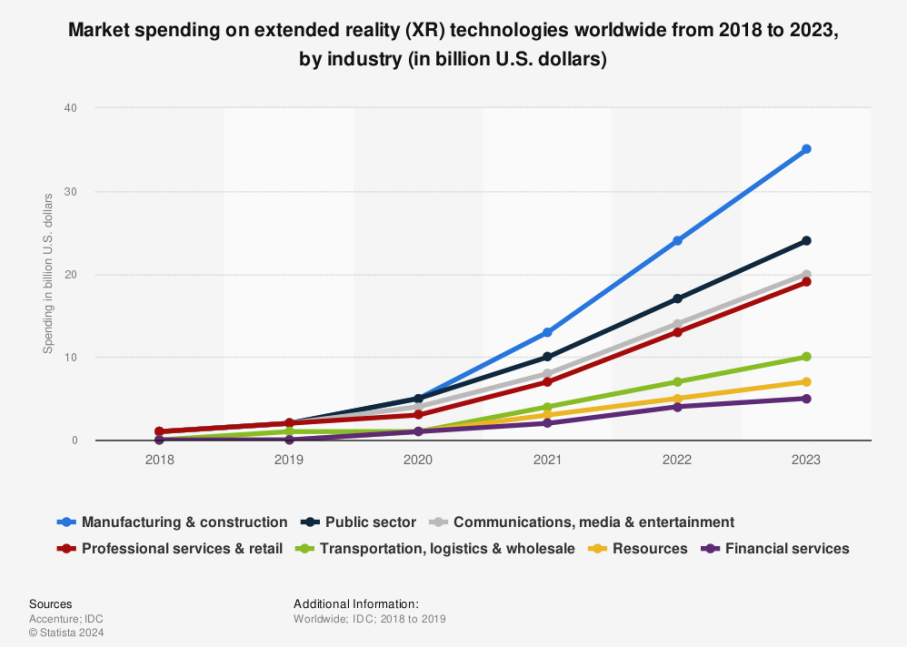


Figure 2.2 Global market spend on extended reality (XR) technologies 2018-2023, by industry, Accenture (2019)

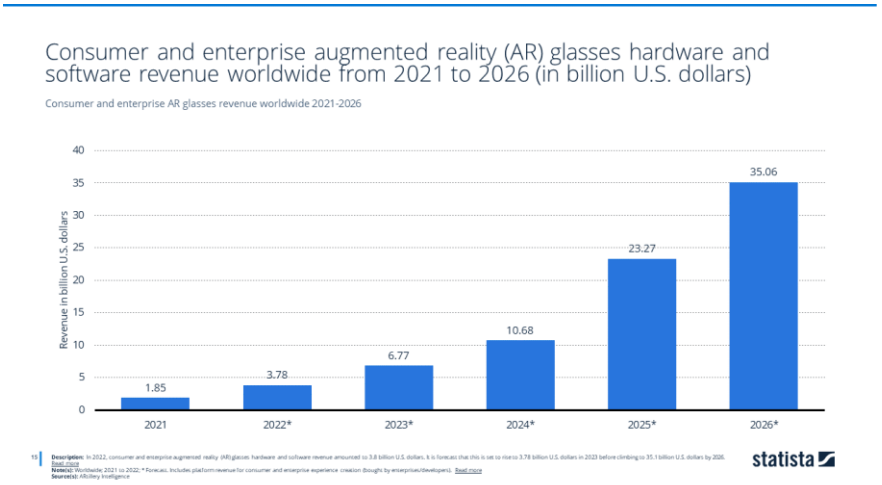


Figure 2.3 Consumer and enterprise AR glasses hardware and software revenue worldwide from 2021 to 2026 (in billion U.S. dollars), ARtillery Intelligence (2022)

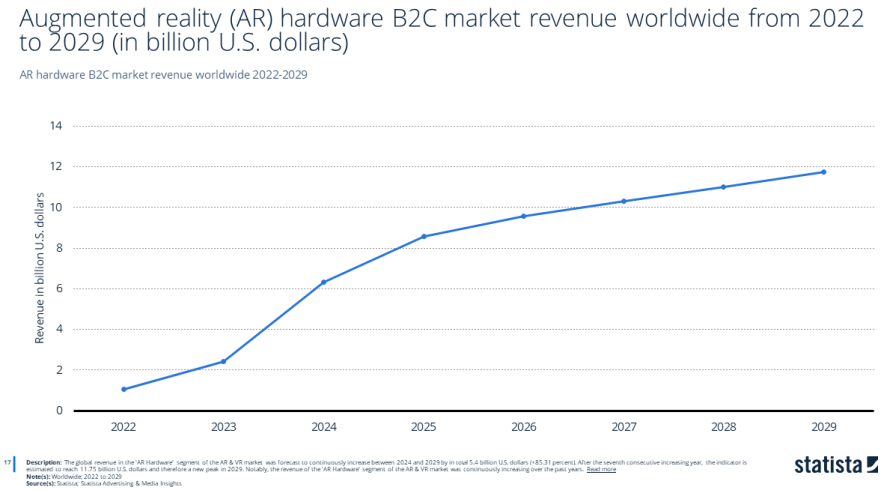


Figure 2.4 AR hardware B2C market revenue worldwide from 2022 to 2029 (in billion U.S. dollars), Statista (2024)

In summary, the above data provides a concise overview of the state of the retail industry. The pandemic has led to the closure of many brick-and-mortar stores, and the diversity of omnichannel retailing has provided consumers with more channel choices. Still, it has also exacerbated customer churn in brick-and-mortar retailing. The prevalence of omnichannel retail has called on retailers to engage consumers through diversification and increase consumer retention. The immersive in-store experience has become one of the unique manifestations of omnichannel retailing through offline retail integrated with online technology. Adopting extended reality technologies promises to enhance the real estate impact of brick-and-mortar retail through enhanced in-store

experiences, shopping enjoyment, and additional product information. The next section will further outline existing studies and the adoption of extended reality in the retail market.

2.2.2 Definition of Extended Reality

Extended Reality (XR) is the umbrella for all types of current and new realities, such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) (Adriana Cárdenas-Robledo et al., 2022; Rauschnabel et al., 2022a). ***VR*** has been defined as fully immersive, multisensory, user-centred, highly interactive, three-dimensional (3D) computer-generated environments and the technologies that construct such environments (Aukstakalnis, 1992; Cruz-Neira, 1998). ***AR*** has been defined as a range of technologies that integrate real-world and virtual information to enhance a specific reality (Lamantia, 2009; Milgram and Kishino, 1994). AR involves the use of a non-immersive display-based interaction on which computer-generated images are overlayed electronically or digitally (Milgram and Drascic, 1991). In this thesis, AR is used to refer to mobile AR, which is a near-physical reality (Microsoft, 2022; Rauschnabel et al., 2024). ***MR***, also known as immersive AR (iAR) or wearable AR, has been defined as a highly interactive existing display system that displays both real and virtual objects (Microsoft, 2022; Rauschnabel et al., 2024; Zhang et al., 2021).

MR has high levels of immersion and local presence, which users can feel "being there"; AR has low levels of immersion and local presence, which is more "functional" integrated virtual content, such as textual information (Rauschnabel et al., 2022a). VR has high levels of immersion and telepresence, which refers to the degree to which users perceive themselves as being in the virtual world, independent from their actual reality (Rauschnabel et al., 2022b). The MR interaction requires specific equipment or wearable hardware, namely, head-mounted displays (HMDs) (Speicher et al., 2019). Based on the above definitions, Figure 2.5 adapts and represents the difference between VR, AR, and MR (Rauschnabel et al., 2024; Speicher et al., 2019; Technolush, 2019).

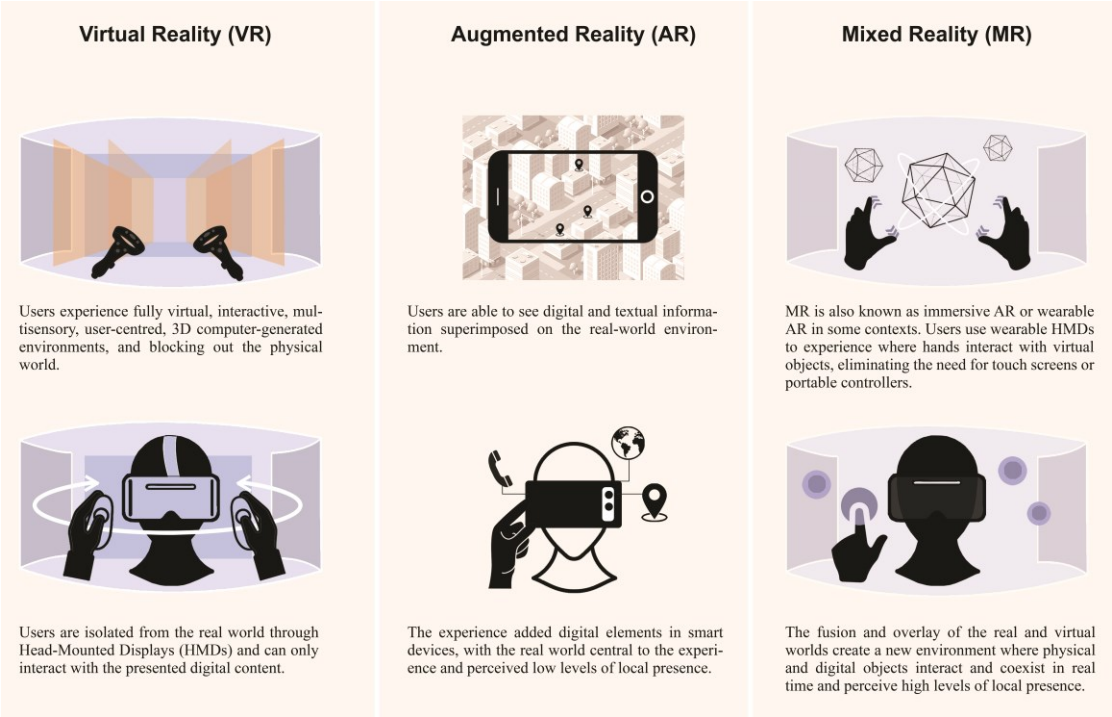


Figure 2.5 Differences in comparison of AR, MR and VR. Adapted from Rauschnabel et al., 2024; Speicher et al., 2019; Technolush, 2019

The retail potential of MR lies in its ability to combine *embodied interaction*, *postdigital spatiality*, and *tangible user interfaces (TUI)*. These capabilities enable physical products to be integrated seamlessly with digital content, like how customers have brought virtual elements into the physical environment.

Embodied Interaction

The dual potential of MR enables physical products to integrate with digital content, transforming users' perception and interaction with the physical world. Studies indicate that experiences blending real and virtual objects help users better integrate the virtual and real worlds, thereby generating a sense of embodiment – the perception that a virtual body or avatar is an extension of one's own physical body (Genay et al., 2021). By embedding tangible interactions within spaces and enabling embodied experiences within spaces, it is revealed that the configuration of objects and space can influence social interactions by strategically guiding behaviour (Hornecker and Buur, 2006). When customers reflect digital cues through behavioural actions, such as walking, picking up products, or configuring items within their perception of the physical

environment, digital embodiment assists them in better integrating digital information into their mental models of the environment, yielding a heightened sense of presence (Chylinski et al., 2020). This postdigital spatiality retail, which intuitively and user-centred merges physical and digital elements, evokes affective experiences (Heller et al., 2021). Through tangible user interface (TUI) and spatial experience design, this thesis highlights how affective design achieved through embodied interaction creates memorable postdigital spatiality experiences within the experience economy.

Postdigital Spatiality

This experience economy shifts emphasis from product or service attributes towards the situational affordances of participation (Heller et al., 2021). This also explains the role of post-digital spatiality in retail environments, where the digital and physical worlds are not separate spatial experiences but are intertwined. When merging virtual content, it is essential to consider the nature of the surrounding environment to maximise users' sense of embodiment (Genay et al., 2021). When designing applications, evoking positive user emotions directly influences the intention to use AR, thereby affecting purchasing intent (Soon et al., 2023). Postdigital consumption emphasises more thoughtful consumption, such as personalised customisation that fosters a direct connection between customers and products (Humayun and Belk, 2020). The postdigital spatiality environment offers digital devices, embodied interaction capabilities, affective engagement, and service connections, enabling the creation of unique and memorable experiences within a digital economy.

Tangible User Interfaces

The positioning of MR in retail spaces is not merely an overlaying technology but a technology capable of simulating and extending physical experiences. This understanding and practice form the foundation of the design philosophy in this thesis: an integrated approach that unifies digital interface design and physical spatial planning (Jin, 2025). This holistic experience is enhanced through embodied interaction and the transition between TUI (Chylinski et al., 2020). TUI design should consider a user-centred approach, technological features, and retail integration (Ricci et al., 2025), in order to reduce digital exclusion and support the feasibility of a participatory economy.

The following section contextualises the situation of VR, AR, and MR in the retail sector by comparing and illustrating their practical applications and the state of research, explaining the implications for these studies and addressing the existing research gaps.

2.2.3 Virtual Reality in Retail

The origins of virtual reality can be traced back to the 1960s (Sutherland, 1965). It was not until the mid-1980s that it began attracting research centres' attention due to sufficient development (Brooks, 1988; Fisher et al., 1988). There was a rapid increase in the volume of VR research, including display technologies, interactive devices, interface technologies and application design (Cruz-Neira, 1998). As devices advance and open resources increase, the practical applications of immersive technologies are progressively more widespread. Retail executives and researchers are beginning to acknowledge the vital role of technology in competitive retail markets.

Integrating channels has become a competitive prerequisite, and the direction of retail development can be led by emerging technologies such as VR or AR (Grewal et al., 2017). Compared to e-commerce, virtual commerce (v-commerce) increases sensory depth because it can transmit more detailed three-dimensional images than two-dimensional (2D) static images (Keller and Lehmann, 2003). V-commerce refers to the use of VR, AR, and MR as a medium for commercial transactions of real-world products and services (de Regt and Barnes, 2019). V-commerce can use HMDs such as the HTC Vive or Meta Quest, which can bring an immersive 3D environment to customers (Peukert et al., 2019). Immersion is a key feature that drives the significance of virtual e-commerce. Previous studies have examined the manipulation experiment of immersion. Users were classified as hedonistic and pragmatic. Results found that immersion had a positive effect on the hedonistic path, whilst the effect on the utilitarian path was negative. Low-resolution headset displays and lower readability were the main factors in the negative impact, and when VR is more advanced in resolution and readability, immersion also positively affects utilitarian use (Alzayat and Lee, 2021; Erensoy et al., 2022; Peukert et al., 2019).

Some consumer studies have approached this from the perspective of user demographics and found that hedonistic consumers, 18 to 34 years old, are happy to

embrace v-commerce as the retail solution of the future, whilst older consumers are less receptive due to their ingrained habits (Xue et al., 2020). This is similar to another study, which found that consumers under the age of 35 prefer online shopping (3D simulations, handheld computers) because of their increased ability to capture visual information (Burke, 2002). It shows that age 35 (approximately) is the dividing point regarding preference for using digital technology, whether for v-commerce or online shopping.

Participatory experience is one of the advantages that consumers embrace about VR. Customer satisfaction can be improved through the co-creation of value, where users can participate in the co-design and experience the co-production of virtual worlds (Kohler et al., 2011). Lombart et al. (2020) found that consumers participated in purchasing more food when experiencing a VR store and a 3D model store compared with a physical grocery store (Lombart et al., 2020). The impact of VR on consumers' purchase intentions has been found to be due to changes in their memory and affect on brands (Martínez-Navarro et al., 2019). Some psychologists explained that when the retail space mobilises the consumer's emotional experience, it inspires high levels of loyalty, builds a network of brand awareness associations, and the consumer's memory recalls snippets of brand information unconsciously (Conway et al., 1994; Curci and Luminet, 2009; Dolcos et al., 2005; Sharot et al., 2004). All of the above studies indicate that VR appeals to young audiences and that the advantages are derived from bringing a high sense of immersion, increased creative engagement, and mobilisation of brand affective memory.

However, VR has some negative aspects, such as dissociation (derealisation), vertigo, fatigue and safety risks. *Dissociation* (disruption of functions such as consciousness, memory, identity or environmental perception) might affect the judgement of users about the existence of reality (derealisation) or might lead to feelings of disappointment or depression about the real world when detached from the virtual world, even groups with initially high levels of dissociation might increase dissociative symptoms (Aardema et al., 2006; Murray et al., 2007). *Vertigo* and *discomfort* associated with fully immersive experiences are a common argument propounded by many (Alzayat and Lee, 2021, p. 202; Erensoy et al., 2022; Peukert et al., 2019), which is distinctly a vulnerability of VR in comparison to AR and MR. *Fatigue* caused by heavy headsets

and extensive wear may lead to neck and muscle discomfort and can cause higher head pressure for users wearing glasses. *Safety risks* from the real world are not visible in VR, and users may fall or accidentally injure others, so there needs to be enough space. Some other aspects to be aware of include device resolution, which impacts image rendering quality and the sense of immersion. And, the HMDs' field of view also influences the range of the surrounding scenery that can be seen. High-quality VR experiences require superior equipment, which could be more expensive.

Retailers and companies may be concerned about the available HMD specifications for comparison for investment. The list below compares some common VR HMDs in the market (Table 2.1).

Table 2.1 Current VR headset specifications and price as of July 2024

Brands	Device Specifications	Price
Meta Quest 3	• Type: Standalone • Battery: Up to 2.2 hours of usage on average • Headset weight: 515g • Resolution: 2064 × 2208 pixels per eye • Refresh rate: Up to 120 Hz • Field of view: 110°W × 96°H • Can wear glasses	£479.99
Sony PlayStation VR 2	• Type: Tethered • Headset weight: 560g • Resolution: 2000 × 2040 pixels per eye • Field of view: Approx. 110°W • Refresh rate: Up to 120 Hz • Can wear glasses	£529.99
HTC Vive Pro 2	• Type: Tethered • Headset weight: 850g • Resolution: 2448 × 2448 pixels per eye • Refresh rate: Up to 120 Hz • Field of view: Up to 120°W • Can wear glasses	£779
Valve Index	• Type: Tethered • Headset weight: 809g • Resolution: 1440 × 1600 pixels per eye • Refresh rate: 144 Hz • Field of view: 108°W × 104°H • Can wear glasses	£1,549
Apple Vision Pro	• Type: Standalone • Battery: Up to 2 hours • Headset weight: 600-650g • Resolution: 23 million pixels (approx. 3,660 × 3,200 pixels per eye) • Refresh rate: 100 Hz • Field of view: No release • Cannot wear glasses	£3,499

2.2.4 Augmented Reality in Retail

AR applications are frequently spotted in retail. AR is used in in-store e-commerce systems to help customers with personalised advertising and shopping assistance (Zhu et al., 2004). AR systems are also used in virtual try-on and virtual fitting rooms, where customers can view reflections of themselves trying on virtual clothes that overlay on their bodies (Pachoulakis and Kapetanakis, 2012). Some companies have started experimenting with AR screens to virtual fit apparel and shoes (*Timberland Augmented Reality Campaign*, 2014) (Figure 2.6). A study comparing AR purchases to traditional online shopping in the sunglasses industry found that AR positively impacts the retail user experience (Poushneh and Vasquez-Parraga, 2017).



Figure 2.6 AR apparel fitting room. A screen capture of Timberland AR campaign, Lemon & Orange (2014)[1]

In addition, some studies investigated the value of various attributes of AR, including portability, interactivity, and customisation (Kumar et al., 2023), interactivity and vividness (McLean and Wilson, 2019), decision-making comfort (Carrozzi et al., 2019), customer satisfaction (Do et al., 2020), usefulness (Gatter et al., 2022), presence and perceived realism (Daassi and Debbabi, 2021a). AR applications have appeared in many retail assortments and are readily available in smart device mobile stores. Along with

[1] Lemon & Orange (2014). https://www.youtube.com/watch?v=5TZmQPdhpak

these extensive studies and implemented market applications, it proves the relative maturity of mobile AR technology in retail.

Some studies have argued that privacy concerns, security threats, and technological barriers to AR pose significant challenges (Kernaghan, 2014; Kour, 2024). Consumers are reluctant to adopt these technologies due to concerns about personal behavioural data being collected (Cowan et al., 2021; Kosinski et al., 2013), and application security vulnerabilities and attacks (Chen et al., 2018). In addition, an industry report states that a quarter of the downloaded AR apps are rarely used after the initial download (Nikhashemi et al., 2021). AR has more available app resources and is used more often than VR and MR in retail. AR generates advantages over VR and MR due to its device affordability, portability, and accessibility. However, because mobile AR interacts with smart devices, the sense of immersion, presence and interactivity is inferior to MR and VR.

2.2.5 Mixed Reality in Retail

In the present retail market, the practical implementation of MR is still sparse. Especially compared to relatively developed mobile AR applications in retail, MR is still young in retail markets. The reasons are various, such as expensive investments (Golosovskaya, 2021; Jurkėnas, 2024), a lack of available applications and resources, and limited studies of MR retail. For most companies, the biggest deterrent to investing in MR is the cost of headsets and hardware (Mordor Intelligence, 2019). However, the global MR market is predicted to grow at a compound annual growth rate of 41.8% during 2022–2027 (Mordor Intelligence, 2019). The global AR and MR market is expected to reach $103.9 billion, with hardware being the main component and the software part expected to reach $32 billion (Research and Markets, 2021). This means that enterprises are considering MR investment, but investors still need to comprehensively assess its capabilities and limitations to evaluate its potential benefits to the business.

MR retail has been studied in a few product categories. For example, a case uses grocery retail to design a grocery shopping assistant system for in-store grocery purchases that can be used to navigate product recommendations, product comparison and special

offers (S. Jain et al., 2021) (Figure 2.7). Other retail sector studies and market applications include record shop retail (Xi et al., 2024), red wine retail (Gil-López et al., 2023), vending machine grocery (Fuchs et al., 2019), and fashion show installation experience (Magnopus, 2019). They are all through MR to gain additional information and assist with the purchase.



Figure 2.7 MR shopping assistant system, Jain et al. (2023)

More studies focus on the development of MR technology functionality. For instance, they have explored the development of MR that uses voice recognition technology to search and filter specific products to support commodity navigation (Dou et al., 2019). Augmented relevant product content and recommendations through contextual capture and gaze detection (Cheng et al., 2017). Through spatial recognition and detection to obtain metadata about the spatial surface for layout display, the designer can design the merchandise layout elements once and then apply this layout to different rooms (Dou and Tanaka, 2020) (Figure 2.8).

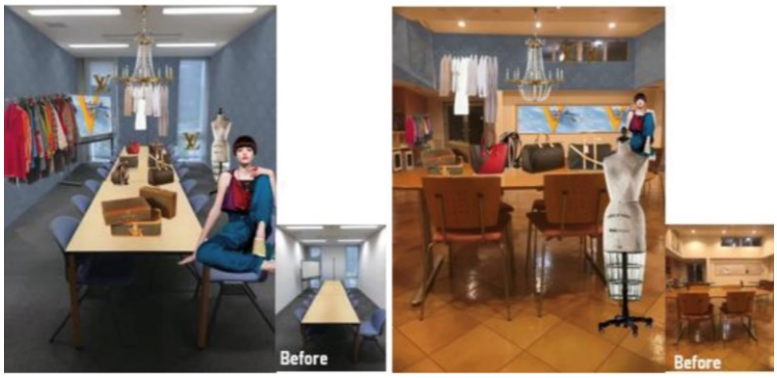


Figure 2.8 Mixed-reality responsive store layout system, Dou and Tanaka (2020)

Moreover, a study identified four research gaps related to MR user experience and digital retailing: 1) The validity of the customer experience framework and the relationship between the different stakeholders in retail. 2) The factors influencing the MR user experience framework in retail are uncertain. 3) Antecedents of customer experience value, that is employee influence on user perception of MR contents, are uncertain. 4) The impact of the physical environment constraints on HMD usage (Jain and Werth, 2019). This study demonstrates that MR acceptance in retail, the MR user experience framework, and the MR physical environment barriers are still uncertain. While existing research has primarily focused on small- to medium-value retail categories, there is limited investigation into the use of MR for high-value products. This thesis addresses this gap by exploring MR applications in high-value retail categories, thereby extending the relevance and applicability of MR technology to a broader range of retail sectors.

On the other side, MR also faces various limitations, such as anchoring issues, stability, and hologram visibility in direct sunlight (Guttag, 2020; Miller et al., 2020). The high cost of devices and ROI concerns are also deterrents for retailers (Jalo et al., 2021). Similar to AR and VR, some common concerns among XR technology users may include reliability, ethics, security, technological instability and resolution (Chen et al., 2018; Cowan et al., 2021; Keil et al., 2019; Kernaghan, 2014; Kosinski et al., 2013; Kour, 2024). Nevertheless, MR can offer numerous advantages, including immersion, convenience of interaction, realism of visual effects, high interactivity, and less motion sickness due to the transparent nature of the headsets (Rauschnabel et al., 2024). The retail industry has shifted from a product orientation to a consumer experience

orientation (Bourlakis et al., 2009). MR allows consumers to experience environments and events that they would not be able to experience with traditional shopping methods.

MR headsets allow users to interact directly with virtual objects using their hands without the need to hold a smart device or a pair of portable controllers. This affords consumers the capability to interact with physical and virtual products with both hands to complete natural shopping behaviours, enhancing embodied interaction. It is especially relevant with the benefit of using MR in physical stores, tactile. Most of these studies used the Microsoft HoloLens (1st generation), HoloLens 2 (2nd generation), and Magic Leap to develop. HoloLens is an untethered (runs on its own without connecting to a PC) holographic computer[3], often used by enterprises because of its advantages in lightweight, ergonomic hardware design, good resolution, and eye tracking. This thesis, therefore, adopts HoloLens 2 to conduct experiments. Table 2.2 also introduces some other brands of available MR headsets for stakeholders' reference. It includes both optical see-through and pass-through MR headsets. Optical see-through headsets, such as HoloLens 2 and Magic Leap 2, display the physical environment directly through transparent displays or optical lenses. Pass-through headsets, namely, Meta Quest 3, Apple Vision Pro, and Varjo XR 4, capture the physical environment through cameras and display it through the internal display. Pass-through headset quality varies, and differences in lens type and software processing power may result in varying degrees of minor delays during the capture environment (Eisenberg and Jensen, 2020).

[3] Microsoft HoloLens. https://learn.microsoft.com/en-us/hololens/hololens1-hardware (Accessed in 2024)

Table 2.2 MR headset specifications and price in 2024

Brands	Device Specifications	Price
Meta Quest 3	• Type: Standalone • Battery: Up to 2.2 hours on average • Weight: 515g • Resolution: 2064 × 2208 pixels per eye • Refresh rate: Up to 120 Hz • Field of view: 110° W × 29°H • Can wear glasses	£479.99
Microsoft HoloLens 2	• Type: Standalone • Battery: Up to 3 hours • Weight: 566 g • Resolution: 1440 × 936 pixels per eye • Refresh rate: 60 Hz • Field of view: 43° W × 29°H • Can wear glasses	£3,349
Magic Leap 2	• Type: Standalone • Battery: Up to 3.5 hours • Weight: 260 g • Resolution: 1440 × 1760 pixels per eye • Refresh rate: 120 Hz • Field of view: 44.6°W × 53.6°H • Cannot wear glasses	£3,370
Apple Vision Pro	• Type: Standalone • Battery: Up to 2 hours • Weight: 600-650g • Resolution: 23 million pixels (approx. 3,660 × 3,200 pixels per eye) • Refresh rate: 100 Hz • Field of view: No release • Cannot wear glasses	£3,499
Varjo XR 4	• Type: Tethered • Weight: 665g + headband 356g • Resolution: 3840 × 3744 pixels per eye • Refresh rate: 90 Hz • Field of view: 120°W × 105°H • Can wear glasses	€5,990

To better conclude the differences between VR, MR, and AR in retail, Table 2.3 outlines their advantages and disadvantages.

Table 2.3 Comparison of advantages and disadvantages of XR technology in retail

	VR	MR (wearable AR)	AR (mobile AR)
Advantages	• Highly immersive interaction • Provide more extended information • Share experiences remotely and in real-time • High sense of presence in a fully artificial environment • Can view effects that do not presently exist, reducing the reliance on imagination • Can provide certain conveniences, such as virtual fitting	• High-mid immersive interaction • Provide more extended information • Share experiences remotely and in real-time • High sense of presence in a mixed artificial environment • Can view effects that do not presently exist, reducing the reliance on imagination • Can provide certain conveniences, such as virtual fitting	• Provide a certain extended information • Share experiences remotely and in real-time • Portable • Affordable devices • Equipment with relatively less presence • Apps easy to access from the app store • Relatively less requires additional space to use • Can view effects that do not presently exist, reducing the reliance on imagination • Can provide certain conveniences, such as virtual fitting
Disadvantages	• Battery life of HMDs • Holding hand controllers • Expensive HMDs • Relatively less portable • Equipment with a strong sense of presence • Common physiological discomfort (neck, arms, eye fatigue) • Need onboarding • Require much space to use • Common ethical concerns (namely, privacy, data storage, personal data collection) • Development costs can be expensive • Detachment from reality and distortion • Technical errors may occur • Information overload due to advertising and irrelevant information, such as spam • Over-glorification of virtual products may lead to customer dissatisfaction	• Battery life of HMDs • Expensive HMDs • Relatively less portable • Equipment with a strong sense of presence • Common physiological discomfort (neck, arms, eye fatigue) • Need onboarding • Require a certain space to use • Common ethical concerns (namely, privacy, data storage, personal data collection) • Development costs can be expensive • Technical errors may occur • Information overload due to advertising and irrelevant information, such as spam • Over-glorification of virtual products may lead to customer dissatisfaction	• Battery life of smart devices • Holding tablets or smartphones • Low immersive interaction • Equipment with a relatively low sense of presence • Common ethical concerns (namely, privacy, data storage, personal data collection) • Development costs can be expensive • Technology is relatively developed, but technical errors may still occur • Information overload due to advertising and irrelevant information, such as spam • Over-glorification of virtual products may lead to customer dissatisfaction

In Section 2.2, through reviewing VR, AR, and MR in the retail context, it is found that XR has a positive impact and beneficial effects on retail from different perspectives, yet certain limitations have not been overcome. Therefore, selecting one of the technologies is a key decision for retailers. Existing studies have compared VR, web, and physical store shopping (Erensoy et al., 2022), VR shopping versus physical store shopping (Waterlander et al., 2015), AR shopping versus web-based shopping (Zare Ebrahimabad et al., 2024), AR shopping versus VR shopping (Xi et al., 2024), and MR in-store shopping versus physical store shopping (Kang et al., 2023).

However, no studies have addressed the comparison of AR, MR, and VR technologies in shopping with different retail categories, consumer preferences, and demographics. Especially in MR versus AR, device investments are significantly varied, but customers can both experience virtual objects overlaid in reality. Therefore, retailers may hesitate to invest in wearable MR or mobile smart devices for AR. A study discusses VR compared to AR, focusing on consumers aged 18–34 and the Western market, limiting other markets' generalisability (Xue, 2022). It suggests extending the research scope to consumer age groups above 34 years and the Asian market. Consumer technology preferences influence acceptance and real usage (Davis, 1993), so preferences in intention to use, experience, and purchase are necessary to be explored before development. In summary, three research gaps were identified in Section 2.2:

1) Addressing the issue of short in-store dwell time and lack of shopping enjoyment.

2) Lack of research on XR technologies (VR, MR, AR) in retail with user acceptance and consumer demographics.

3) Lack of comparison between MR and AR retailing, including consumer intent to use, experience, and purchase.

Matching retail categories and technological types and understanding consumer preferences are the means of increasing customer engagement and enhancing sales conversion. MR technology shows its retail possibility, emphasising the significance of MR-based commercial design work. The following section introduces retail scale and jewellery retailing as the pilot sector chosen for this thesis, outlining the rationale

behind its selection. It also further explores the research gaps in interface design within the context of MR technology applied to retail.

2.3 Mass Customisation and User Interface Design in Jewellery Retail

2.3.1 State of the Jewellery Retail Market

The previous section outlined the potential of MR and its cases in retail. This section focuses on the jewellery industry as a pilot project, interpreting the rationale for selecting mass customisation retailing. This choice supports the development of the MR product configurator as a commercial tool for enabling mass customisation and positions configurator interface design as one of the design works. There are four reasons for the adoption of the jewellery retail sector in designing the application of MR technology and developing a design framework.

First, consumer market research indicates that consumers prefer to experience MR technology in customised jewellery retail (see Chapter 4). Among AR, MR, and VR, consumers prefer to use MR in retail purchase contexts (Jin et al., 2023). Second, investment feasibility plays a key role. Considering the return on investment (ROI), which is the efficiency and profitability of investment, the cost of products may dictate investors' interest in the technology, especially when HMDs have not yet reached mass market adoption. Small and medium-sized independent retailers may find it challenging to transition to MR retail (Jalo et al., 2021), and medium to large enterprises are the most likely investors. Fine jewellery, as a premium product category, aligns with this market background.

Third, product categories would affect consumer engagement. Shoppers are more likely to invest time in purchasing long-lasting, high-value, and meaningful products (Hennigs et al., 2015). Until MR technology becomes as routine an electronic device as smartphones, used for everyday purchases such as groceries, ROI may mismatch the

expectations of consumers. Fourth, apparel retail requires body data or scanning, raising ethical concerns. In contrast, jewellery shopping involves minimal personal data collection, making it more acceptable to consumers who may be hesitant about adopting unfamiliar technologies. Given these considerations, the jewellery industry is an appropriate starting point for MR retail integration. The following section explores the future of digitalisation in jewellery retail and the potential benefits of combining MR.

Fine jewellery and costume jewellery are two critical areas of the jewellery industry. During the COVID-19 pandemic, due to short-circuited demand, fine jewellery revenues have fallen by 10-15%, and its digital transformation is lagging behind other luxury categories (McKinsey & Company and The Business of Fashion, 2021b). Costume jewellery also experienced an unprecedented 59.6% decline during this period, although statistics show that the market is recovering and growing and is expected to reach US$60 billion by 2026 (IMARC Group, 2022). A report from McKinsey and the Business of Fashion (BOF) (2021) forecasts global trends in fine jewellery sales for 2019-2025, with significant growth in online sales and a slight decrease in in-store sales (Figure 2.9). This means that interest in remote buying is increasing, and more trust is being placed in digital transactions.

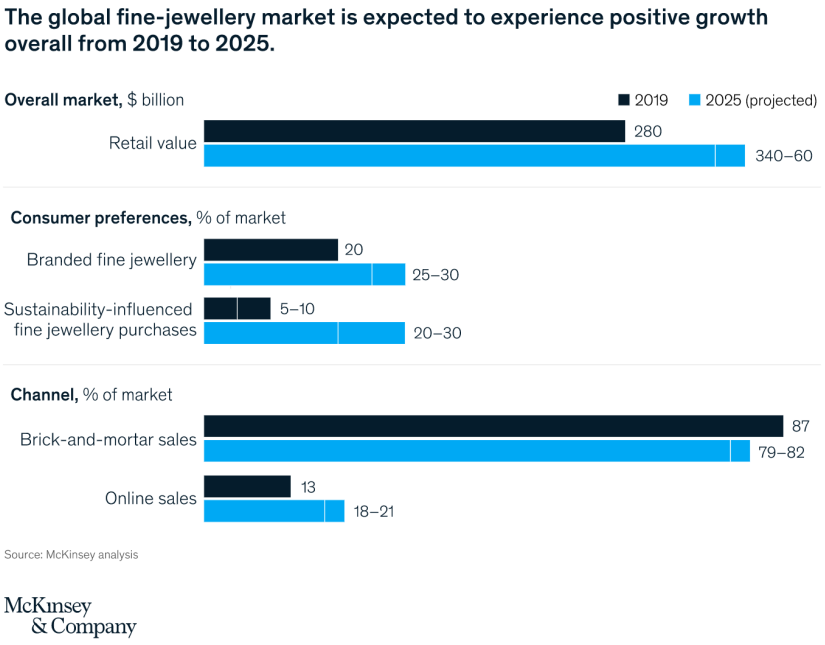


Figure 2.9 State of Fashion: watches and jewellery, McKinsey & Company and The Business of Fashion, 2021b

The current fine jewellery market is still dominated by brick-and-mortar stores (McKinsey & Company, 2014). It is also evident that brick-and-mortar stores still dominate the current fine jewellery market, forecasting that by 2025, approximately 80% of fine jewellery purchases will still be made in brick-and-mortar stores (McKinsey & Company and The Business of Fashion, 2021b). Customers' concern for branding and sustainability is stimulating their purchasing power. Most consumers prefer to purchase expensive items from brick-and-mortar stores as they offer touch-and-feel items that are perceived to be more reliable (McKinsey & Company, 2014). McKinsey & Company and BOF (2021) forecast that the Asian market will lead the global growth of the fine jewellery market, with the main contributor being China (Figure 2.10). Therefore, the Chinese consumer segment will be included in the analysis in subsequent studies as a part of an Asian market research cohort and the UK as a Western market research cohort.

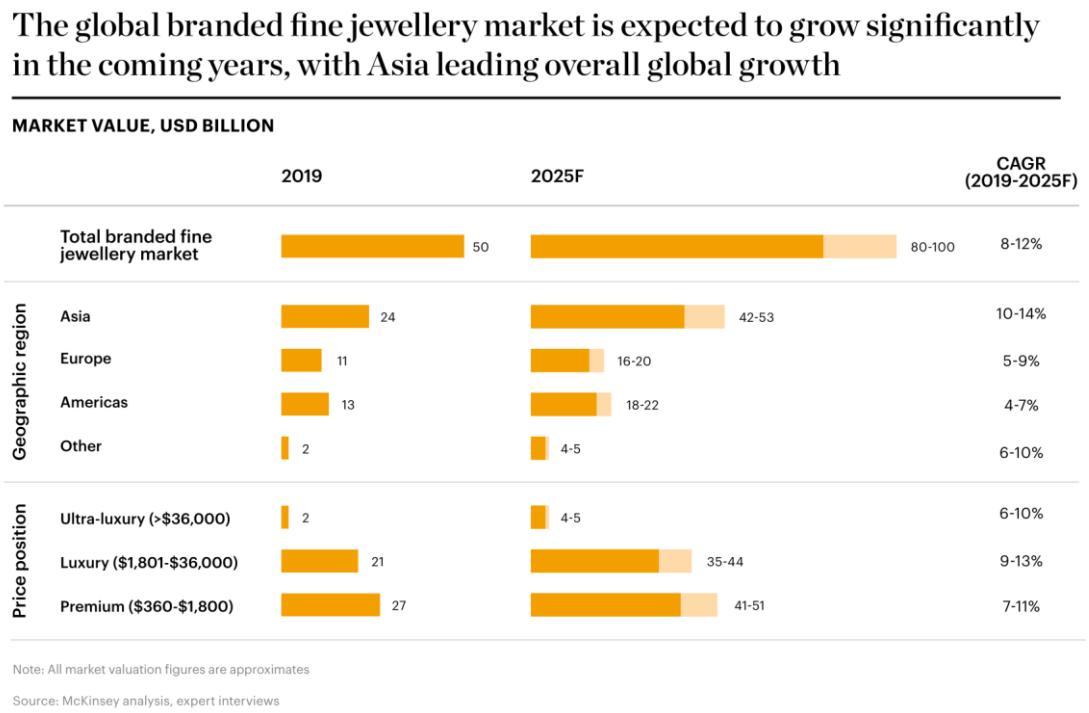


Figure 2.10 State of Fashion, McKinsey & Company and The Business of Fashion, 2021b

Consumer research reported that women account for the vast majority of sales in the fine jewellery market, while men account for only 5% to 10% of the global market, with wedding rings providing the bulk of sales (McKinsey & Company and Business of

Fashion, 2020; McKinsey & Company and The Business of Fashion, 2021b). Nevertheless, this market segment is driven by an increasingly gender-neutral aesthetic and the influence of celebrities, providing opportunities for brands. Moreover, as the culture develops, many men are beginning to wear engagement rings for marriage. More and more countries are likely to legalise homosexual marriage or unions, meaning the market should become increasingly inclusive and diverse in the future. It highlights that the ring category has a broad audience.

However, rings are not as popular as necklaces and earrings in the costume jewellery market. According to an analysis of the costume jewellery market, in 2020, necklaces accounted for the most purchased item, followed by earrings, bracelets, and then rings (Vaibhav and Roshan, 2020). According to forecasts, by 2027, there appears to be less difference between necklaces and earrings, with rings in third place in demand over bracelets (Vaibhav and Roshan, 2020). Consumers are more inclined to purchase fine jewellery with value retention for items such as rings because it represents a commitment (Vaibhav and Roshan, 2020). Therefore, this research uses a ring as a pilot product category to design and develop MR applications.

Another report from McKinsey and BOF (2021) indicates that digitalisation, sustainability and customer engagement are the three most promising opportunities for the future of retail for jewellery (McKinsey & Company and The Business of Fashion, 2021a) (Figure 2.11). This corresponds with the increasing studies in immersive technology in retail. The importance of customer engagement implies that customers are not simply satisfied with purchasing but that the customer engagement journey is an important component. Designers sometimes design products to be more in line with their tastes rather than the demands of the users (Hsu, 2012). It therefore involves customers as co-designers in the initial stages of design, which can enhance customer engagement (Sanders and Stappers, 2008).

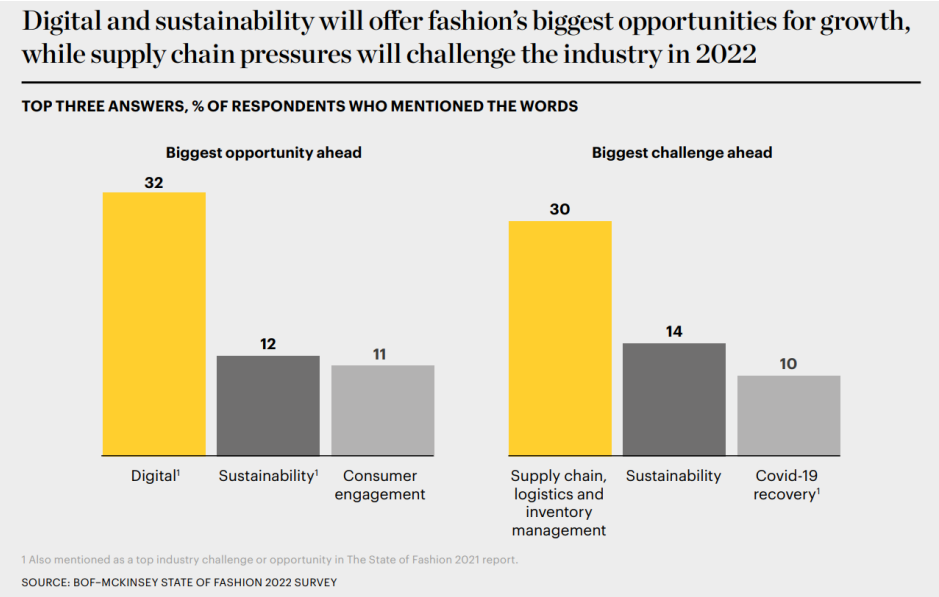


Figure 2.11 State of Fashion 2022, McKinsey & Company and The Business of Fashion, 2021a

Co-design is an approach to developing products with stakeholders, including individuals, groups, or organisations, designing with people rather than for people (McKercher, 2020). The collection of customer needs during the design process is referred to as customer voice collection, which aims to invite customers into the design decisions (Carulli et al., 2013). According to estimates, decisions at the initial design stage determine 70-80% of product development and manufacturing expenses (Kalpakjian and Schmid, 2013).

Other than involving customers in the initial design development process, another method of inviting customers to be co-designers is mass customisation (MC). Mass customisation is an approach to manufacturing that involves producing customised products within a defined product line in an economically efficient manner to meet the needs of individual consumers (Gilmore and Pine, 1997). Mass customisation can be achieved through computer-aided design, whereby consumers can modify standard products within a predefined range using computer applications to produce products that match their tastes and requirements (Nayak et al., 2015). MR technology can further aid mass customisation, provide a more comprehensive visual grasp of product information, and provide a participatory opportunity for customers to display creativity. Retailers are able to collect customer preferences to provide better design through a co-design process. Purchasing with MR technology could be a potential solution to refine

and extend service in brick-and-mortar purchasing. This is intended to leverage an augmented bespoke user experience with the unique attributes of virtual interface co-design afforded by the technology. Brick-and-mortar stores have the potential to benefit from offering this predicted high-value digitally augmented purchase opportunity.

This section introduces the possibility of improving customer satisfaction by involving customers in co-design in design ideation and participating in customised products during the purchase stage by adopting MR applications as a tool. In the following, the thesis will discuss the computer applications to achieve mass customisation in retail to explore the design direction for designing an MR mass customisation application.

2.3.2 Web-based Product Configuration User Interfaces

This section illustrates the state of the market for mass customisation of user interface (UI) for web-based purchasing. The current dominant and large-scale shopping method in the e-tailing (selling products and services via the Internet) market remains 2D web-based online shopping. A review of product customisation approaches to web-based UI assists in transitioning the design approach from a 2D UI to a 3D UI.

Self-designed products are unique and increase the added value of products (Brock, 1968). Customised products gain popularity when customers perceive that the value exceeds mass-produced standard products (Du et al., 2006). For example, when customisation processes are perceived as knowledge gain (Jiang et al., 2015), enjoyment and creativity (Schreier, 2006), or gain anticipated fulfilment value with the chosen product or service (Jiang et al., 2014). Nevertheless, specialist customisation is costly in terms of time and labour. Many merchants seek to reduce costs by mass customisation using web-based product customisation user interfaces or modular product components (Kratochvíl and Carson, 2005).

UI design refers to the visual and interactive design of digital products, which is part of user experience design (McKay, 2013). User experience (UX) design refers to a holistic experience for a product (McKay, 2013). UI is designed to provide navigation of customisable products and help users adapt to customisation rules (Dailey, 2004). Configurators, also known as parametric configurators or customer innovation toolkits, are user interfaces for product mass customisation. Parametric design enables users and

designers to manipulate numerical values (parameters) to change ideas (Drogemuller et al., 2024). Designers can create many modular variants, and users can consistently adapt the modular and generate options. It is equipped with tools for customers to design and develop their own products (Thomke and Hippel, 2002), and it is based on customers' ability to design their products (Hippel, 1988). The configurator allows for trial-and-error experimentation and feedback on the simulation results, and users can try their preferences repeatedly until the best product design is achieved (von Hippel and Katz, 2002). Configurators are more attractive to highly knowledgeable consumers, who may consider increasing their knowledge and information inflow (Stremersch et al., 2003). An increasing number of shoppers are buying personalised products online through configurators, which are defined as knowledge-based software applications (Grosso et al., 2017). Consumers are prepared to pay a substantial premium for configured products, especially if they positively perceive the configuration process (Franke and Piller, 2004).

There are some product configurator adoption cases in the market. For instance, IKEA's planning tool[4], also known as IKEA Configurator, is a web 3D design tool. It is presented as a 3D model on the web and allows customers to select products from IKEA's product list and freely assemble their own home. Other retail sector web configurators, such as the MINI website[5] and HomeByMe[6], are customised for cars and interior furnishings. ShapeDiver[7] is a central system, a unified configurator build platform that visualises products in 3D and transforms parametric 3D pieces from Rhinoceros 3D and Grasshopper into an online application. Many brands, such as

[4] IKEA planning tools. https://kitchen.planner.ikea.com/gb/en/planner/. (Accessed in March 2025).

[5] MINI website. https://www.mini.co.uk/en_GB/home.html. (Accessed in March 2025).

[6] HomeByMe. https://home.by.me/en/. (Accessed in March 2025).

[7] ShapeDiver. https://www.shapediver.com/. (Accessed in March 2025).

Moveis Moveu[8], Shapelamp[9], and Merz Mobel[10], embedded their brand data in such a central system platform to develop web-based parametric configurators. Compared to developing an independent platform, a central system can reduce technology costs by building on an existing framework. For private configurator platforms, maintenance is relatively costly, but brands can build their tailored modules, system architecture, and interfaces, such as Nike By You. Therefore, the system platform developed also depends on brand scale and investment expectations. In jewellery retail, brands such as Nove25[11], Revelaire Jewlry[12], Luis & Freya[13], and YŪ by YOU[14] offer web configurators to allow customers to customise product components to personalised products parametrically. These market cases indicate that web-based configurator design and MC business model have been implemented in a relatively mature manner.

In terms of designing UX, UI, and service, the user-centred design principle is widely used in the design and development process (Norman, 2002). It refers to an iterative design process in which designers focus on user needs at every stage of the design process (Norman and Draper, 1986). Users participate in the entire design process, and designers find design solutions that meet user needs through continuous iteration of design solutions (Norman and Draper, 1986). Due to sparse MC UI design studies in MR, gaining experience in web configurator design, including parametric components and functions, is necessary to design a user-centred MR product configurator. The following will analyse a few web jewellery configurator cases, including five fundamental configurator aspects: a) UI customisation workflow; b) UI layout; c) customisation methods; d) product categories and quantities for customisation; and e)

[8] Moveis Moveu. https://moveismoveu.com/. (Accessed in March 2025).

[9] Shapelamp. https://shapelamp.com/. (Accessed in March 2025).

[10] Merz Mobel. https://www.merz-moebel.de/modell/sideboard-m4313/. (Accessed in March 2025).

[11] Nove25. https://www.nove25.net/gb/fine-jewelry. (Accessed in March 2025).

[12] Revelaire Jewlry. https://revelaire.co/. (Accessed in March 2025).

[13] Luis & Freya. https://luis-freya.com/PERSONALIZE/Product-selection/. (Accessed in March 2025).

[14] YŪ by YOU. https://yubyyou.com/. (Accessed in March 2025).

customisable parameters. These analyses form the design basis for the MR product configurator in this thesis.

a) UI customisation workflow and b) UI layout

Nove25 is a jewellery brand that offers a wide range of customised products, including rings (24 types), bracelets (16 types), necklaces (8 types), and earrings (8 types) (Figure 2.12). Customisation is divided into four configuration procedures: model (style), stone, colour (metal part plated in different colours), and size (Data from 2023). Customers need to select a product in the product menu and visit its product detail page before configuring it. It allows the customer to see the overall number of configuration steps, which can then be configured by opening each option.

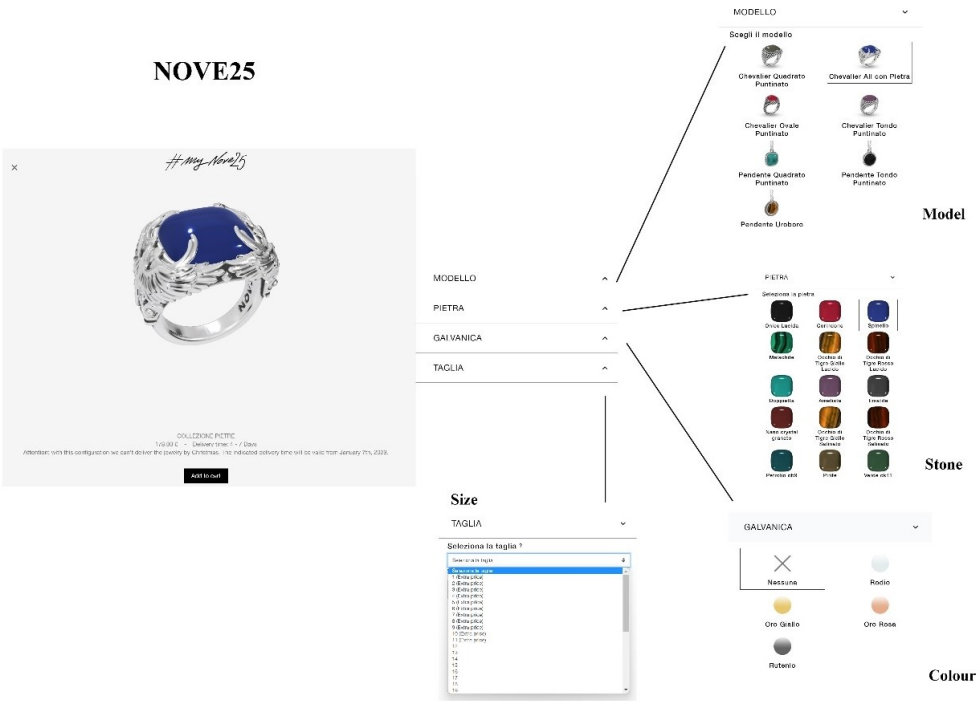


Figure 2.12 NOVE25 Rings configurator. Screen captures of the web page

Luis & Freya jewellery offers only rings that can be customised and are made in four steps: choosing a size and material, customising the text on the ring, and choosing whether to add diamonds (Figure 2.13). The interface requires that users complete the tasks regarding the stages; that is, the UI shows the current configuration step but does not display all the progress and functions.

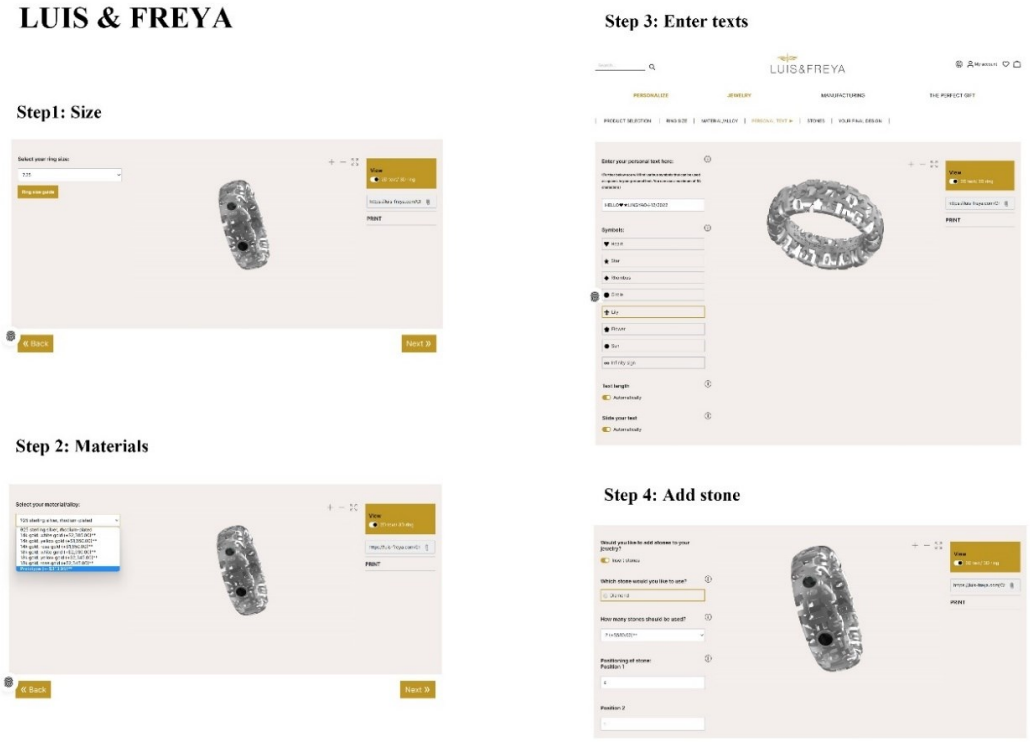


Figure 2.13 Luis & Freya Rings configurator. Screen captures of the web page.

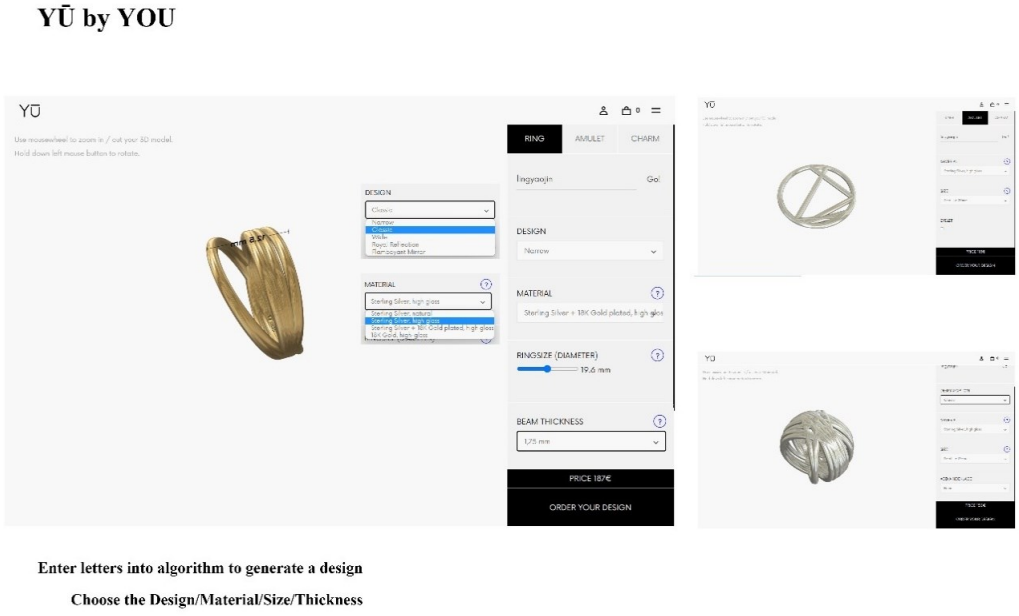


Figure 2.14 YŪ by YOU configurator. Screen captures of the web page.

YŪ by YOU jewellery customisation generates customised products through algorithms (Figure 2.14). Customers can enter letters, and the system generates a pattern. Then,

customers amend the design parameters, such as product material and thickness. When customers enter a string of letters to generate a jewellery design, all three types of jewellery are created simultaneously. Customers configure the options under each type bar. The interface displays all three customisable types on the same page, enabling the customer to view the three different types of jewellery under the same letter.

In terms of UI design, they employ fold, flip, and scroll parameter navigation. The parameter adjustment area has been designed on the left, right, or both sides. The customisation workflow is progressive or overall on one screen, which is relevant to the purpose and brand style of the UI designer and retailer. Therefore, no specific rules or UI layouts derived from online configurators were used to design the MR configurators.

c) Customisation methods

The above brands' customisation approach involves a modular design and input of special characters generated by the system algorithm. Algorithm-generative products are able to increase the efficiency of designer output through design automation, but cannot evaluate the design visualisation and personalisation level of the generated results, implying that they are not generating the optimal design for consumers (Jiang et al., 2022). Moreover, customers are usually not directly involved in the algorithmically generative design, whereas through the product configurator, customers can be involved in the design process. In terms of manufacturing techniques, algorithm-generative products are digitally manufactured (namely, 3D printing), which is economical for smaller batch production and considerably more costly than traditional manufacturing (Pereira et al., 2019).

Modular design customisation (product design consists of modules) and production efficiency are similar to mass production (Bouchard et al., 2023). Modularity in configurators optimises resources and reduces inventory, whereas algorithmically generated jewellery requires a made-to-order approach with a longer production cycle (Bouchard et al., 2023). Using algorithm design in MC, customers can create a vast number of designs using algorithms, whereas configurators operate within preset parameters. Therefore, the quantity of preset parameters is crucial for achieving diversity of custom design. This research focuses on designing a mass customisation

product configurator to balance the purpose of personalisation, participatory production, and efficiency; therefore, it will adopt a modular design.

d) Product categories and quantities for customisation and e) customisable parameters

The parameters of the configurator are an important design component where product designers provide design rules for customers to participate in the design. Table 2.4 summarises parameters set by a sample of retailers using an online product configurator for mass customisation. The tables subject the parameter names to a consistent process. These brands all include rings for customisation. According to jewellery market reports (see Section 2.3.1), rings are a jewellery category that caters to all genders due to commitment culture meanings. Therefore, this research uses rings as a pilot product for designing configurator parameters.

Table 2.4 Comparison of brand parameters

Brands	Types	Size	Metal Materials	Stone Colour	Model	Engraving	Thickness	Stone Type	Ring Shape	Ring Curvature	Add wedding bands
NOVE25	Rings; Pendants; Bracelets; Earrings; Necklaces	✓	✓	✓	✓	/	/	/	/	/	/
Luis & Freya	Rings	✓	✓	✓	/	✓	/	/	/	/	/
YŪ by YOU	Rings; Amulet; Charms; Earrings	✓	✓	/	/	✓	✓	/	/	/	/
DANFIL	Earrings	✓	✓	✓	/	/	/	/		/	/
STERNS 1896	Rings	✓	✓	✓	/	✓	/	/	/	/	✓
Tom Dent (Configurator builder)	Rings	/	✓	✓	/	✓	/	✓	✓	✓	/

The standard parameters of these brands are materials, stone setting (colour, type, quantity), size, and engraving, while other parameters are tailored by the brand's product design. Table 2.5 lists ring combinations and parameters set by each brand. It indicates the potential manufacturing assembly possibility and the customer product co-design scope. The MR product configurator parameters are set based on this scope (see Chapter 5, Section 5.6).

Table 2.5 Rings parameter variables

	Model	Stone	Size	Metal Materials	Engraving	Design style	Stone Quantity	Stone size	Thickness	Combination
NOVE25	n=4	n=15	n=38	n=4	/	/	/	/	/	9120
Luis & Freya	/	n=10	n=12	n=8	22≤n≤38	/	/	/	/	960
YŪ by YOU	/	/	n=88	n=4	n≥4	n=5	/	/	n=3	5280
STERNS 1896	/	/	n=16	n=7	n≤20	/	n=3	n=4	/	1344

The quantity of combinations of parametric configurations reveals that the greater the range of parameter types and number of elements, the greater the variety of combinations. For consumers, more combinations represent more creative possibilities and product uniqueness. For retailers, this could mean a potential increase in warehouse capacity and manufacturing costs, but there could be a corresponding decrease in customer returns (Alford et al., 2000). The problem of optimal sizing and positioning of inventory is challenging for brands (Mourtzis, 2016). MR offers the possibility of viewing and fitting virtual products, and users can try virtual products before making decisions. This could potentially assist in optimising the product storage footprint of brick-and-mortar stores.

The configurator makes product diversity and leanness through modular product design, flexible processes, and integration between supply chains (Fogliatto et al., 2012). However, the limitations of web-based configurators include: the lack of immersion and interactivity with product and brand, the lack of tactile feedback, the lack of virtual fitting of customised products, and the lack of perceived product scale. Practitioners are increasingly exploring XR technologies as a solution for enhancing mass customisation experiences. A market survey of over 3,000 consumers stated that 47% of consumers would pay extra for customised or personalised products using immersive technology (Accenture, 2020). MR provides an excellent medium through which customers can customise jewellery more successfully than 2D configurators due to real-time spatial evaluation of changing models in space and the overlay of reflection on the user's body.

2.3.3 Extended Reality Product Configuration User Interfaces

Besides offering web configurators, MC can also work by rendering and effects through hand sketches or parametric software (such as Adobe Photoshop and Rhino) for customer customisation. This method requires customers to wait while designers amend and continuously iterate their designs, creating waiting dwell time and bringing an ineffective experience. Therefore, another option is to integrate with a generality and modularity MR configurator so that clients can view instant results of design modifications (Jiao et al., 2003). Consumers can promptly view whether the configured effects meet expectations to improve their satisfaction.

On the other hand, it solves realistic customer communication problems through co-design (Seth and Smith, 2004) and helps users better understand products by empowering them with greater control of product features (Altarteer et al., 2016). VR systems offer significantly better perceptual experience value and product customisation than 2D static images (Altarteer et al., 2016). Its visualisation and interaction can also enhance engineers' decision-making (Mujber et al., 2004) and assist engineers in evaluating product designs (Mei et al., 2021). The hedonic value of virtual content is one of the factors contributing to user engagement; if the experience fulfils the hedonic needs of the user, co-creation is no longer considered a task (Kohler et al., 2011). Users create or co-create experience content that could bring the vibrancy and creativity of the virtual and physical place (Kohler et al., 2011).

Some studies have explored VR couch configurators that allow retailers to configure products and showcase them to customers in furniture retail (Zenner et al., 2020). VR luxury luggage shopping applications make it possible to streamline decision-making processes (Altarteer et al., 2013). MR-based retail systems and mass customisation studies are sparse in the field. A case of MR configurators shows its possibility in the healthcare product sector, which assists doctor-patient communication in purchasing healthcare products, browsing information, and customising prosthetics (Górski et al., 2023). MR can also support multi-view collaborative design products so that multiple users can collaborate in modifying or discussing a product (Ong and Shen, 2009). MR has also been explored in grocery retail, where a grocery assistant system is designed to identify products and display product information (S. Jain et al., 2021) (Figure 2.15).



Figure 2.15 Grocery assistant system interface design, Jain et al. (2022)

However, many existing studies focus on the functionality of MR applications and overlook design considerations, such as UI and related service design. Some studies highlight discomfort factors such as equipment weight, eye fatigue, neck pain, and overall user comfort, which affect the duration of use (S. Jain et al., 2021; Thomas and Holmquist, 2021). Encouraging consumers to spend more time browsing merchandise and extending the interface dwell time of consumers can be conducive to business growth (Kao et al., 2021). This points to the need for ergonomically designed MR interfaces. Although interface design cannot eliminate hardware-related discomfort, a well-structured UI can help minimise user fatigue to increase customers' intent to use.

Moreover, there is a notable lack of MR-specific UI design principles to support graphic UI designers in developing commercial 3D interfaces, especially for those who do not have access to MR headsets during the design phase or who lack familiarity with MR context. As a result, designers often rely on frequent and iterative communication with software engineers to assess the feasibility of their concepts and potentially extend the development process (Camburn et al., 2017). An organised design framework could effectively support and enhance design usability and efficiency (Barbieri et al., 2013). MR product configurator design in commercial environments, its content utility, hedonic considerations, and bullet points differ from sectors such as healthcare, education, and construction (Höllerer et al., 2001; Silva et al., 2024). To tailor for commerce, this research explores the design of an ergonomic MR product configurator, aiming to provide recommendations for MR configurators in brick-and-mortar stores.

In summary, Section 2.3 highlights the concepts of using jewellery retail as a pilot sector to design an MR product configurator for mass customisation in brick-and-mortar stores. Invite customers to participate in the design process to conduct user-centred design.

Continuing the three research gaps identified in Section 2.2, this section identified additional research gaps that need to be addressed:

4) There are no design recommendations or practices for parametric configurators for MR mass customisation in retail.

In the body chapter, a new gap is identified in the configurator prototyping stage, which will be depicted in Chapter 5 (see p. 126). The research gap is below:

5) Lack of a participatory rapid prototyping approach to aid rapid iterative testing of the early-mid MR commercial systems (see Chapter 5 Section 5.2.2).

MR mass customisation is an integral part of the holistic customer experience in retail stores. At the same time, brick-and-mortar store environments also play an essential role in providing a place to attract customers, create an experience atmosphere, and facilitate transactions. Therefore, the next section will examine how the physical retail environment design influences customer experience with MR, highlighting the relationship between spatial design and interactive technology. It will also present the rationale for conducting studies within pop-up retail environments as a pilot market.

2.4 Brick and Mortar Retail Store Design and Inference

2.4.1 Brick and Mortar: Traditional Retail and Pop Up Retail

The previous sections reviewed the potential of the MR product configurator for mass-customised jewellery retailing. This section further examines considerations for implementing MR in brick-and-mortar stores, beginning with a review of traditional store environment design factors to inform MR store environment design. It then analyses the role of pop-up stores — that is temporary stores — as a place for deploying MR applications within this thesis. Not all pop-up stores are suited to adopt MR. This section then provides recommendations for selecting appropriate pop-up store typologies for MR implementation.

A growing number of brick-and-mortar shops closed for multiple reasons, such as policy and decreased footfall (Saker-Clark, 2025). In 2024, more than 13,000 high street shops in the UK permanently closed, and the closure of shops on the high street in the UK continued until April 2025, including a variety of categories such as fashion (shoes, jewellery, clothes), groceries, and food (Kara and Sian, 2025, p. 2; Saker-Clark, 2025). MR retail offers an opportunity to encourage physical retail by delivering an augmented customer experience that attracts consumers to return to brick-and-mortar stores. Moreover, brick-and-mortar shops enable a tactile experience where customers perceive them as reliable (McKinsey & Company, 2014). Providing HMD experiences in physical stores can increase in-store traffic by making MR experiences more available to consumers without the expense of purchasing expensive equipment (Farah et al., 2019). Therefore, this research aims to design for brick-and-mortar retail stores.

Traditional retail is typically operated through brick-and-mortar stores, where retail categorisation based on hierarchies includes numerous classifications such as retail goods, retail enterprises, shopping purposes, size, and type (Dolega et al., 2021). Urban planning-based studies combined with analyses by retail geographers classified shopping locations as retail outlets, retail areas, and shopping centres (Guy, 1998). Researchers also proposed methods for shopper classification (Jarratt, 1996) and motivation segmentation to segment markets from a human perspective (Westbrook and Black, 1985). Market segmentation, whether by retail or consumer typology, significantly influences the conceptualisation and execution of retail design, helping retailers position themselves in the industry.

With the rise of omnichannel retail, shopping methods have become more diversified, and the negative impact of COVID-19, the vacancy rate of physical stores on shopping streets is increasing as a consequence (Christiaans, 2016). These social and technological changes lead to continuous retail categorisation and strategy upgrades. Correspondingly, retail planning and design should closely follow policies, retail types, consumer types, and the ongoing progress and transformation in the economy and society to plan a more dynamic, inclusive retail development framework and sustainable business. In particular, the development of XR innovative retail has introduced more

possibilities for retail design. Planning an appropriate MR strategy based on retail and consumer genres could be a vital step in facilitating retail execution.

The performance of physical retail has become more diversified due to omnichannel retailing. An interesting phenomenon is the rapid disappearance of boundaries between pop-up stores and traditional retail with the rise of multichannel retailing (Alexander and Bain, 2016). Correspondingly, the retail experience is no longer confined to physical experiences in physical spaces but increasingly integrates digital technology into physical spaces (Centre for Economics and Business Research [CEBR], 2014; Verhoef et al., 2009). Pop-up stores are temporary stores that operate for a limited period. They are considered a new experiential marketing tactic aimed at attracting consumers (Niehm et al., 2006). Pop-up stores typically intend to engage participants in a series of dramatic, pleasure-oriented, and memorable experiences (Pine and Gilmore, 1998). By offering entertainment and interactive environments, they create experiential value and a joyful atmosphere (Klein et al., 2016).

Convenience and availability are no longer the sole drivers of consumer purchases, and hedonic motives are increasingly weighing on e-commerce (Childers et al., 2001), such as a multisensory consumer experience. Multisensory experiences emphasise the creativity of interaction, socialisation, and communication in store environments, with the market experience being dominant rather than mere production (Gilmore and Pine II, 2002). Consumers potentially only browse for entertainment, and unplanned purchases may arise midway through a browse, as when consumers view something that promises to bring pleasure (Goworek and McGoldrick, 2015). Many renowned retailers have embraced the opportunity. Debenhams launched the first AR pop-up in the UK in 2011, where customers used their smart devices to conduct AR wardrobe try-ons and share photos of their virtual outfits on social media to increase brand exposure. Pop-up brick-and-mortar stores as experienced delivery spaces show their uniqueness and encourage consumers to try and interact with new products through AR technology.

Unlike permanent stores, pop-ups focus more on marketing, experience, and uniqueness rather than sales and revenue (Russo Spena et al., 2012). Attractive store design is a crucial cue of in-store user experience and requires enhancing user engagement to foster brand-customer interactions (Russo Spena et al., 2012). Renowned brands are inclined

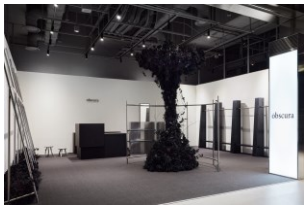
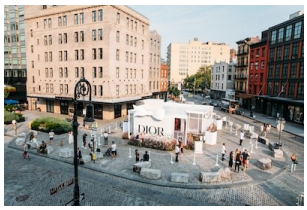
towards investment in pop-up retail endeavours to enhance their brand image, test novel strategic markets, and introduce new product offerings (Hagtvedt and Chandukala, 2023). For emerging or non-well-known brands, pop-up retailing as a means to explore innovation is used to expand awareness and test the potential for market investment (Warnaby and Shi, 2018). The most important reason for pop-ups is that the operator is trying to build customer relationships and trust. Other reasons include increasing sales of specific products, seasonal events and organising events for partners (Pomodoro, 2013; Rosenbaum et al., 2021). Marciniak and Budnarowska (2009) highlight that this retail approach increases brand awareness through rapid "viral" communication, with sales as a secondary objective (Marciniak and Budnarowska, 2009). MR is an innovative interactive tool aligned with the pop-up store marketing goal. Retailers are expected to test new purchasing strategies and expand new markets through pop-ups (Yu et al., 2018). Pop-up store integrations with MR purchasing could be an opportunity to help retailers test new products and brand marketing. Therefore, this thesis uses pop-up retail as a pilot place to conduct studies.

2.4.2 Pop Up Store Typology for Mixed Reality

Pop-up stores, although temporary and small-scale, still exhibit various distinctions. This section will describe the general pop-up typology and analyse the pop-up implementation recommendation for MR.

Pop-up stores come in various display formats, location settings, and objectives. Design-oriented pop-up stores are distinguished into short-term standalone, short-term kiosks, pop-in stores, invisible pop-ups (AR and application-based pop-ups), virtual walls, and collaborative pop-ups (Yu et al., 2018). Location-oriented pop-up stores can be categorised as guerrilla stores, nomad stores, pop-ups in shopping malls, and event-driven pop-ups (Yu et al., 2018). Objectives-oriented pop-up stores' goals are communicational, experiential, transactional, testing, and institutional (Yu et al., 2018). Below, I will use these pop-up typology taxonomies to analyse their association with MR implementation. These are typical case situations and do not represent all cases. By six examples, spatial independency and dimension of different pop-up store types are analysed (Table 2.6).

Table 2.6 Pop-up store typologies

Pop-up Store Typology	Definition	Sample Images	Spatial Independency	Space Dimension
Short-Term Standalone Stores	Mobile or fixed and usually operated by a single brand. It could be located indoors or outdoors (Yu et al., 2018).	[15] 	Independent	Spacious
Short-Term Kiosks / Nomad store	Mobile formats, such as vans, store-on-wheels, portable kiosks, and re-locates frequently (Yu et al., 2018).	[16] 	Dependent/ Hybrid	Small
Pop-In Stores	Store within a store. Use some installation art to split up a small space in a store (Yu et al., 2018).	[17] 	Hybrid	Limited
Collaborative/ Event-Driven Pop-Up	For special events, such as celebrating company milestones, new product launches, and participatory experience (Yu et al., 2018).	[18] 	Independent	Spacious

[15] Obscura Pop-Up Store (Abdel, 2023). https://www.archdaily.com/1006421/obscura-pop-up-store-practice

[16] Setting Up a Pop-Up Shop (Dana, 2018). https://stonesandfindings.com/setting-up-a-pop-up-shop-part-1/

[17] Fashion Pavilion (Grimshaw and Lewis, 2011). https://www.archdaily.com/173344/fashion-pavilion-john-lewis-grimshaw-architects

[18] Dior Beauty Pop-Up (Laufik, 2021). https://www.bizbash.com/production-strategy/experiential-marketing-activations-sponsorships/media-gallery/21784085/see-inside-the-dior-beauty-popup-that-went-viral-during-nyfw

Pop-up Store Typology	Definition	Sample Images	Spatial Independency	Space Dimension
Guerrilla Stores	It tends to employ non-conventional, less costly tools (Yu et al., 2018).	[19] 	Hybrid	Various
Pop-ups in Shopping Malls	It can be short-term independent stores or kiosks within a shopping centre (Yu et al., 2018).	[20] 	Hybrid	Limited

Spatial independency refers to whether it has a clear spatial boundary or whether the interior and exterior spaces of a store are shared with other public spaces or brands or are standalone. For the use of MR, designers primarily need to ensure its security, which includes the safety of the user when using it, the safety of other customers passing by, the safety of the equipment, and the safety of the products in the shop. Therefore, retail shops with independent spaces or clear space boundaries could help minimise the potential hazards by setting a fixed MR access boundary. Short-term standalone stores and event-driven pop-ups usually have entire interior spaces. Pop-in stores, guerrilla stores, and mall-centred pop-ups circulate and open up to the external environment. Some nomad pop-ups usually only have improvised tables for product displays and are fully integrated with the external public space as part of the overall environment. Spatial independency is associated with the scale and budget of the retail brands. Low-budget

[19] Comme des Garçons Guerrilla Store (Fairs, 2007). https://www.dezeen.com/2007/06/16/comme-des-garcons-guerrilla-store-4161/

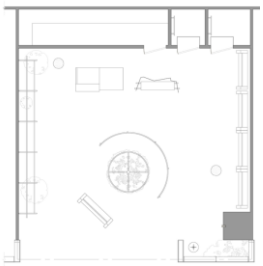
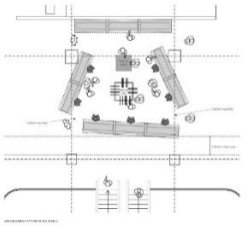
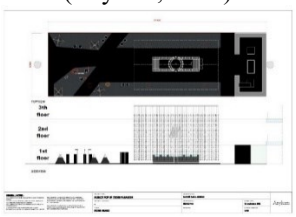
[20] Hublot Pop-up Store (Asylum, 2012). https://www.archdaily.com/279815/hublot-popup-store-asylum

retailers often opt for low-cost and mobile selling methods. Brands in chains and mid-to-high-end retail may opt for standalone, event-oriented, pop-in stores and shopping mall pop-ups to provide a high-quality environment.

Space dimension refers to the floor area of the space available in the pop-up space. Standalone pop-up shops create events with the entire space and are relatively spacious. Kiosk stores have a small number of tables and are small-scale. The dimensions of pop-ups in stores or malls are limited because they depend on the floor area allocated for them due to using shared spaces. Event-driven pop-ups are usually set up as standalone, portable, and mobile spaces with a relatively spacious area. Guerrilla stores are commonly held in different formats and venues without fixed space dimensions. Invisible pop-ups (AR and app-based pop-ups) refer to application-based pop-ups on smart devices, using AR or geo-location technology to allow customers to virtual shop for a limited time (Yu et al., 2018). Virtual walls refer to walls that display merchandise catalogue pages, 3D images, or QR codes to allow customers to purchase by scanning a QR code (Yu et al., 2018). Neither is included in the table because they do not require physical space and are irrelevant to the purpose of MR in-store adoption.

The dimensions and independence of the space limit the space usage area and mobility available to consumers and affect how consumption is engaged. In other words, fully open access spaces with small dimensions have the potential to disrupt the experience and cause hidden risks when users are using MR HMDs (Jung et al., 2018). Apart from space independency and dimension, store ambience also influences whether it suits MR deployment. Store ambience includes many factors, such as lighting, sound, temperature, product displays, signage, odour, and layout (Bitner, 1992; Turley and Milliman, 2000). Turley and Milliman (2000) expanded the classification and categorised store ambience into five categories: outdoor, general indoor, store layout, interior displays, and human variables (Turley and Milliman, 2000). Based on classifications in traditional store ambience, Table 2.7 analyses spatial layout, interior displays, and indoor lighting, which are subject to the impact of interior design plans, brand identity, and surrounding environmental policy regulation. The light source intensity will affect MR visibility, suggesting stores should prevent direct sunlight or harsh bright light environments (Guttag, 2020; Miller et al., 2020).

Table 2.7 Comparison of pop-up store typology interior factors

Pop-up Store Typology	Floor Plans Samples	Spatial Layout	Interior Displays	Lights
Short-Term Standalone Store	(Abdel, 2023) 	Grid & Free Mode	Brand Strategy & Shopping Mall Policy	Artificial light source & natural light & Mall Management
Short-Term Kiosk/Nomad store	N/A	Portable Units	Minimal Decoration & Shopping Mall Policy	Artificial light source & Mall Management
Pop-In Store	(Grimshaw and Lewis, 2011) 	Regular/ Irregular & Free Mode	Installation & Artistic Collaboration	Artificial light source
Collaborative Pop-Up/ Event-Driven Pop-Up	N/A	Regular Rectangular & Rounded	Decorative & Experiential & (Shopping Mall Policy)	Artificial light & Nature light
Guerrilla Store	N/A	Irregular & Free Mode	Eye-catching & Creative	Natural light & Artificial light source
Pop-Up in Shopping Malls	(Asylum, 2012) 	Rectangular & Rounded	Brand Strategy & Shopping Mall Policy	Artificial light source & Mall Management

Based on typological external environmental factors, six factors are analysed concerning the type of pop-up stores: surroundings, entrances, parking, store front, architecture, and employees (Turley and Milliman, 2000) (Table 2.8). These factors can influence customers' judgement and behavioural responses to the brand image. For

example, the quality of the interior and exterior environment is related to brand identity (Baker et al., 1994), the availability of parking is related to the duration of shopping (van der Waerden et al., 1998), and the quantity of employees is related to the availability of spare staff to provide MR customer services. The table is a summary based on the cases and general rules. The specific implementation requires managers to judge in the context of the actual circumstances.

Table 2.8 Comparison of pop-up store typology exterior factors

Pop-up Shop Typology	Surroundings	Entrances	Parking	Store Front	Architecture	Employee
Short-Term Standalone Store	Street/ Shopping Mall	• Store and/or Mall • 1 or 2 entrances	Street & Mall car parks	Formal signage	Existing buildings	• Multiple/Few staff • Staff training • Uniform/Dress code
Short-Term Kiosk/Nomad store	Street/ Shopping Mall	• Mall and/or Kiosk • No need, or 1 entrance	Street & Mall car parks	Concise symbols	Existing buildings & Outdoor	• Few staff or only a shop owner • No training • No uniform
Pop-In Store	Store	• Store and Mall • 2 entrances	Mall car parks	Formal signage	Existing buildings	• Multiple staff • Staff training • Professional uniform
Collaborative Pop-Up /Event-Driven Pop-Up	Street/ Shopping Mall	• Store and/or Mall • 1 or 2 entrances	Street & Mall car parks	Formal signage	New building/Marquee & Existing buildings	• Multiple staff • Staff training • Professional uniform
Guerrilla Store	Public area	• Various	Various	Conspicuous symbols	Outdoor & Existing buildings	• Only a shop owner
Pop-Up in Shopping Malls	Shopping Mall	• Installation and Mall • 2 entrances	Mall car parks	Formal signage	Existing buildings	• Multiple staff • Staff Training • Professional uniform/Dress code

Based on the above analysis, Table 2.9 summarises the pop-up typology matching the MR HMDs adoption. As previously mentioned, the market niche for MR is currently more suitable for medium to large retailers due to the high cost of the equipment. Guerrilla and kiosk pop-ups prioritise affordability and convenience and are not applicable for MR implementation. Their limited investment scope and insufficient space for MR usage make them inapplicable for input MR. Secondly, in-store and mall-based pop-ups face challenges in implementing MR, primarily due to restrictions on altering lighting conditions and the need to comply with mall regulatory policies. In contrast, standalone and event-driven pop-ups are more suitable for MR, as they offer independent spaces, adjustable lighting, and matching financial resources.

Table 2.9 Pop-up store types applicable to mixed reality HMDs

Pop-up Store Typology	Applicable Inputs MR	Reason for MR HMDs Adoption or Non-adoption	Implementation Considerations
Short-Term Standalone Store	Yes	• Sufficient space for movement • Adequate finance for system development and maintenance • Adequate finance for HMDs investment • Adequate employee assistance • High traffic flow	• Safety boundary of usage • Salespeople's HMDs training • Waiting area • Traffic flow route • HMDs security
Short-Term Kiosk/Nomad store	No	• Lack of space for movement • Finance constraints • Insufficient manning • HMDs security issue • Shopping mall or public area policy limitation • Obstructed passage	• N/A
Pop-In Store	Yes	• Restricted space for movement • Adequate finance for system development and maintenance • Adequate finance for HMDs investment • Adequate employee assistance • Need to direct traffic	• Safety boundary of usage • Salespeople's HMDs training • Waiting area • Traffic flow route • HMDs security • Limited movement area
Collaborative Pop-Up / Event-Driven Pop-Up	Yes	• Sufficient space for movement • Adequate finance for system development and maintenance • Adequate finance for HMDs investment • Adequate employee assistance • High traffic flow	• Safety boundary of usage • Salespeople's HMDs training • Waiting area • Traffic flow route • HMDs security
Guerrilla Store	No	• Finance constraints	• N/A
Pop-ups in Shopping Malls	Yes/No	• Restricted space for movement • Adequate finance for system development and maintenance • Adequate finance for HMDs investment • Adequate employee assistance • High traffic flow • Could be restricted by mall policy	• Safety boundary of usage • Salespeople's HMDs training • Traffic flow route • Shopping mall policy • HMDs security • Waiting area • Limited movement area

This section analyses the applicability of pop-up store typologies for implementing the MR experience. It provides guidance on the sampling strategy for the field study of the thesis and supports the pop-up research design rationale (see Chapters 6 and 7).

2.4.3 Retail Store Environment Design Factors

The retail environment atmosphere can impact consumer buying behaviour, whether in traditional or pop-up stores (Spies et al., 1997). Some environmental psychology studies analyse the impact of environmental cues (such as scent, temperature, colour, music, and scent), design dimensions, and social dimensions on the psychological, affective and behavioural responses of customers (Birren, 1982; Eroglu and Machleit, 1993; Gifford, 1988; Mehrabian, 1974; Spies et al., 1997; Turley and Milliman, 2000). The retail store environment significantly impacts consumers' impulse buying behaviour, such as the stimulation and pleasure of lights, music and colours that enhance impulse buying tendencies (Saad and Metawie, 2015). Store environments also influence consumer judgements on products (Bellizzi et al., 1983; Crowley, 1993). Moreover, when using MR technology for purchase, technology usability and ease of use influence consumer judgements of adopting MR (Davis, 1989), whilst changes in the physical environment can influence technology usability (Jain and Werth, 2019). Therefore, the inferences of interest in this section relate to store interior environment design and usability of MR technology, that is, exploring the relationships between design factors and MR customer experience.

User experience studies claim that store ambience should involve the multisensory experience of the audience in the design, that is, sight, smell, sound, taste and tactile (Eroglu and Machleit, 1993; Hultén, 2011; Pine and Gilmore, 1998). Multisensory experiences are often used as a secondary alternative by small and medium enterprises (SMEs), resulting in pop-up stores that offer only minimal experiential retailing (Alexander and Bain, 2016). This observation echoes the previous section's classification of pop-ups, where small retailers such as kiosks and guerrilla stores that treat experience as a secondary need may not capitalise on the value of MR. Instead, adopting MR in association with well-designed physical retail environments can enable a multisensory dimension to the experience.

Due to the sense of urgency and limited space of pop-up retail, the store atmosphere, functional design, and space planning are worthy of emphasis (Shi et al., 2021). Attractive store design is a controllable key factor for the success of both pop-up stores and permanent stores (Lowe et al., 2018). Baker (1994) explored the holistic perspective

and categorised retail store environment design into environmental, design, and social factors (Baker et al., 1994). These factors can be considered from functional and aesthetic elements (Marans and Spreckelmeyer, 1982). Functional elements include layout, comfort, and privacy; aesthetic elements include architecture, colour, material and style (Baker et al., 1994). Based on Baker's study, Ye et al. (2023) suggest that the essential design factors of pop-up store design are signage, style and layout components.

Subsequent studies have explored the influence of environmental cue features, including colour (Babin et al., 2003; Baker et al., 1994; Ballantine et al., 2010; Bottomley and Doyle, 2006), signage (Ye et al., 2023), layout (Baker et al., 1994; Ballantine et al., 2010; Ye et al., 2023), merchandise display (Blazquez et al., 2019), decoration and furnishing (Baker et al., 1994, p. 1; Jang et al., 2018; Triantafillidou et al., 2017; Ye et al., 2023), lights (Ballantine et al., 2010), sound (Ballantine et al., 2010), walls and ceilings (Berman, 2013; Jang et al., 2018). Studies listed in the previous statement cover the majority of factors that should be considered in traditional retail interior environment design. Ballantine et al. (2010) suggest that the factor with a dominant influence on consumers is product displays. Moderate influences are colour, layout, lighting, and space dimensions. The lesser influences are sound, employees, crowdedness, design features, and comfort features. Subsequently, Ye et al. (2023) proposed a different ordering and identified the more significant influences on consumers: product display, colour, layout, decoration, and signage. The less influential factors are materials, shelves, flooring, and ceiling. Based on the literature review, Table 2.10 summarises the design considerations from traditional store interior studies.

Table 2.10 Traditional store interior environment design factors

Level of significance	Design Factors
Dominant and moderate influence	Light, Merchandise display, Colour, Decoration, Signage, Spatial layout, Space dimension.
Less influence	Sound, Employee, crowd, design features, comfort features, Materials, Shelves, Floors, Ceilings.

However, these studies have not been evaluated in the MR context. Whether these factors similarly affect consumer experience in MR retail stores and whether MR-specific design factor considerations differ from traditional stores remains uncertain. No empirical studies have identified how interior design factors impact customer

behaviours in the real marketplace using MR HMDs. Many studies were conducted in a laboratory environment (Xi et al., 2024), so stakeholders are unable to evaluate the actual effects of MR in-store experience compared to the general in-store experience. Due to retail product managers' lack of understanding of the MR customer experience in stores, they are unable to develop effective MR commercial strategies for a seamless customer journey. Furthermore, due to a lack of empirical studies to guide MR-specific consumer behaviours, no relevant interior perspective studies provide guidelines for brick-and-mortar store environment design for MR retail. These problems prevent interior designers from designing practical projects for MR retail stores.

In summary, Section 2.4 depicts the importance of implementing MR in brick-and-mortar retail and demonstrates that pop-up stores could be used as a marketing strategy to test the consumption market. It also points out that fieldwork is essential to understanding customer behaviours in the real market to help designers further conduct user-centred design. Continuing from the five research gaps identified in Sections 2.2 and 2.3, this section identified additional gaps:

6) Lack of research on MR environments integrated into brick-and-mortar retail stores.

7) Lack of research on user experience and evaluation of MR technology integrated with brick-and-mortar retail stores.

8) No interior environment design guidelines exist for mixed reality integrated with brick-and-mortar retail stores.

Technology acceptance is a critical factor for enterprises in evaluating the success of an MR retail action or design plan, whether before investment, during user testing, or after market implementation. During the process of designing UI, customer experience, and store design, as well as collecting customer feedback to iterate, design management plays a key role in coordinating and integrating design teams to ensure an effective workflow. The following section examines methods of evaluating customer experience and how customer experience management integrates these design departments.

2.5 Technology Acceptance and Customer Experience Management

2.5.1 Technology Acceptance in Mixed Reality Retail

> *"Imagination augments the values of reality (p. 3). The sheltered being gives perceptible limits to his shelter. He experiences the house in its reality and in its virtuality, by means of thought and dreams" (p. 5).*
>
> *The Poetics of Space (Bachelard, 1994).*

MR augments the imagination of customers in physical stores. This experience of coexistence between virtual and reality shapes the perceptions of customers towards the environment. Individuals perceive 'experience' differently, and this perception can be positive or negative. A previous experience affects user attitude toward MR and influences customer intention to reuse MR (Jin et al., 2023). Whether consumers accept and return to use it is pivotal for the market's success (Rese et al., 2017).

The Technology Acceptance Model (TAM) is widely employed in exploring technology intention, user behaviour and immersive technology marketing (Davis, 1989). It is applied to test the user acceptance of a new system with new technology based on the Theory of Reasoned Action (TRA) (Fishbein and Ajzen, 1975). TAM proposes perceived ease of use and perceived usefulness as vital predictors of user attitudes. It explains the influence of the relationship between system, cognition, attitude and behaviour on user motivation from a psychological perspective. Many studies have adopted this model to analyse the acceptance of AR technology from multiple perspectives. These include perceived enjoyment, which is the ability of AR to provide an enjoyable experience (Olsson et al., 2013). Studies also indicate that consumers' acceptance of AR technology relates to impulse buying behaviours (Do et al., 2020), novelty, interactivity and vividness (McLean and Wilson, 2019).

However, the differences in immersion degree and device between AR and MR may impact consumer perception of use and acceptance, which suggests further research on MR technology acceptance for shopping. In other words, MR has some drawbacks regarding bystander privacy (Corbett et al., 2024), social awkwardness, HMD

discomfort and injuries, and hair and make-up concerns (Thomas and Holmquist, 2021). More specifically, the size, weight, and presence of the HMDs cause consumers to notice the bystander's gaze and perceive it as awkward socially. These issues point back to the significance of designing an ergonomic layout for MR interfaces (see Section 2.3.3). Moreover, other negative user evaluation of MR includes data security (De Guzman et al., 2019), ethics concerns (Slater et al., 2020), social implications (Katins et al., 2024) and malicious user interface design (Wang et al., 2024) still influence its marketability. Also, overly realistic MR applications can lead to safety risks by blurring virtual elements and reality, such as in a public environment crossing a street without noticing traffic signals (Jung et al., 2018). These problems emphasise the significance of thoughtfully designed commercial user interfaces and store spatial layouts to create a positive and safe experience, along with evaluating consumer attitudes toward adopting the MR experience in the public retail space.

User technology acceptance studies of MR have been conducted in the areas of educational and learning aids (Rasimah et al., 2011; Vrellis et al., 2020), remote collaborative decision-making (Wang and Dunston, 2013), visualisation of museum information (Hammady et al., 2020), and cultural heritage (Kara and Çakıcı Alp, 2024). MR technology acceptance studies in the retail sector investigate second-hand record shop retailing (Xi et al., 2024) and a grocery shopping assistant system (S. Jain et al., 2021). Nevertheless, these product categories cannot represent a high-value segment, limiting guidance on consumer acceptance of mid-to-high-end products using MR, that is, fashion retail or jewellery retail. Moreover, as researchers proposed, the limitation of their study is the lack of shopping contextualisation within a retail store (S. Jain et al., 2021; Xi et al., 2024). Based on the medium to high-value fashion retail sector proposed in this thesis, current knowledge lacks relevant research on consumer acceptance of MR mass customisation applications in brick-and-mortar store contexts.

This section underlines the significance of consumer technology acceptance for the future large-scale marketisation of MR. It enables stakeholders to have confidence in forecasting the prospect of market success by using the TAM model to pretest market preferences or evaluate their design outcomes or marketability strategies.

2.5.2 Customer Experience Management for MR Commercial Design

Customer experience (CX) is holistic, including the entire lifecycle of the customer from pre-purchase to post-purchase (Verhoef et al., 2009). Effective business strategy and customer experience management (CEM) can help retail executives strategically plan for market deployment to advance their brand benefits (Verhoef et al., 2009). The design of MR applications (see Section 2.3), physical store environments (see Section 2.4), and customer evaluation (see Section 2.5.1) are considered part of the MR customer experience. CEM aims to improve its experience efficiency by holistically organising and managing all design phases.

Customer experience management focuses on identifying all the cues that people discover during the buying process, which involves analysing the customer journey by identifying and integrating lifecycle touchpoints (Berry et al., 2002). Schmitt (2003) proposes that CEM has five stages: analysing the world of customer experience, building the experience platform, designing the brand experience, designing the customer interface and continuous innovation (Schmitt, 2003). Another study extends the CEM framework of Schmitt (2003), defined CEM as eight phases: instigation and objective setting, coordinating and overseeing the changes, undertaking customer research, defining the experience, undertaking action research, prioritising areas for development, developing and piloting the changes, and changing the support systems (Johnston and Kong, 2011). Although these studies from management and marketing perspectives discussed the CEM framework extensively, a CEM framework for the MR experience has not been established for immersive retail.

In particular, CX is influenced by plenty of variables such as customer demographics, psychological, personal, social, and cultural characteristics, technology, shop typology, product or service category, and location (Bitner, 1992; Verhoef et al., 2009). This implies that practitioners should adequately incorporate these factors into the initial market research stage when analysing the CX world and designing an experience platform to create a personalised experience aligned with brands.

While designing the brand experience stage, MC retail's value is enabling consumers to interact with companies through personalised and co-created experiences, exerting

their influence in every part of the business system (Prahalad and Ramaswamy, 2004). Consumers can participate in co-creation, creating new value beyond the market (products and services) (Prahalad and Ramaswamy, 2004). During this stage, designers can encourage consumers to participate in the design process to ideate user-centred design solutions to fit customer demands better. MR UI and store environment as part of in-store services provide an experience platform virtually and physically in a commercial environment for co-design.

In the retention and continuous innovation stages, customer experience feedback is a key indicator for estimating customer retention or conversion. Customer experience is individual and subjective, so customer experience measurement is consistently challenging due to its complexity (Jain et al., 2017). Some traditionally measured dimensions include experience satisfaction, purchase intent, loyalty, recommendation, experience quality, and experience value (Jain et al., 2017). Some commonly use measurement tools include, for example, the User Experience Questionnaire (Schrepp, 2015), Brand Experience Scale (Zarantonello et al., 2007), Experience Quality Scale (Chang and Horng, 2010), and Customer Experience Index (Kim et al., 2011). Some studies have used these tools in MR experience, suggesting that more experienced users perceive experience better and have more positive intentions towards using MR (Obermeier et al., 2021). Customers have shown an increased willingness to engage with retailers after the MR experience (Holopainen et al., 2018). Managers should use appropriate tools according to the stage of experience, measure customer responses regularly, and design strategies to shape customer perceptions of the experience.

Furthermore, a marketing study concludes a future research agenda for AR/MR, which partly aligns with this thesis's proposed research gaps: 1) Designing effective AR experiences – how to personalise virtual environments content to enhance the AR experience; 2) AR and marketing strategy – how marketers can use AR more effectively at different stages of the customer journey to increase brand engagement and improve the relationship with customers; 3) Driving AR adoption – how offline contextual factors affect AR adoption and exploring barriers to consumer use of AR technology (see Research gap 6); 4) AR as a marketing intelligence tool – using AR experiences to provide insights into store layout and design (see Research gap 8); 5) Driving AR adoption and consumer behaviour – how the MR experience affects consumer

acceptance and use of the technology (see Research gap 9) (Tan et al., 2022a). These research agendas highlight the intersection between design and marketing, revealing gaps still unexplored in MR customer experience research from management perspectives. All these findings emphasise the need to design a practical MR customer experience management framework to strategically plan design into commercial implementation.

This section informs the thesis's research design framework by incorporating CEM and marketing perspectives. It identifies the UI, UX, and store design as crucial components during a holistic CEM structure. Retailers and businesses must address these problems before adopting MR technology in order to offer a seamless and inclusive customer experience in brick-and-mortar retail settings. Continuing from the research gaps identified in previous sections, this section further identified additional gaps:

9) Lack of research evaluating user acceptance of mixed reality product configurators integrated into brick-and-mortar stores.

10) Lack of a holistic mixed reality customer experience management framework in integrating the MR commercial design.

In summary, Section 2.5 highlights that customer technology acceptance is an essential prerequisite for MR marketability, and customer experience perceptions influence MR acceptance. The CEM framework is instrumental in planning an efficient CX strategy and a holistic commercial design. Addressing these ten research gaps identified in the literature review promises to provide practical solutions in MR UI, store design, marketability, and management strategy for accelerating the progress of the future MR retail market.

2.5.3 Design Engagement

As discussed, MR represents an emerging approach to service and experience in retail, combining embodied interaction, postdigital spatiality, and TUI. The aim is to enhance consumer engagement across the entire customer journey (Verhoef et al., 2009). Brands, users, and bystander customers' holistic engagement suggest that participatory

experiences must closely align digital content with consumers' lives and social environments (Scholz and Smith, 2016). This concept informs the direction of this thesis, which develops both theory and practice through a series of design-oriented approaches, framed here as *Design Engagement*.

The goal of design engagement is not just to engage people in a dialogue or purchase but to involve them in exploring new ways of doing things (Teal and French, 2016). Through co-design, co-creation, participatory design, and user-centred design, the design engagement values in MR retail have been articulated (see Sections 2.2, 2.3, 2.4 and 2.5). Design engagement, as a holistic umbrella term for the thesis, integrates various design methods, including co-design of products, co-creation of virtual worlds, participatory design, and user-centred design development, throughout the different design stages of this thesis. By leveraging this principle as a research design approach, it addresses the research gaps.

2.6 Summary of Research Gaps

The previous sections have introduced the main concepts studied in this thesis are *mixed reality*, *omnichannel retail*, *store interior environment design*, *mass customisation user interface design*, and *customer experience management*. From the preceding review of the state of industry practice and literature, the following ten research gaps including both practice and theory have been summarised in the fields of design, retail, and HCI:

- Research gap 1: Addressing the issue of short in-store dwell time and lack of shopping enjoyment. (Derived from Chapter 2.2)
- Research gap 2: Lack of research on XR technologies (VR, MR, AR) in retail with user acceptance and consumer demographics. (Derived from Chapter 2.2)
- Research gap 3: Lack of comparison between MR and AR retailing, including consumer intent to use, experience, and purchase. (Derived from Chapter 2.2)
- Research gap 4: Absence of design recommendations and practices for mixed reality parameterised configurators for mass customisations in retail. (Derived from Chapter 2.3)
- Research gap 5: Lack of a participatory rapid prototyping approach to aid rapid iterative testing of early-mid MR commercial systems. (Derived from Chapter 2.3)

- Research gap 6: Lack of research on MR environments integrated into brick-and-mortar retail stores. (Derived from Chapter 2.4)
- Research gap 7: Lack of research on user experience and evaluation of MR technology integrated with brick-and-mortar retail stores. (Derived from Chapter 2.4)
- Research gap 8: No interior environment design guidelines exist for mixed reality integrated with brick-and-mortar retail stores. (Derived from Chapter 2.4)
- Research gap 9: Lack of research evaluating user acceptance of mixed reality product configurators integrated into brick-and-mortar stores. (Derived from Chapter 2.5)
- Research gap 10: Lack of a holistic mixed reality customer experience management framework in integrating the MR commercial design. (Derived from Chapter 2.5)

There are noticeable research gaps in the adoption of MR technology in the retail industry, from design guidance to strategic presence. The research gaps derive four research questions and will be interpreted in the next chapter (see Section 3.2). This thesis will address ten research gaps, contributing to academia and industry through a series of empirical and explanatory research methods grounded in human experiences.

Contributing Publications to Chapters

Some of the works contained in this thesis have been published or are under review. The contributions to the publication are listed below.

Contribute to the Field of Retail and Marketing:

- Jin, L., 2025. Comparison of Customer Experience in Traditional and Mixed Reality Fashion Shops. Proceedings of Academy of Marketing Science Annual Conference. Montreal, Canada. In press.

  This conference paper forms the basis of Chapter 6 and solves the research gaps 1 & 6.

- Jin, L., Dalton, R., Fagan, D., 2023. Extended Reality (XR) Survey: A Consumer Technology Acceptance Preference Study on Retail, in: Proceedings of the 8th Colloquium on European Research in Retailing 2023. University of Portsmouth, Portsmouth, UK, pp. 207–218.

This conference paper forms the basis of Chapter 4 and solves the research gap 2.

Contribute to the Fields of HCI and Design:

- Jin, L., 2023. Comparison of User Intent for Mixed Reality and Augmented Reality in Hedonistic Shopping Experiences, in: Extended Reality, Lecture Notes in Computer Science. Springer Nature Switzerland, Cham, pp. 437–455.

  This conference paper forms the basis of Chapter 4 and solves the research gap 3.

- Jin, L., 2025. Adopting Mixed Reality Product Customisation in Brick-and-Mortar Retail: Stakeholder Insights for Commercialisation Challenge, in: Proceedings of the 2025 ACM Designing Interactive Systems Conference, DIS '25. Association for Computing Machinery, New York, USA, pp. 1886–1899.

  This conference paper forms the basis of Chapter 5 and solves the research gap 4.

- Jin, L., Fagan, D., 2024. MRPaperPro: Mixed Reality Interdisciplinary Design Prototyping Technique, in: Proceedings of the 2024 ACM International Conference on Interactive Media Experiences, IMX'24. Association for Computing Machinery, New York, USA, pp. 268–275.

  This conference paper forms the basis of Chapter 5 and solves the research gap 5.

Under Review:

- Jin, L., 2025. Can Traditional Retail Brick-and-Mortar Shops Employ Wearable Mixed Reality In-store?

  This journal paper forms the basis of Chapter 6 and solves the research gap 7.

- Jin, L., Karnik, A., Fagan, D., 2025. Designing Commercial Physical Environments to Optimise Accessibility for Mixed Reality User Experiences.

  This journal paper forms the basis of Chapter 7 and solves the research gap 8.

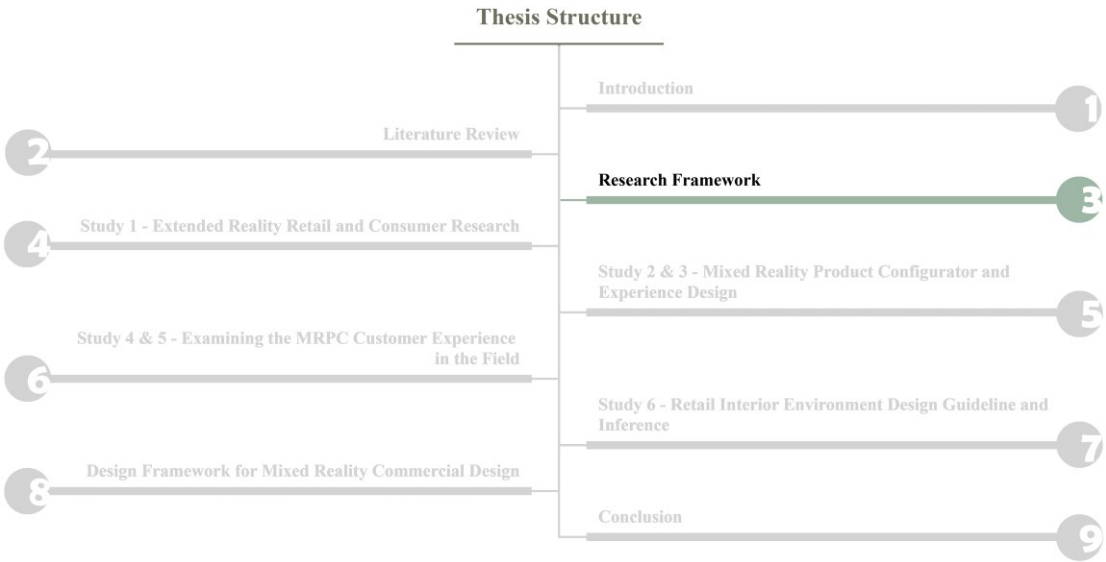
- Jin, L., Karnik, A., 2025. Design Principles on Mixed Reality Product Configurator Interfaces.

  This journal paper forms the basis of Chapters 5 and 7 and solves the research gaps 4 & 9.

2.7 Chapter Summary

This chapter reviews the six topics of ***mixed reality***, ***mass customisation***, ***jewellery retailing***, ***configuration design***, ***brick-and-mortar store interior design***, *and* ***customer experience management***. These help to identify ten research gaps (Section 2.6) to be addressed in this thesis. These knowledge gaps frame the research questions and research objectives of this thesis. The research questions and methodology will be described in the next chapter.

3 Research Framework



3.1 Introduction

This chapter introduces how the research aims are transformed into actionable research questions and objectives. It presents the rationale for the research, including philosophical and theoretical perspectives, methodology, methods, and sampling strategy, and explains the rationale for the choice of research methods.

3.2 Research Questions and Objectives

The literature review identified research gaps and motivations that led to the determination of the research questions and objectives as follows. To fulfil the meta-question, four research questions are raised and addressed in four chapters.

The research questions interpret the aims of this thesis, which is to enhance the MR technology experienced in the brick-and-mortar retail environment regarding accessibility and inclusivity in order to provide a seamless customer experience. In a general context, accessibility is defined as the design of environments, interfaces, products, or services to be usable and available to people with disabilities (Emiliani and Stephanidis, 2005). Accessibility for individuals with disabilities is not the focus of this thesis, but rather inclusivity for access to technology and experiences. In this thesis, *MR experience accessibility* means enhancing the usability and ease of use of the technology when customers are experiencing MR shopping in brick-and-mortar stores. *Inclusivity MR design,* in the context of MR retail, is defined as ensuring that MR retail design considers and benefits a wide range of customer groups to meet different user needs, regardless of their ability to be familiar with digital tools (previous MR experience), age, gender, or educational background. Inclusivity encompasses broader dimensions, which are experience accessibility, user diversity, technological familiarity, and cultural responsiveness. This thesis proposes an MR commercial design framework that incorporates customer preferences, demographic factors, and experience accessibility improvements to aid in creating an inclusive in-store MR retail experience for public domain.

Meta Question: How is it possible to design accessible customer experiences in mixed reality retail environments for brick-and-mortar stores? ***(Research gap 10)***

Objective (Chapter 8):

- Determine a systematic mixed reality customer experience design management framework to improve the accessibility of brick-and-mortar store experiences, from technology matching, designing MR interfaces and store interior environment to consumer acceptance.

3.2.1 Research Question 1

RQ1: What is the feasibility of, and user preference for, mixed reality adoption in the retail industry? (Research gaps 2 and 3)

Objective (Chapter 4):

- **RQ1_OBJ1:** Determine matching immersive XR technologies in retail with user acceptance and demographics, and design scope in retailing.

RQ1 defines the feasibility of implementing MR technology – whether customers are willing to engage with MR as part of their shopping experience. Focusing on independent MR preferences would potentially overlook consumers who may prefer other immersive technologies. A cross-sectional comparison of VR, MR, and AR can comprehensively understand consumer preferences.

3.2.2 Research Question 2

RQ2: How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments? (Research gaps 4 and 5)

Objectives (Chapter 5):

- **RQ2_OBJ1:** Designing a participatory rapid paper prototype method for usability testing of MR commercial applications to iterate system design.
- **RQ2_OBJ2:** Define the standpoint and user requirements for the MR product configurator and design a user-centred user interface.

RQ2 investigates how to design and develop a practical and hedonic MR product configurator with reusable design features and ergonomic UIs to satisfy the MR retail experience.

3.2.3 Research Question 3

RQ3: What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops? (Research gaps 1, 6, and 7)

Objectives (Chapter 6):

- **RQ3_OBJ1:** To compare customer experience frameworks in traditional and MR brick-and-mortar shops.
- **RQ3_OBJ2:** To investigate the barriers to accessibility of Mixed Reality Product Configurators in brick-and-mortar stores and the associated design solutions.

RQ3 discovers and defines the barriers and obstacles encountered in the customer experience in a brick-and-mortar shop context using the developed MR product configurator.

3.2.4 Research Question 4

RQ4: How is it possible to design inclusive mixed reality retail interior design guidelines for diverse demographics? (Research gaps 8 and 9)

Objectives (Chapter 7):

- **RQ4_OBJ1:** To determine an elaborate guideline of design factors and values for planning and implementing mixed reality store interior environments.
- **RQ4_OBJ2:** To anticipate the user acceptance of the MRPC as an innovative retail purchase approach and evaluate the MRPC design.

RQ4 explores designing a more inclusive physical environment for MR-based experiences in shops to reduce the obstacles to customer experience in adopting MR virtual experiences.

The four research questions collectively answer the meta-question of developing a commercial design framework to guide strategic planning and design development in MR retailing, through interdisciplinary design considerations and multi-stakeholder design engagement, to construct a more accessible MR experience in brick-and-mortar shops. The "*design engagement*" is defined as a mode of holistic working that integrates co-design, user participation, iterative experimentation, and experiential evaluation.

This approach across ideate and design activities, gathering feedback, and continuous innovation. To achieve this research aim, the following elaborates on the detailed research means adopted for answering these research questions.

3.3 Research Paradigm

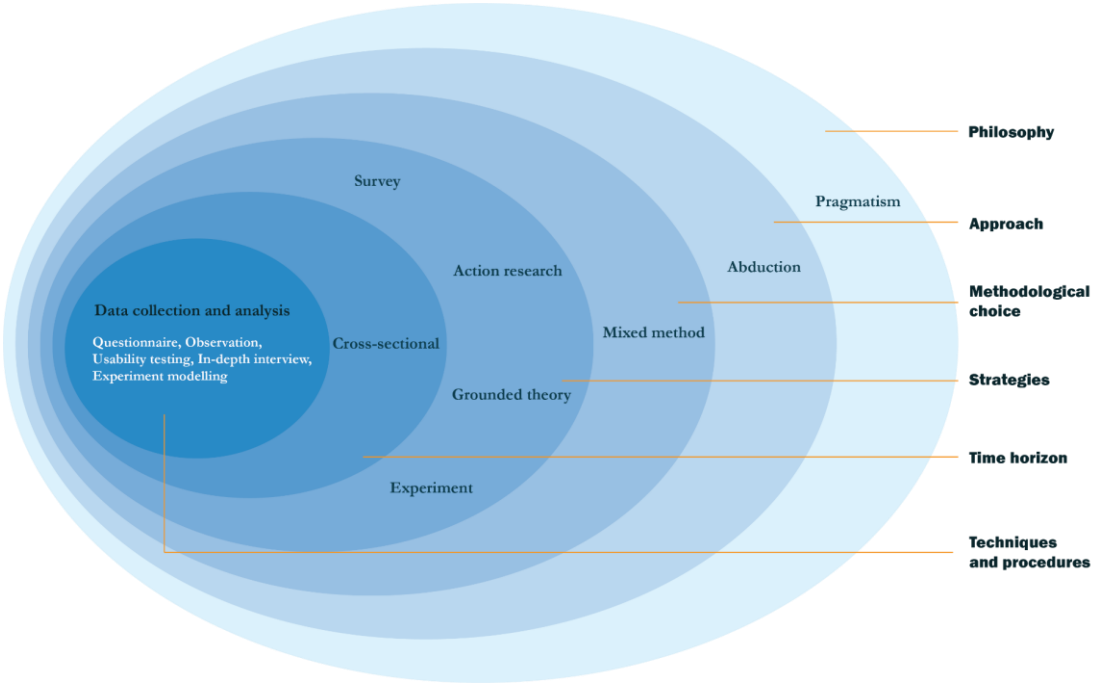


Figure 3.1 Thesis research hierarchy. Adapted from Saunders et al. (2019)

Figure 3.1 demonstrates the research framework hierarchy in this thesis and the choice of philosophy and approach (Saunders et al., 2019) (Section 3.3). The rationale of the thesis methodology, strategies, techniques, and design framework will be addressed in Section 3.4. The research design structures will be introduced in Section 3.5, and the thesis studies sampling strategies will be concluded in Section 3.6.

3.3.1 Epistemology

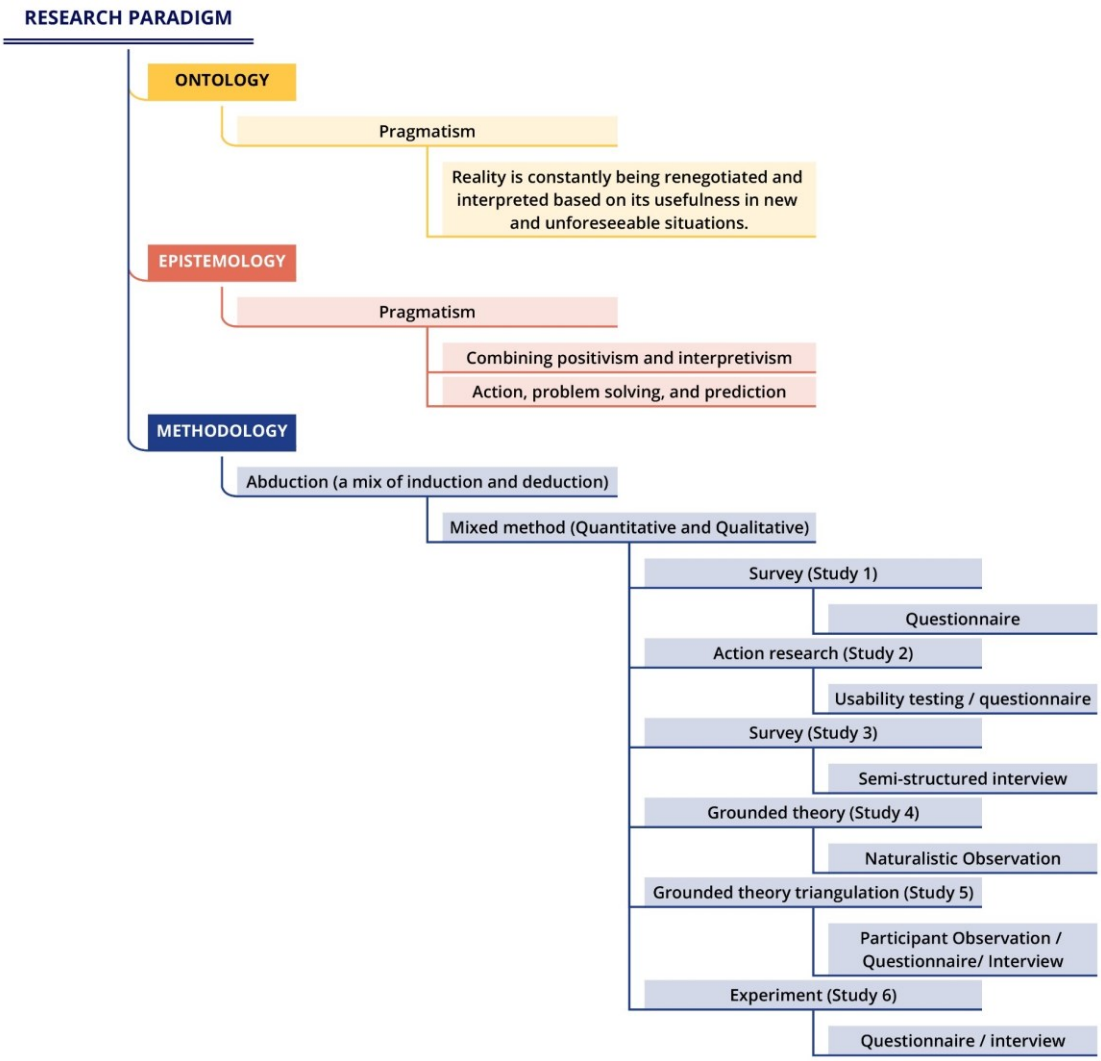


Figure 3.2 Research paradigm

Research methods are inevitably rooted in ontology and epistemology. Epistemology, methodology, and methods are interrelated, and the flowchart illustrates a holistic framework for the research paradigm (Figure 3.2). Epistemology is defined as a theory of knowledge embedded in a theoretical perspective (Crotty, 1998). Epistemology demonstrates the research position of the researcher, and therefore, identifying, interpreting, and justifying epistemology is fundamental (Crotty, 1998).

The philosophical perspectives of this thesis are rooted in ***pragmatism***. Pragmatism believes knowledge is generated based on experience, crafted from unique human

experiences. Social knowledge is created from shared experiences in society, aiming to produce constructive knowledge for universal application (Goldkuhl, 2012; Morgan, 2014). It emphasises practical interest, investigates a part of reality, provides constructive knowledge, and is action-oriented (Rescher, 2000).

Moreover, pragmatism considers the priority of action over theory and experience over fixed principles (Rosenthal, 2022). Pragmatists believe that there are many different means of explaining the world and conducting research, that a single point of view cannot explain the whole situation, and that multiple realities may exist (Kelemen and Rumens, 2008). Therefore, it combines forms of positivism and interpretivism, and its features include prescriptive (giving guidelines), normative (demonstrating values), and prospective (suggesting possibilities) (Goldkuhl, 2012).

Based on the philosophical underpinnings of pluralism, it shifts between deductive and inductive reasoning back and forth, that is, abductive reasoning (Goldkuhl, 2012; Morgan, 2014). The methodology suggests using mixed methods, incorporating qualitative and quantitative research (Goles and Hirschheim, 2000). Researchers give one or more reasons to justify the rationale for their use of the methodology. Data are generated through evaluation and intervention, contribute through intervention and design, and are used for evaluation and intervention (Goldkuhl, 2012). Conceptual development is co-constructed by researchers and practitioners (Clark and Ivankova, 2016). The thesis aims to research through design to produce constructive knowledge for universal application, and design practices are an important part of the outcome. The outcome is for research for design, where research questions and objectives demonstrate the need for using a mixed methods approach to provide prescriptive and prospective knowledge. Therefore, pragmatism is highly compatible with this research.

3.3.2 Approach

While the means of science are deductive and inductive reasoning, there is a third approach, abductive reasoning, which follows a pragmatist perspective (Kovács and Spens, 2005). Pragmatist philosophy is the mixed methods research paradigm, including deduction and induction as approaches. It proposes the problem and solves or refines it from a practical application perspective.

Inductive reasoning aims to build theories, while deductive reasoning aims to test existing theories (Streefkerk, 2022). The limitation of inductive reasoning lies in the inability to prove theories from induction, hence, the higher the sample size, the greater the reliability and generalizability of the data results (Bhattacherjee, 2012). The limitation of ***deductive reasoning*** is that if a theory does not yet exist, a deductive study cannot be conducted to test it. Consequently, theories resulting from inductive research are often considered to be the starting point for deductive research (Streefkerk, 2022). Due to the aforementioned reasons, this thesis utilised *abductive reasoning*, which aligns with the research objectives.

3.4 Research Methodology

In line with the pragmatic abductive reasoning theoretical perspective, a mixed methods approach as a methodological guide is employed. The methodology and methods are outlined (Table 3.1).

Table 3.1 Research paradigm hierarchical structure used in this thesis

Criteria	Selection	Characteristics
Philosophy	Pragmatism	Giving guidelines, demonstrating values, and suggesting possibilities.
Approach	Abductive reasoning	A combination of deductive and inductive.
Methodological choice	Mixed methods	Quantitative and qualitative.
Strategies	Survey, Action research, Grounded theory (triangulation), Experimentation	Conceptual development is co-constructed by researchers and participants.
Time Horizon	Cross-sectional	With a regional perspective on the current time.
Data collection methods	Questionnaires, Semi-structured interviews, Usability testing, Naturalistic observation, Participant observation, Experiment	It uses multiple methods for small-scale, in-depth and large-scale, rapid data collection, including diverse stakeholders.

3.4.1 Methodological Choice

Quantitative research involves the use of hypotheses, variables, and statistical procedures to analyse data (O'Leary, 2017). Qualitative research, on the other hand,

entails gaining a rich understanding through the study of a few in-depth cases (O'Leary, 2017). Mixed methods research combines statistical data with descriptive explanations to offset the weaknesses of both quantitative and qualitative approaches, allowing for stronger evidence through triangulation (Clark and Ivankova, 2016). Triangulation is the use of multiple methods to measure a research question on the same topic to strengthen the reliability and validity of the results and to reduce potential research bias by a single researcher (Creswell, 2009). Triangulation is employed both as a methodology and a data collection method for a study (Creswell, 2009).

The advantage of a mixed methods approach is that its methodological pluralism leads to a superior complementary ability. As an extension of qualitative and quantitative methods, the mixed methods approach makes them compatible and complementary (Johnson and Onwuegbuzie, 2004). Thus, a mixed methods approach enables arguments that lead to more complete conclusions (Farmer and Knapp, 2008). Drawing on justifications from Farmer and Knapp (2008), the rationale is threefold:

> *"First, the researchers wanted to comprehend and explore phenomenon from the interpretive experience via multiple approaches, using quantitative and qualitative data, to offset the limitations for using only one medium in analysing the experience. Second, by using different methods throughout the study, one method was used to inform the construction and implementation of the proceeding method. Finally, the use of mixed methods allowed for a more comprehensive understanding regarding the interpretive experience (p. 342)".*

Using a mixed research methods approach can effectively address the research questions of this thesis, which is to produce pragmatic solutions through a combination of qualitative and quantitative research methods.

3.4.2 Strategies

The existence of several different research strategies will be presented, including the adoption of the relevant methods of this study (Table 3.2) and a brief description of other methods to exemplify some of the considerations given in the selection of these methods (Table 3.3).

Table 3.2 List of appropriate strategies used in this thesis

Strategies	Characteristics	Appropriate reasons
Survey	• Surveys are categorised as analytical and descriptive. • Analytical surveys involve questionnaires; data analysis involves statistics and mathematics. • Descriptive surveys such as interviews and data analysis can use qualitative tools.	It fits the intent of collecting large and inductive, small and deductive social audience purchase behaviour patterns and in-depth user behaviour and decision patterns.
Action research	• Action research focuses on a holistic approach to problem-solving rather than a single method of collecting and analysing data. • It simultaneously uses several different research tools, such as documents, participant observation notes, questionnaires, structured and unstructured interviews, and case studies. • Researchers collaborate with participants, and decisions about possible outcomes of research are made collaboratively.	It meets the objective of engaging in participatory design with consumers to better satisfy consumers's demands of the system user interface design.
Grounded theory	• From data collection to data processing, it offers a set of systematic and precise techniques along with explicit analytical processes to formulate innovative theories. • No research hypotheses or concrete questions have to be predetermined; theories emerge naturally from observation.	It aligns with the aim to conclude pop-up in-store behaviour of traditional stores and construct a new theory based on MR in-store behaviour.
Experimentation	• It is objective, valid and replicable results. • Experimentation requires the advanced formulation of research questions or hypotheses. • The purpose is to measure the relationship between the dependent and independent variables.	It fits the aim of controlling multiple variables to measure design factors and values.

Survey is a common research method that can be used to measure demographics, behaviour, and attitudes (Jamshed, 2014). Surveys are categorised as analytical and descriptive, with common forms of data collection such as questionnaires and interviews (Gray, 2004). Analytical surveys involve the use of questionnaires, emphasising sample size, variables, and structural aspects, aiming to test the relationships between variables and resembling experimental research. On the other

hand, descriptive surveys such as interviews are typically used to explore audience attitudes, values, and opinions, having ethnographic features (Gray, 2004).

Action research has some alternative names, such as participatory research and collaborative inquiry. They focus on the same theme of a group of constituents identifying a problem and solving the actual problem in a way that they all find ideal (O'Brien, 1998). It emphasises the importance of researchers and participants collaborating in the research process (O'Brien, 1998). The action research process is periodic and continuous, usually with four steps in each cycle, which are planning, action, observing, and reflecting (O'Leary, 2017; Zuber-Skerritt, 2021). Reassessment and iteration of the problem are based on the level of success of the action, which continues until the problem is solved (Susman, 1983). It accommodates the simultaneous use of multiple techniques, such as documents, participant observation records, questionnaires, structured and unstructured interviews, and case studies (O'Brien, 1998).

Grounded theory is a research methodology that focuses on understanding behaviours and interactions, encompassing various stages from systematic data collection to the development of conceptual theories (Goulding, 2002). It offers a set of systematic and precise techniques along with explicit analytical processes to formulate innovative theories (Glaser and Strauss, 1999). Grounded theory employs a structured approach to examine social, symbolic, and context-specific behaviours (Glaser, 1999). Several methods, such as direct observation, participant observation, semi-structured and structured interviews conducted in natural environments, are suitable for employment with this methodology (Turner, 1983).

Experimentation is a standard positivist research method that aims to produce objective, valid, and replicable results (O'Leary, 2017). The experimental research design process consists of a planning phase and an operational phase in formulating research questions or hypotheses and conducting research on relevant literature and theories to identify the dependent variable (the subject of the study) and the independent variable (the variable that influences the dependent variable) (O'Leary, 2017). Experimental analyses may use descriptive and inferential statistics to describe the data and evaluate statistical

hypotheses to answer the research question and prove whether the hypothesis is valid (Gray, 2004; O'Leary, 2017).

Table 3.3 List of inappropriate strategies unused in this thesis

Strategies	Characteristics	Inappropriate reasons
Case study	• Case studies explore multiple topics and scopes of individual cases in a more focused group of people, organisations, or environments (Gray, 2004). • Case study research attempts to identify cause-and-effect relationships rather than merely describing a situation. It tries to reveal the relationship between a phenomenon and the context in which it is situated (Gray, 2004). • The case study method requires collecting data from multiple sources and benefits from a pre-formulated theoretical hypothesis (Gray, 2004; Walsham, 1995).	The objective is not to explore the different topics of regional and specific cases.
Discourse analysis	• Analysing different texts and discourses. • Emphasising the understanding of opinions, beliefs and phenomena behind the discourses (Atkinson et al., 2000).	The objective is not to emphasise the phenomenon of consumer discourse or the culture behind it.
Ethnography	• The researcher conducts field research observations and interviews by capturing the natural daily activities and social meanings of participants (Hammersley and Atkinson, 2019). • It is unstructured and flexible and requires the researcher to be actively involved in the activities of those being studied (Hammersley and Atkinson, 2019).	Researchers do not need to examine how societies and individuals operate in relation to a particular social community.
Phenomenological research	• It relies on the experience of the audience and is unstructured and hard to replicate. • Focusing on the interpretations of events by the audience, the researcher needs to have a deep understanding of the audience's thoughts, feelings and experiences (Larsen and Adu, 2021).	The objective of the study does not involve an in-depth interpretation of the phenomenon of consumer experience.

3.4.3 Techniques

Each research method contains several different data collection methods, and the usage of the method determines the type of data and analysis methods. The choice of data collection methods is explained in Table 3.4, along with other data collection methods that are not applicable (Table 3.5). It contains some common research methods and neurophysiological measures in the area of design and HCI.

Table 3.4 List of appropriate data collection methods used in this thesis

Methods	Characteristics	Appropriate reasons
Questionnaire	It is possible to get a large number of responses from a dispersed group of users rapidly and inexpensively. Can use single or dual factors analysis. Participants' quantity needs to be enough to be effective. It is only appropriate for investigating superficial data, not for in-depth investigations. It may cause bias if the content is related to usage patterns or emotions. Applicable to the investigation of established objective facts.	It is very suitable for multi-variable tests and analysis of the relationship between the variables for large-scale consumer market research.
Usability testing	Usability testing involves testing various aspects such as consistency, ease of use, usability, layout, interaction clarity, information provision, and readability. It can take place in the early stages, middle stage or before the system is released. A moderator is involved in usability testing, and end-users test the system screen-by-screen.	It is consistent with the assessment of this thesis for exploring the usability of system design and interaction design.
Semi-structured interview	Responding in-depth. Unsuitable for multi-variable tests. Time-consuming and labour-intensive. The interviewer needs interview skills. Require skilful facilitation. Short-period data results are less effective.	This technique enables the researcher to drill down into the ideas and opinions behind the responses of multiple stakeholders.
Grounded theory	It does not involve any treatments, experiments, or manipulated social settings. Consequently, the data will be considered as natural phenomena in people's real lives. Obtains first-hand information that is more effective than information obtained by other means. Observe what employees do and how they do it in the natural environment or the workplace, which is better than other methods for collecting information on non-verbal behaviour. It is suitable for generating new theories.	It aligns with the research objective to generate a new theory framework in a new MR context.
Experiment	The environment needs to be manipulated. Use descriptive statistics to describe and summarise data sets. Using inferential statistics for prediction, extrapolating from the current sample size results to the feasibility of applying to a larger population.	It provides the ability to recognise design elements and understand experimental effects to generate rigorous guidelines.

Questionnaire surveys are suitable for collecting data on a limited range of topics from a large, diverse and widely distributed group of people (Gray, 2004). They can be structured, semi-structured, or unstructured. Structured surveys will offer options for participants to choose from, while semi-structured ones will provide an opportunity to both answer questions and fill in information. Unstructured surveys, on the other hand, do not provide fixed answers, and the questions are open. A common design for

structured responses is the scale, which has three options: Likert, Guttman, and Thurstone scales (O'Leary, 2017).

Usability testing (user testing) refers to the system design that can be tested to identify and address existing issues (Nielsen, 1994). It is one of the commonly used methods for system usability analysis in HCI, whereas another method is heuristic evaluation. Usability testing involves testing various aspects such as consistency, ease of use, usability, layout, clarity of interaction, information provision, and readability (de Vreede et al., 2005; Nielsen, 1994). It can take place in the early stages of design to test concepts, in the middle to evaluate the effectiveness of system design, and can also be used to validate the overall system capability before the system is formally released (Nielsen, 1994; Rubin and Chisnell, 2011). A moderator is involved in usability testing, and end-users test the system screen-by-screen. In contrast, heuristic evaluations do not have a facilitator, and the UX experts complete a holistic test before the evaluation (Nielsen and Molich, 1990).

Interviews can be structured, semi-structured, and unstructured, and can be completed online and face-to-face (O'Leary, 2017). Structured interviews ask questions in a standardised form through pre-designed questions, while semi-structured interviews create an outline of questions adapted to the conversation. The advantage of this is that the interviewer can deeply dig into the data behind certain points based on the interviewee's answers. Unstructured interviews do not have pre-designed questions but tend to ask questions around a developed theme to elicit a wealth of information and ideas (O'Leary, 2017).

The technique of ***grounded theory*** involves a series of fundamental processes, from theoretical sampling and data processing to theory formation (Glaser, 1999). Firstly, theoretical sampling in grounded theory is an emergent process without preconceived topics or research hypotheses (Glaser, 1999). Researchers identify new themes through data interpretation and comparison. Secondly, the coding process consists of three axial structures: open coding, raw data decomposition, and conceptualisation of initial categories. This process may generate initial codes through keywords or phrases. Axial coding conceptualises these open codes by clustering concepts to generate descriptive keywords and assess the relationships between the previous and current levels. Selective

coding further refines the previous categories into core categories. The data is then inductively integrated to generate new theories (Glaser and Strauss, 1999). Throughout the theory generation process, researchers continuously compare codes at each level to identify similarities and differences. Finally, to ensure the validity of the theory, a portion of the data needs to be set aside for sampling before coding. This reserved data sample is used in saturation testing, where the theory is considered saturated when no new perspectives or categories emerge from the sample (Glaser and Strauss, 1999).

Experiments, as a data collection and analysis technique, are usually used in conjunction with questionnaires. In contrast to the qualitative analysis approach, which does not rely on the subjective understanding and interpretation of the responses of the researcher, descriptive and inferential statistics are used to describe the data, assess statistical hypotheses, and draw inferences from the sample population to the broader population (Gray, 2004).

Table 3.5 List of inappropriate data collection methods unused in this thesis

Methods	Characteristics	Inappropriate reasons
Diary	• Documenting user interactions with processes and interfaces, recording the impact of user habits, motivations, and familiarity with processes during their experience at that moment, and preventing them from forgetting some details. Choosing the wrong participants will cause bias. • It needs a more extended analysis period. • Long-term analysis could make them lose interest if setting a reminder system inaccurately affects their real-time action.	This method distracts the user from using the system and is ineffective in collecting user behaviour to use the system.
Focus group	• Suitable for multi-user tests. • Group discussion provides interactivity. This could help overcome non-talkative interviewees. • Physically, it needs a large space for multiple users. • It limited the number of questions in the interview. 5-7 a group, two or more groups.	The study entails multi-stakeholder participation, and this activity is geared towards a specific group of multi-users.
Heuristic Evaluation	• The evaluators consist of UX experts with relevant skills. • The evaluator completes the whole test to provide guidance and recommendations. • Evaluation topics are based on a heuristic checklist.	This method is less suitable for research objectives than usability testing. Heuristic evaluation relies on evaluators cross-checking the product against design rules, and these participants are often not end users.
Workshop	• It can be used in the early and middle stages of UX design.	Inviting multiple stakeholders to participate

Methods	Characteristics	Inappropriate reasons
	• It is divided into exploration, empathy, design, prioritisation, and critique workshops. • Design workshops are collaborative sessions between designers and stakeholders to generate ideas and solutions rapidly. • Some qualitative experience may be needed to support the completion of a workshop.	jointly and coordinate their schedules can be challenging. Geographic constraints could also make activities difficult to launch.
Eye tracking	• Track the order in which users look and position, and identify where they are attracted to the attention of consumers. • HoloLens 2 has eye tracking, but if the user has certain types of contact lenses and glasses, and the user has specific eye physiology or eye conditions, or has had eye surgery that the system does not yet support, there are limitations to participants.	Sight and attention tracking are not essential objectives of this study. Considering the time constraints, this method is impossible to execute.
Galvanic skin response (electrodermal activity)	• Measures emotional state by measuring user sweating. It is ideal for assessing the level of emotional arousal during the in-store shopping experience. • Participants moving their hands frequently may produce artefacts or false readings in the GSR, as physical activity can cause sweating and sharp changes in ambient temperature. • Moreover, there is a slight time delay between measurement and response.	The objective of this study is not to assess emotional arousal during in-store shopping.
EEG: electroenceph-alography (brain activity)	• To measure brain activity to control the computer and distinguish different types of activity and status. • Expensive for equipment.	Limited access to the equipment makes it difficult to obtain measurement instruments. In addition, the objective of the study is not to focus on changes in the cerebral activity of the user.

3.4.4 Design Framework

The previous sections explain rationality on a philosophical level and the method selection of this thesis. This section summarises the overall framework of the strategies applied from a design perspective, including the design framework rationale and how it is embedded throughout the chapters. Figure 3.3 depicts the holistic stages of the research design, including research about design for identifying the problems (Study 1) to research through design (Studies 2 – 6), and research for design, abducting from the research studies to generate a new design framework to use to guide future research.

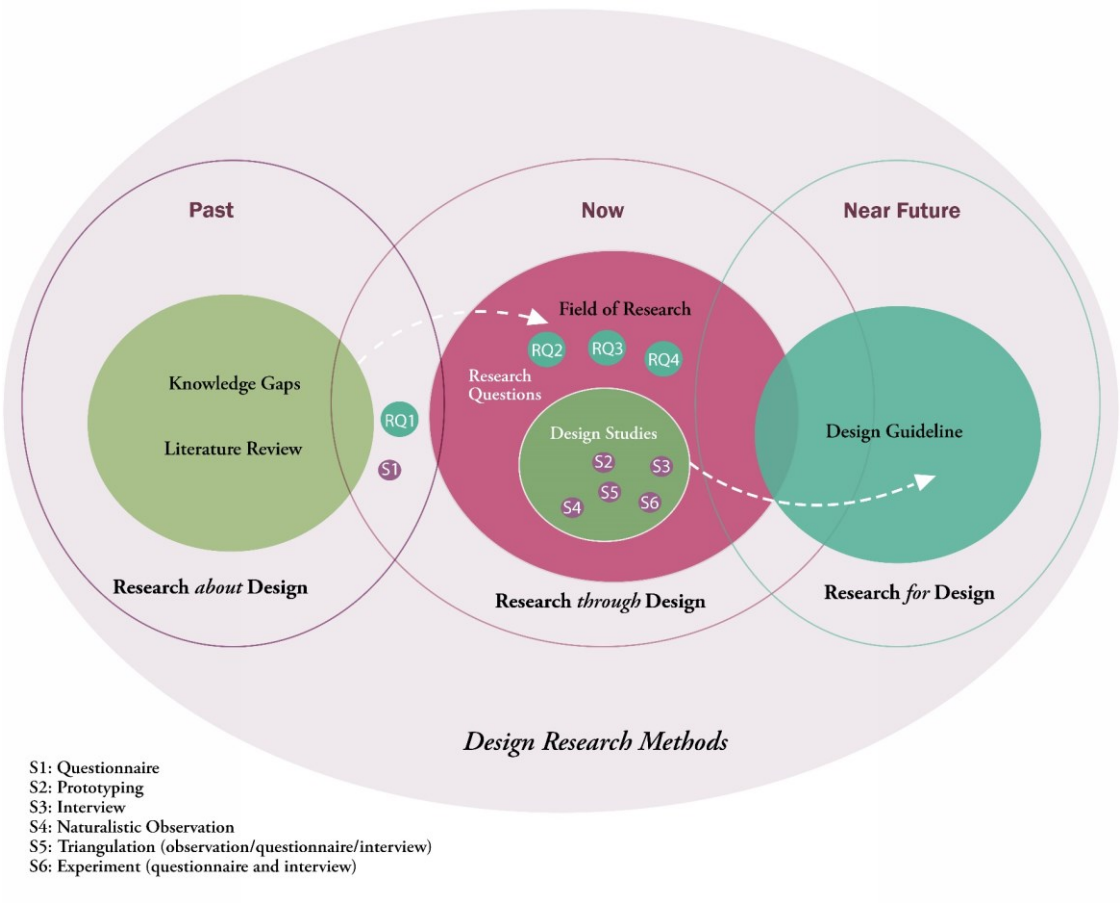


Figure 3.3 Design research stages

To ensure the rationality and rigour of the design research outcomes, the thesis design framework followed the process sequence of Design Science Research Methodology (DSRM) by Peffers et al., 2007. The DSRM suggests a structured six-stage process sequence: identifying the problem, defining the solution, designing, demonstrating, evaluating, and communicating (Peffers et al., 2007). This thesis applies these sequences to MR UI design and store interior design studies, leading to the development of the MR commercial design brochure (Figure 3.4).

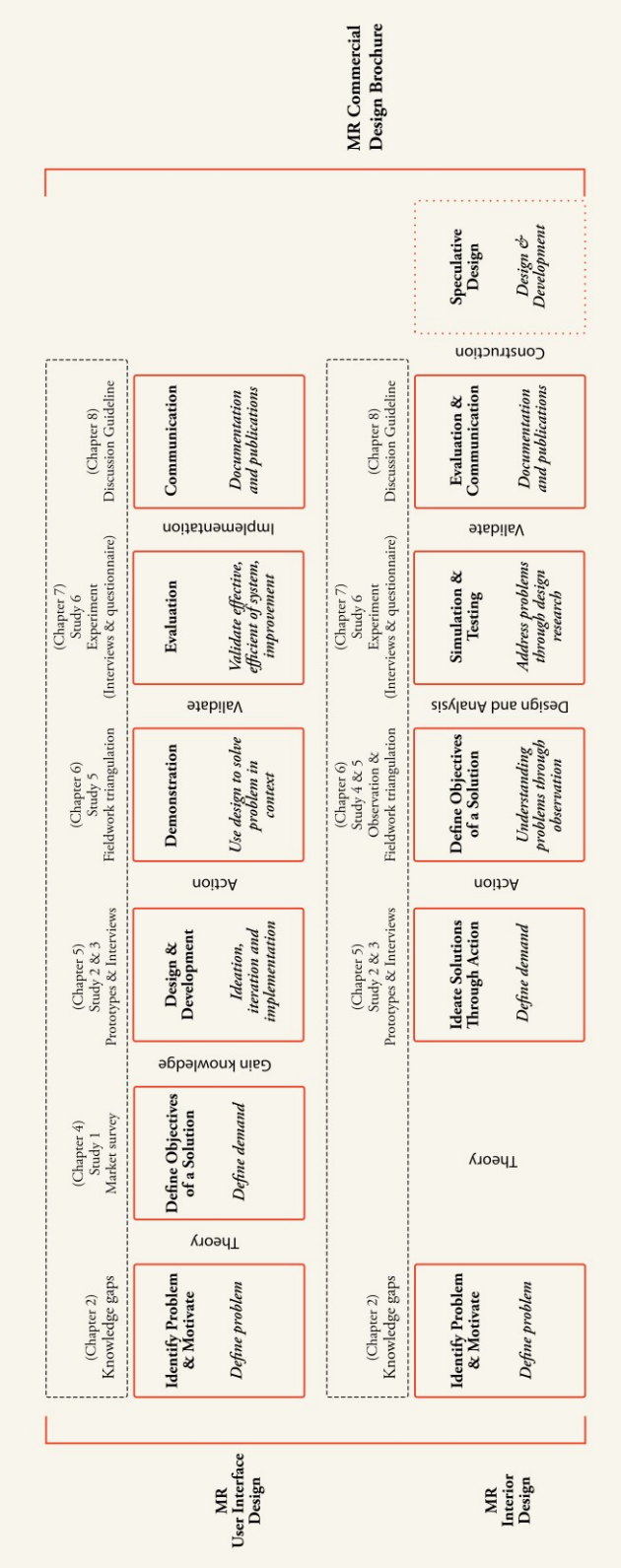


Figure 3.4 Thesis design research frameworks. Adapted to the structure of this thesis from DRSM, Peffers et al. (2007)

Following the sequences, Stage One identifies the problem and motivation in fields by reviewing literature (see Chapter 2). Stage Two defines the solution through a survey study to guide the MR product configurator design ideation (see Chapter 4). Stage Three adapts the findings of Study 1 to design, develop, and ideate solutions through MR product configurator design and define the mass adoption requirements (see Chapter 5). Stage Four demonstrates the MR product configurator app in a marketplace and defines the problems and solutions of traditional stores adopting MR technology in stores and customer experience barriers (see Chapter 6). Stage Five, evaluation, simulation, and testing based on the findings of customer experience barriers, evaluates the design of the MR product configurator app and provides interior design solutions to address MR accessibility problems in stores (see Chapter 7). Stage Six, building on the traditional customer experience management framework as a foundation and new knowledge from previous six studies, this thesis culminates in the "*Mixed Reality Commercial Design Brochure: Design the Space and Interface for Commerce Mixed Reality in Brick and Mortar Stores*", which intends to guide stakeholders in implementing the associated actions (see Chapter 8 and Appendix F). Finally, the design framework is communicated and evaluated by inviting industrial practitioners to read the design brochure.

3.5 Research Design

This section provides an overview of the research design procedures and corresponding research questions, objectives, and structures needed to address the research. Table 3.6 summarises the relationship between methodology, research questions, and participants of each study. Then, the research design structures of each study are shown in the following sections.

Table 3.6 Summaries of research design methodology

Strategies	Data Collection Methods	Participants	Research Questions	Objectives
Study 1 Survey	Questionnaire	General consumers	RQ1: What is the feasibility of, and user preference for, mixed reality adoption in the retail industry?	RQ1_OBJ1: Determine matching immersive XR technologies in retail with user acceptance and demographics, and design scope in retailing.
Study 2 Action research	Usability testing	General consumers	RQ2: How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments?	RQ2_OBJ1: Designing a participatory rapid paper prototype method for usability testing of MR commercial applications to iterate system design.
Study 3 Survey	Semi-structured interview	Consumers, XR experts, Retailers, UI, UX designers, Architects	RQ2: How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments?	RQ2_OBJ2: Define the standpoint and user requirements for the MR product configurator and design a user-centred user interface.
Study 4 Grounded theory	Naturalistic observation	A UK pop-up store and its customers	RQ3: What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops?	RQ3_OBJ1: To compare customer experience frameworks in traditional and MR brick-and-mortar shops.
Study 5 Grounded theory triangulation	Participant observation, questionnaire, interview	A UK pop-up store and end-users	RQ3: What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops?	RQ3_OBJ2: To investigate the barriers to accessibility of Mixed Reality Product Configurators in brick-and-mortar stores and the associated design solutions.
Study 6 Experimentation	Model architecture, questionnaire, interview	End-users	RQ4: How is it possible to design inclusive mixed reality retail interior design guidelines for diverse demographics?	RQ4_OBJ1: To determine an elaborate guideline of design factors and values for planning and implementing mixed reality store interior environments. RQ4_OBJ2: To anticipate the user acceptance of the MRPC as an innovative retail purchase approach and evaluate the MRPC design.

3.5.1 Study 1: Questionnaire Survey

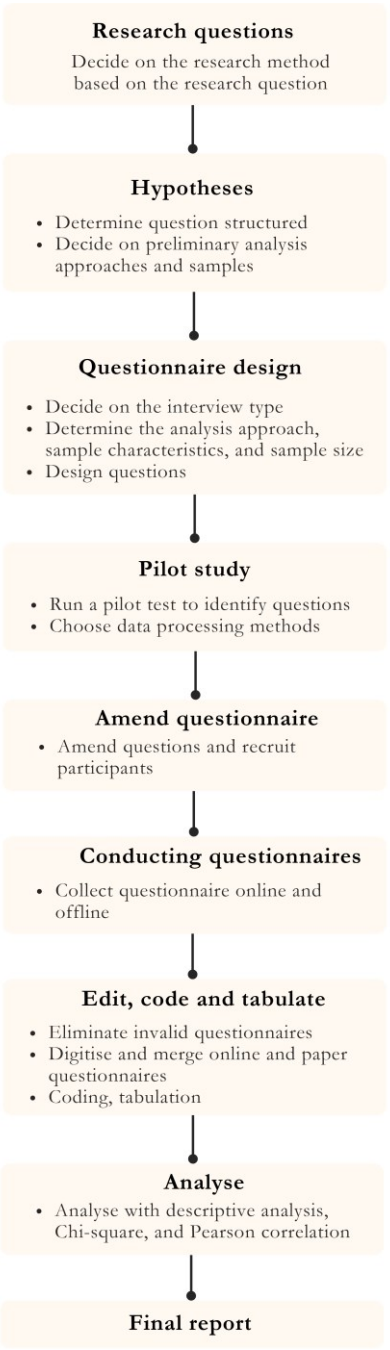


Figure 3.5 Questionnaire survey linear process. Adapted from Gray (2004), p.104

The study used a questionnaire survey to collect consumer intentions and technology preferences through an online questionnaire tool to complete the initial market research and identify market demands. Figure 3.5 shows a linear process of the survey design structure. The process and results are elaborated on in Chapter 4.

3.5.2 Study 2: Usability Testing

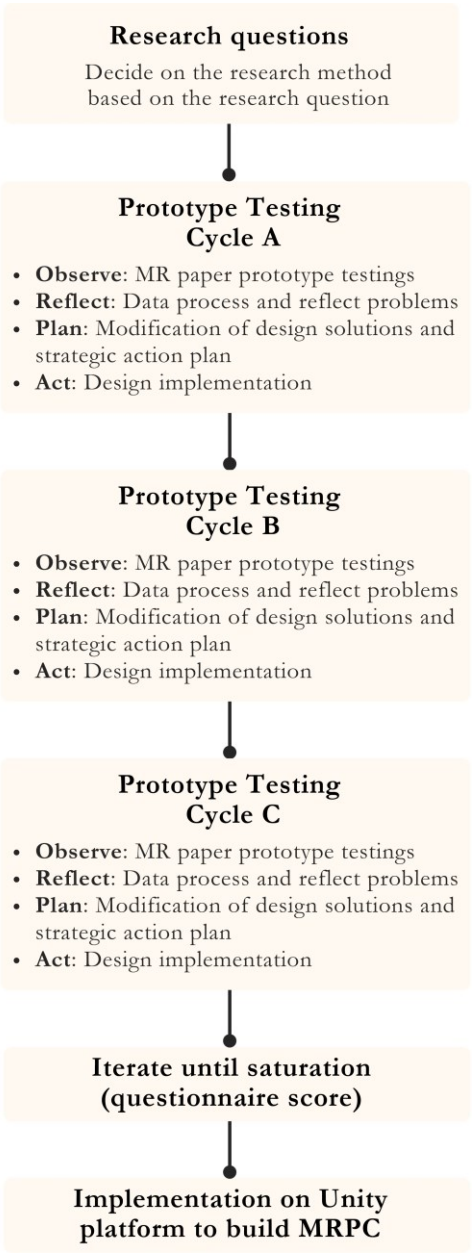


Figure 3.6 Usability testing cycles in action research. Adapted from O'Leary (2017), p.200

This study implemented usability testing and completed data collection through three cycles of iterative design of rapid paper prototypes for participatory co-design of the interface, experience, and indoor environment of the MR Configurator system between users and researchers. Figure 3.6 visualises the flow of the study design structure. The process and results are elaborated on in Chapter 5.

3.5.3 Study 3: Interview Survey

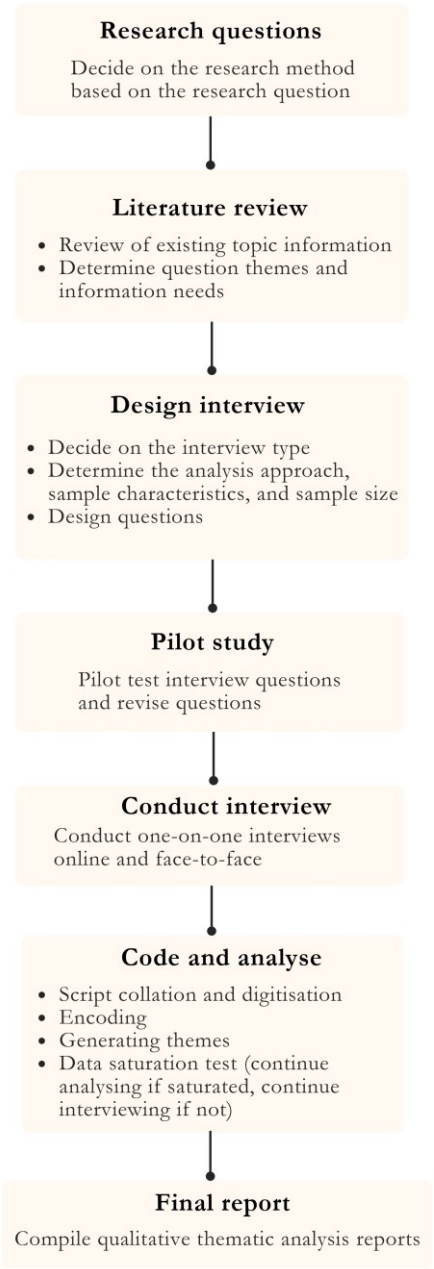


Figure 3.7 Interview survey linear process. Adapted from O'Leary (2017)

This study analyses the significance of this research and the future market outlook of the stakeholders through in-depth interviews with retailers, consumers, XR experts and UI and UX designers using qualitative tools. Study Three design structure is shown in the Figure 3.7. The process and results are elaborated on in Chapter 5.

3.5.4 Study 4: Naturalistic Observation Grounded Theory

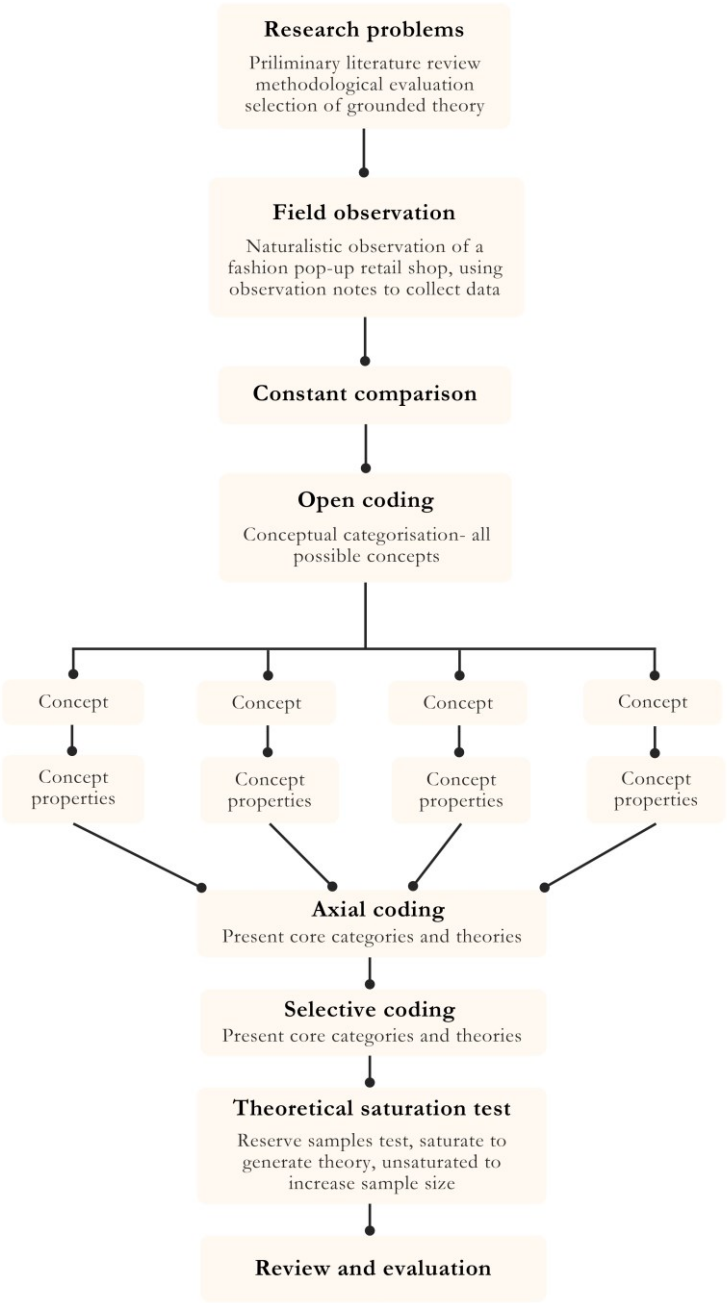


Figure 3.8 Naturalistic observation overview. Adapted from Goulding (2002), p.106

Study Four adopted the grounded theory, which emphasising generating new and experientially-based theories through MR experience (Gummesson, 2003). It addresses the limitations of survey and interview studies and compensates for the laboratory environment's inability to capture natural behaviours in real-life scenarios. Figure 3.8 shows its design structure, and the process and results are elaborated in Chapter 6.

3.5.5 Study 5: Triangulation Grounded Theory

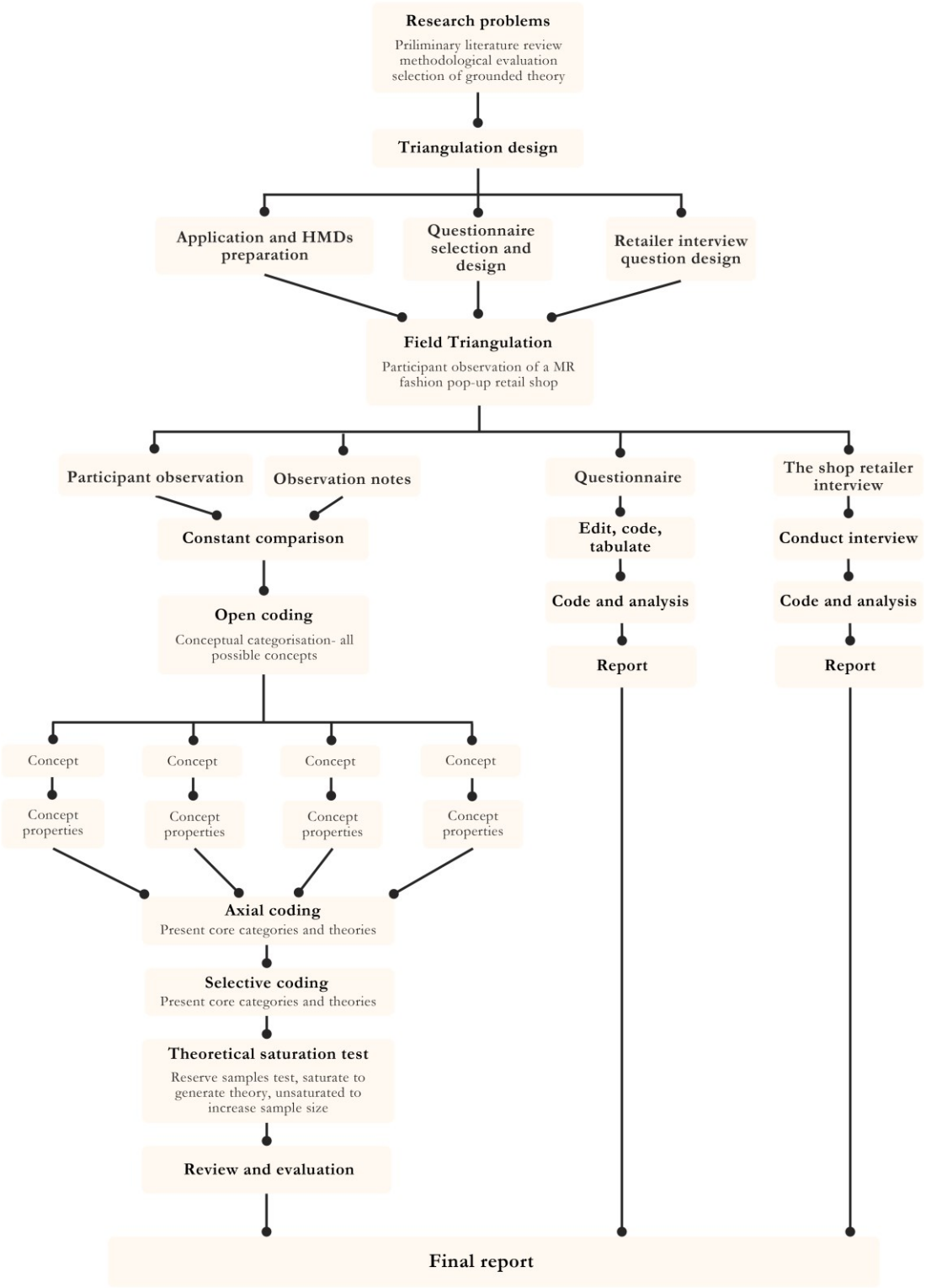


Figure 3.9 Participant observation triangulation process. Adapted from Goulding (2002), p.106

By utilising methodological triangulation in participant observation, questionnaires, observation records (video and notes), and retailer interviews in fieldwork, this method compensates for the potential biases that may arise from having only one perspective of a researcher, thereby enhancing the reliability of the data. Methodological triangulation includes the following methods: 1) Through participating in events, observe the events and dialogue when customers use the MR app; 2) Using observation records, using videos aids in tracking behaviours and events during each participant interaction; 3) Collecting questionnaires, each participant is required to complete a user experience questionnaire (UEQ) to evaluate their experience; 4) Using interviews, the store owner conducted MR experience and semi-structured interviews post-participant observation (Figure 3.9). The process and results are elaborated on in Chapter 6.

3.5.6 Study 6: Experimentation

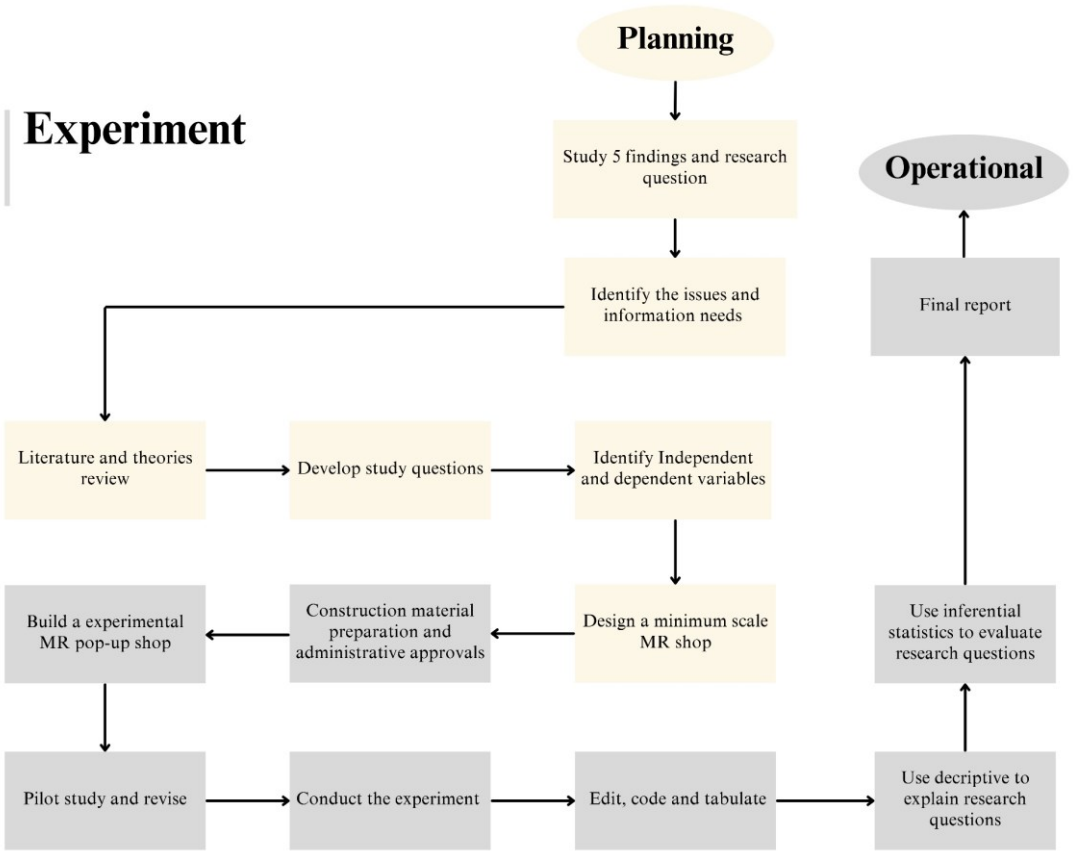


Figure 3.10 Experiment process in the study. Adapted from Gray (2004), p.68

The experimental approach accurately captures and measures user selection through controlled environments and variables while reducing the influence of other factors on user judgement (Gray, 2004). This approach effectively compensates for the limitations of the grounded theory in the previous section, namely, the impact of environmental variables on the user. At the same time, the data from the experimental method is precise for direct implementation of the design. Figure 3.10 presents the experiment process in two stages: the planning stage and the operational stage. The process and results are elaborated on in Chapter 7.

3.6 Sampling Overview

Table 3.7 summarises the sampling methods of the six studies, including the sampling selection, characteristics, rationale of the strategies, and measurement to control bias, of which research methodologies will be reviewed in each chapter.

Table 3.7 Sampling approach and rationale of six studies

Studies	Probability/Nonprobability sampling	Characteristics	Rationale and Measures
S1. Questionnaire	Convenience sampling	**Convenience sampling** is the most commonly used nonprobability sampling method, in which researchers use anyone they can find who meets the eligibility criteria for participation in the study and agrees to participate (Thyer, 2009). Nonprobability sample results may provide a solid foundation for generalisation across multiple subgroups compared to large random samples (Thyer, 2009). However, it cannot calculate sampling error due to the uncertain distribution of the sample statistic, and it is biased in its inability to estimate information about individuals who chose not to participate (Cook and Campbell, 1979). Therefore, additional actions are needed	a) This approach has the advantage of being affordable and accessible and is suitable for developing questions and defining the scope of the protocol early in the study. b) This can be very useful for early exploratory market research and program evaluation research (Thyer, 2009). c) Expanding the sample size minimises the margin of error and enhances the precision of results to increase representativeness. d) By asking the age of the participants who were not involved (unwillingness to use XR technology and time unavailable) fitted in with previous studies, and older people are less engaged with digital devices. Their gender did not show a significant difference from the participant group. Hence, sampling bias from

Studies	Probability/Nonprobability sampling	Characteristics	Rationale and Measures
		to measure the unbiased estimates.	sample demographics is minimised.
S2. Prototypes	Quota sampling	**Quota sampling** specifies quota ratios and selects samples by classifying the overall subjects (region, gender, age) (Wolf et al., 2016).	a) Users need to represent varied demographics (nationality, gender, age) to fit the research aim of globalised consumers. b) The aim is to test system usability. Test content does not need to be projected into the population for precise estimation.
S3. Interviews	Simple random, snowball, and quota sampling	**Simple random sampling**. The size of the sampling error can be calculated and controlled, the sample extracted is representative of the population, and the population parameters can be estimated based on the survey results. The disadvantage is that producing an elaborate list of the overall population is time-consuming, expensive and labour-intensive (Gray, 2004). **Snowball sampling** randomly selects a group of subjects to recommend to other subjects after they have experimented. This approach is most applicable to hard-to-reach groups (Gray, 2004).	a) Retailers, by simple random sampling, are to be representative, and ensure that each group has a probability of being selected. b) UX designers and experts by snowball and quota sampling, as they are difficult to access and hidden groups. Their expertise needs to fit the scope of the study and provide in-depth insights. c) Consumer by quota sampling is used to include the perspective of customers of various ages and genders. They should have experience with online shopping, including consumers who are online-oriented, offline-oriented and both.
S4. Naturalistic observation	Simple random and judgment sampling	**Judgment sampling** or purposive sampling is commonly used in qualitative research. The researcher selects representative samples based on subjective expertise and judgment. This method can potentially obtain quality representative samples or be subject to bias due to subjective influences (Gray, 2004).	a) Retail shops used simple random sampling to be representative, ensuring that each group has a probability of being selected. b) Observation using judgment sampling because it requires the researcher to classify objective facts and phenomena based on empirical judgment. This is the most appropriate sampling method for the nature of naturalistic observation of non-contact sampling.
S5. Triangulation	Convenience and quota sampling	See above.	a) The total number of customers entering the shop daily cannot be estimated; therefore, random sampling cannot be applied. b) The convenience sampling population represented the probable end-user group. c) The non-involved population was asked for reasons, including

Studies	Probability/Nonprobability sampling	Characteristics	Rationale and Measures
			lack of time, 3D vertigo and disinterest. No differences were found between the demographics of this group (gender and age) and the demographics of the subjects. d) By asking participants about their usual level of interest in XR, no significant differences were found between the data of significantly interested (n=3) and non-significantly interested participants.
S6. Experiment	Convenience, snowball, random sampling	See above.	It used convenience and snowball sampling for the experiment (n=64), and random sampling for interviews (n=30). a) Compiling consumer lists is expensive and unavailable for probability sampling. b) In-person experiments and location are the limitations of probability sampling. c) The non-involved population was asked for reasons, including lack of time and distance issues. No differences were found between the demographics of this group (gender and age) and the demographics of the subjects. d) When participants were asked about their usual level of interest in XR, no significant differences were found between the data of significantly interested (n=2) and non-significantly interested participants. e) Subjects need to have basic vision or, after correction, the user has certain eye conditions or has had eye surgery and does not support using HMDs (Microsoft, 2023). Therefore, random sampling does not fit the subcategories in this study. f) Data from clusters that do not accept MR have limited significance for this study, so the bias is acceptable. g) Through random sampling from the subjects, interview data are selected to minimise research subjective selected bias.

3.7 Chapter Summary

This chapter describes philosophy, methodology, and methods regarding theoretical choices and reasons. It summarises the overall thesis structure and introduces the research questions and objectives. Figure 3.11 illustrates the thesis research procedures. Figure 3.12 summarises the empirical studies' cumulative process and how findings led to the next stage of the research.

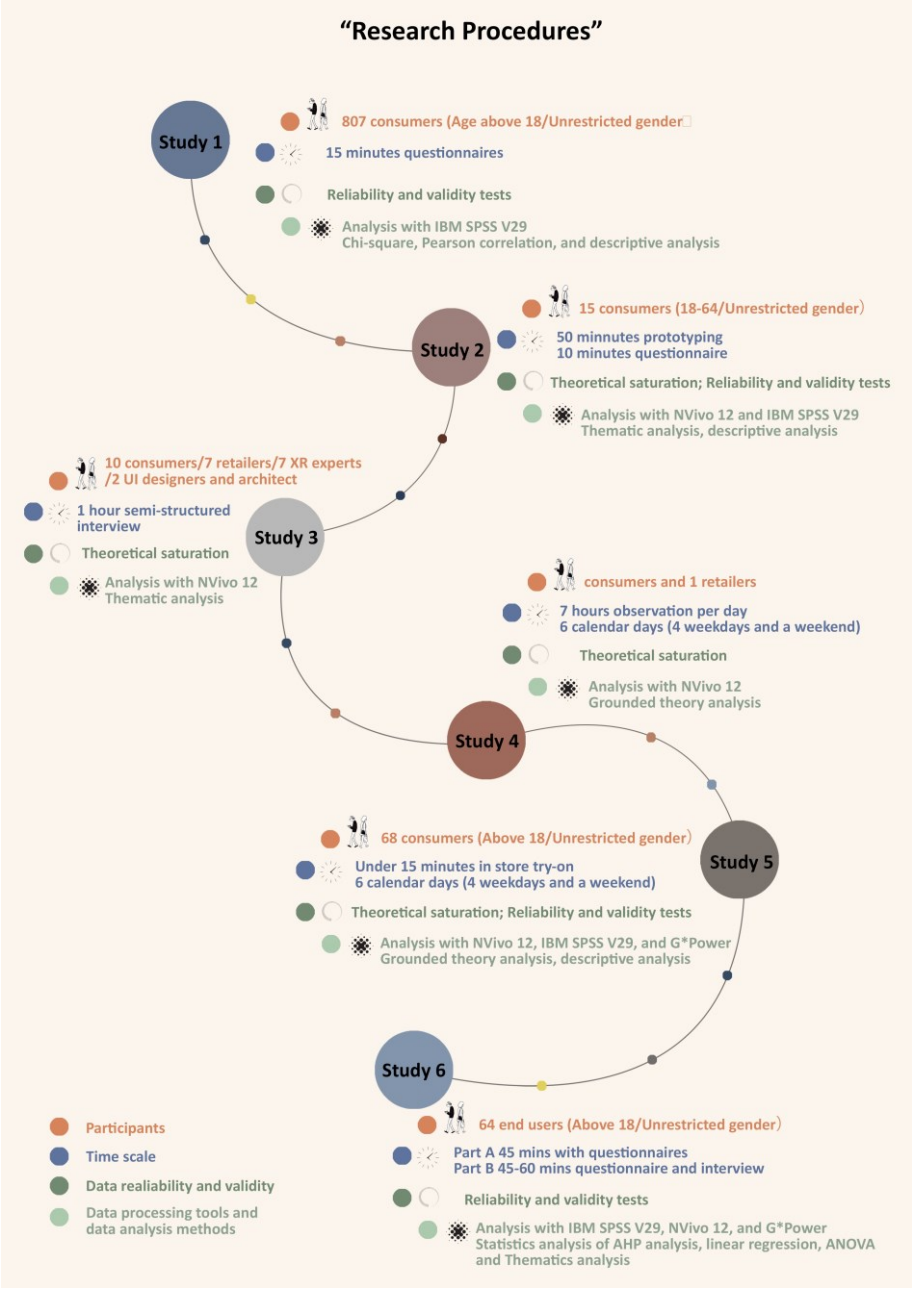


Figure 3.11 Study procedures outline

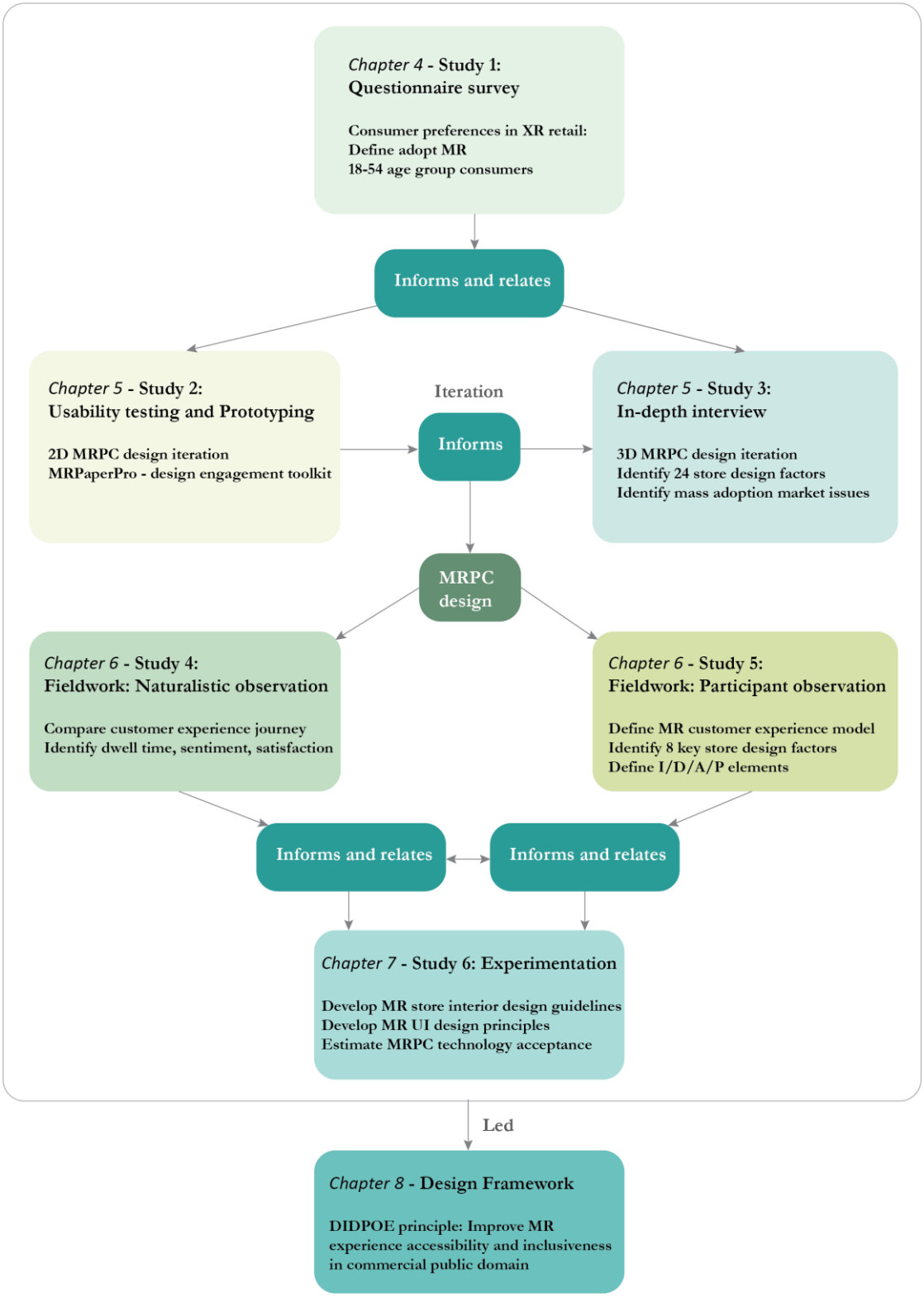
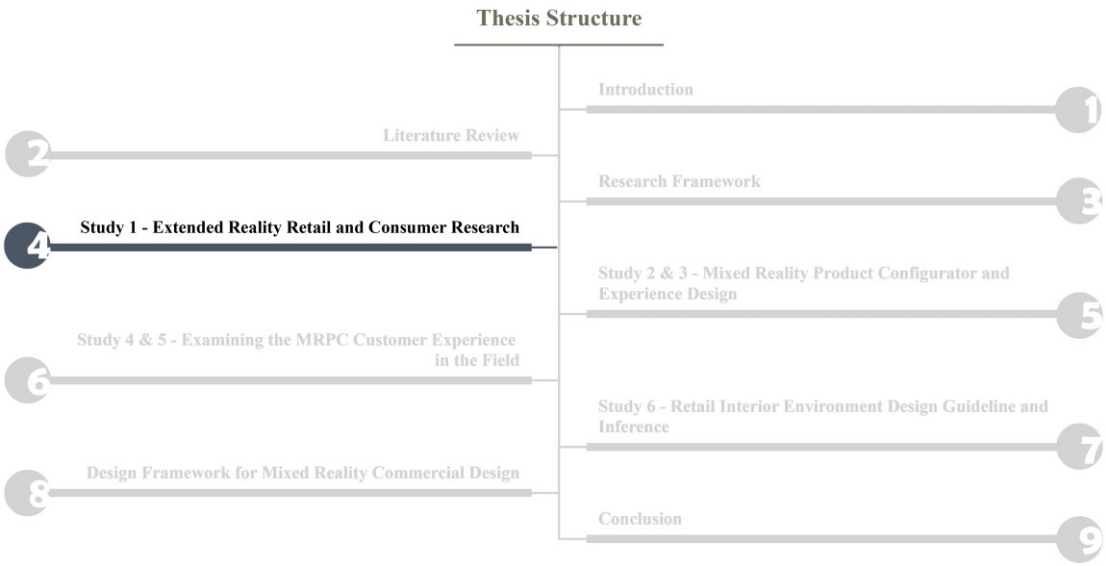


Figure 3.12 Research articulation and progression flowchart

4 Study 1 – Extended Reality Retail and Consumer Research



4.1 Introduction

This chapter identifies the demand, value dimensions, and design development directions for MR in retail. It employs quantitative research by conducting a consumer market survey (n=807) to collect consumer demographics, preferences, and intentions to determine the feasibility of MR technology and its user cohort. It provides recommendations for the adoption of extended reality technology within retail stores. In addition, it provides the knowledge base and data support for the subsequent experimentation of the research.

4.2 Research Background

The adoption of XR in the retail industry has contributed to a more diverse shopping experience for consumers, reduced retail costs, and increased mobility, availability, and sustainability for retail (Bulearca and Tamarjan, 2010; Reinartz et al., 2019; van Esch et al., 2019; Verhoef et al., 2017). AR has been used in multiple retail segments, delivering it more conveniently and rapidly through access to smart devices (namely, smartphones and tablets). VR has been well-known in the entertainment sector, creating fully immersive retail and home experiences primarily through headsets and controllers. In some instances, this is supplemented by other wearable devices such as haptic devices, body-tracking sensors, motion-tracked controllers, and 360 treadmills. MR uses wearable HMDs to present a high level of local presence and interaction (see also Chapter 2). Regardless of the equipment, the accessibility, ease of use, and expense of the hardware are circumstances that retailers need to be concerned about and afford.

The benefits of VR for retailers encompass decreasing operational barriers to customer service, saving time, and lowering costs (Bonetti et al., 2018). Sainsbury's developed the first virtual store in the world and utilised VR technology to aid in the redesign of the supermarket (Sainsbury's, 1995). Italy's InVRsion developed a VR shopping program called ShelfZone (ShelfZone® VR shopping experience by inVRsion, 2016), explicitly designed for large retailers and companies, allowing companies to create stores and shopping centres inside. Swarovski and Mastercard launched a VR

application for the Atelier Swarovski furniture decoration collection, which uses eye-movement tracking technology and sensors to track the gaze of the consumer, display product information, price, add to carts, and help the consumer to complete a virtual purchase (Mastercard And Swarovski Launch Virtual Reality Shopping Experience, 2017). In addition to this, numerous experiments have been conducted in retail VR-based research classified by product category (food, beverages, electronics, apparel), and by simulated retail environments (stores, shopping malls, product aisles, food courts, and changing rooms) (Xi and Hamari, 2021). Although the value of VR in retailing has been highlighted (Speicher et al., 2017), there is a widespread lack of market adoption of VR among retailers and companies compared to AR (see Chapter 2).

AR try-on has increased online conversions and reduced returns for branded companies (Dacko, 2017) and can also help retailers optimise the utilisation of warehouse space and navigation (Program-Ace, 2021). Consumers have responded positively to the entertainment value, enjoyment, and functionality of AR (Huang and Liao, 2015). Table 4.1 includes some examples of AR applications in the market.

Table 4.1 Examples of AR applications in retailing

Retail category	Brand	Description
Home furnishing	Dulux Paint Expert: Decorator	Customers can see paint colours appear on walls and are able to compare different schemes.
	IKEA	Enable customers to see how furniture products can be placed in their homes.
	Wayfair Reality App	
Skincare and beauty	Sephora's AR Makeup Match	Customers can try out make-up products through facial recognition technology for facial colour trials.
	L'Oréal	
	Lancôme	
Fashion	Nike	Shoe fitting, where customers can see a digital product with 360-degree coverage of their feet.
	Gucci's AR	
	ASOS	Digitally mapping each product onto the model to avoid the necessity of entry to their studio to change clothes.
Eyewear	Specsavers	AR try-on eyewear frames.
	Vision Express	
Jewellery	Tiffany & Co's	Customers can visualise jewellery fits on the body.
	Pandora	

Before consumers access innovative technologies and engage in novel experiences, retailers and designers should understand their needs, interests and motivations. Without considering the contextual information of the user, it might lead to low engagement and limited adoption. The extent to which a technology aligns with user

expectations can significantly influence both its acceptance and the effectiveness of its implementation (Scherer and Craddock, 2002). Consumer satisfaction with and attitude toward adopting the technology are factors that drive the adoption of technology by retailers (Alnawas and Aburub, 2016; Foroudi et al., 2018). AR in retail has been developed with practical projects and research outputs, whereas MR (wearable AR) in retail has sparse practice (Jain and Werth, 2019). Both AR and MR offer reality-based augmented experiences, but no studies compare mobile AR and wearable AR user preferences (Rauschnabel et al., 2024). Retailers may be unsure which technology to invest in without a clear understanding of consumer preferences. To address this, this chapter aims to conduct market research to provide recommendations for technology adoption based on consumer demographics and compare consumer preferences for AR and MR to determine a suitable technology for further design and research.

4.3 Research Question and Objective

RQ1: What is the feasibility of, and user preference for, mixed reality adoption in the retail industry?

RQ1 Objective in this chapter attempts to address:

- **RQ1_OBJ1:** Determine matching immersive XR technologies in retail with user acceptance and demographics, and design scope in retailing. (Research gaps 2 and 3)

Study 1 (RQ1_OBJ1) uses a survey to construct a consumer technology acceptance model to compare the three technologies horizontally and investigate consumer preferences for XR in the retail market.

4.4 Methodology

Davis's (1993) technology acceptance model (TAM) has traditionally been acknowledged as a critical quantitative research tool for measuring the relationship between consumers and the innovative technologies to be used, as well as their

perception and acceptance of the innovations (Davis, 1993, p. 19). The TAM could predict user technology acceptance based on the perceived usefulness and perceived ease of use of the technology. The TAM is based on Fishbein and Ajzen's (1975) psychological attitude paradigm, which states that the consequences of a perceived behaviour, which is the potential outcome resulting from performing the behaviour, are an affective evaluation of the behaviour (Fishbein and Ajzen, 1975). Venkatesh and Davis (1996) stated that external variables influence perceived usefulness and perceived ease of use (Venkatesh and Davis, 1996). This study extends the TAM and explores the affective factors (attitude to use and perceived usefulness), user intents (intent to use, intent to purchase, and intent to experience), user demographics (gender and age), technology preference and previous technology experience.

4.4.1 Survey Design

The questionnaire design consists of both scale and non-scale questions. Scale questions are single-choice, while non-scale questions contain single-choice and multiple-choice. An optional text response question was added at the end of the questions. The scale questions were measured using Likert's (1932) five-point scale from definitely yes to definitely not (Likert, 1932). The questionnaire contained seventeen questions, two of which were logical jump questions. The reliability test of the four metric questions' Cronbach's alpha (α) coefficient[21] is 0.83, indicating that the study data has good reliability quality. The CITC values of the analysed items were all greater than 0.4, indicating a good correlation between the analysed items and a good level of reliability. The research participants represent the general consumers, and in a multi-contextual and multi-cultural situation, the participants need to be provided with the fundamental definitions and concepts of the XR. Therefore, the first part of the research content is

[21] Cronbach's α coefficients greater than 0.8 indicate high reliability; coefficients between 0.7 and 0.8 indicate good reliability; and coefficients between 0.6 and 0.7 indicate acceptable reliability (Taber, 2018).

the illustration and explanation of the XR concepts, respectively. The second part is the body of the questionnaire. It contains user demographics (age, gender, geography, employment) (Burke, 2002), single-choice questions, multiple-choice questions, and optional extension text responses (Perkins Coie, 2020, 2019).

Consumer XR Acceptance Model Hypothesis

The following hypotheses will be defined to answer the research question in this section (Figure 4.1). H1 and H2 answer consumer demographics in relation to preferences. H3-H5, by expanding TAM answers the relationship between consumer XR acceptance and intention.

- H1. Genders have significant associations with MR, AR and No XR; VR has no direct associations.
- H2. Age has significant associations with MR and AR; VR and No XR have no direct associations.
- H3. Previous experience with XR has a significant influence on intent to use, purchase and experience.
- H4. Extended reality previous experience has highly significant differences in attitude to use and perceived usefulness.
- H5. Extended reality previous experience has significant associations with AR, VR and No XR, and has no direct significant associations with MR.

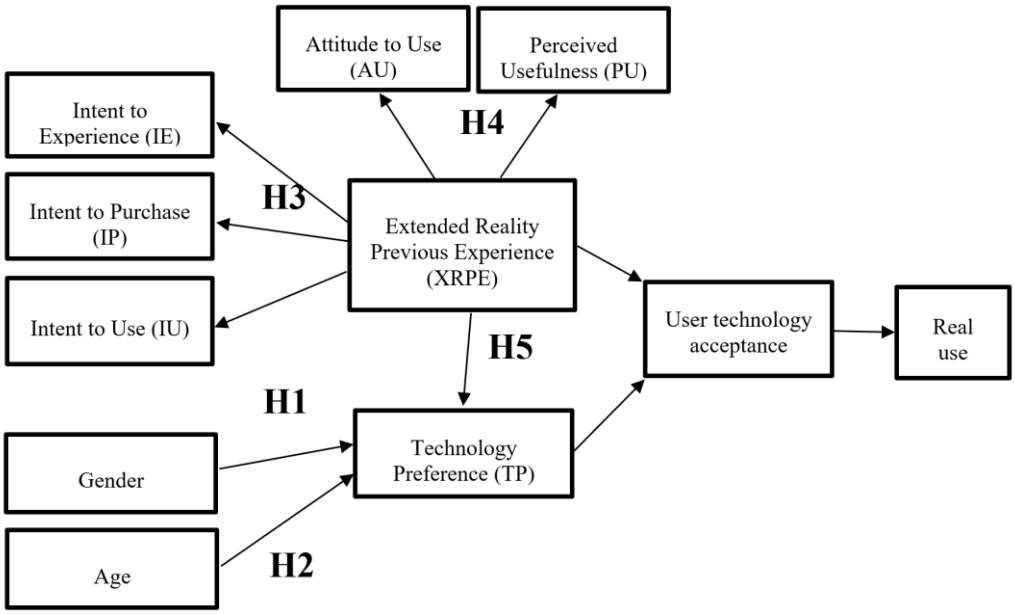


Figure 4.1 Consumer XR technology acceptance model. Expanded from Davis, 1993

4.4.2 Data Collection and Analysis

The questionnaire contained printed sheets and an electronic version of the Qualtrics platform, allowing accessibility for all participants. Data was collected from May to June 2022. Questionnaire distribution occurred in the UK and China. In the UK, the questionnaire dispatch consisted of an offline paper copy and an online electronic version, whereas in China, it was primarily an online questionnaire. Before answering the questions, participants were asked to read the provided definitions and illustrations of VR, AR, and MR to ensure that the participants reached essentially equal cognitive alignment of the three technologies. Participation was voluntary, and participants recruited offline were offered a small packet of sweets as an incentive and online with no incentive. A pilot test was conducted on campus for 10 subjects, and minor modifications were made to the wording of the questionnaire based on the pilot results.

In total, 878 samples were collected from the data pool. Forty-four participants were from paper questionnaires, and 834 were from online completion. After data processing, the remaining 807 valid data were available for use. Invalid questionnaires, such as those with a response rate of less than 70% were removed, and those with a response rate of 70% or more were retained. Those filled in indiscriminately, such as choosing B for all of the options or half for A and half for B, were also removed. The questionnaires were randomly filled in, meaning that respondents chose their answers randomly or gave incoherent or perfunctory answers to the previous and subsequent questions were removed. The statistical analysis used descriptive analysis, Chi-square tests and Pearson correlation tests.

4.4.3 Participant Demographics

This survey sampling approach is convenience sampling, which is a nonprobability sampling method in which researchers use anyone they can find who meets the eligibility criteria for participation in the study and agrees to participate (Thyer, 2009). This approach has the advantage of being affordable, accessible, and useful for early exploratory market research and program evaluation research (Thyer, 2009). To enhance results precision, minimise the margin of error, and increase representativeness,

the questionnaire expands its sample size. Since participation is voluntary, the sample size is distributed unevenly. The proportion of female participants is 60.8%, while the proportion of males is 37.1%. The percentage of participants who are employed is 59.2%, students 26.8%, and non-employed 13.8%. The 18-24 age group accounts for 27.1%, 25-34 years accounts for 22.1%, 35-54 years accounts for 40.9%, and 55 years and above accounts for 8% (Table 4.2).

Table 4.2 Participant demographics of Study one

Demographics	Item	n	per cent (%)
Gender	Female	491	60.8
	Male	299	37.1
	Transgender	0	0
	Non-binary	5	0.6
Age	Under 18	11	1.4
	18-24	219	27.1
	25-34	178	22.1
	35-44	93	11.5
	45-54	237	29.4
	55-64	42	5.2
	65-74	17	2.1
	75-84	5	0.6
	85 or older	1	0.1
Geography	UK	288	35.7
	China	504	62.5
	Europe	8	1.0
	Others	3	0.4
Employment	Full-time	418	51.8
	Part-time	60	7.4
	Unemployed looking for work	12	1.5
	Unemployed not looking for work	20	2.5
	Retired	75	9.3
	Student	216	26.8
	Disabled	4	0.5
Total		807	100

4.5 Results

Analysis of Hypotheses (H1–H5)

The following will analyse the results in direct reference to the structure of the hypotheses discussed in Section 4.4.1.

H1. Genders have significant associations with MR, AR and No XR; VR has no direct associations.

Figure 4.2 shows more female participants than male participants. There are only two participants from the transgender group and five from the non-binary gender group. There are seven participants for whom the underlying consumer profiles are not known. From the statistics, a sample size of less than five is less statistically meaningful. Therefore, the transgender group will not be further analysed. Participants who prefer not to answer gender information data are not accounted for in the statistics. Overall, both females and males show consistency in their ordinal preferences for these three technologies. MR is rated as the most preferred technology among males and females.

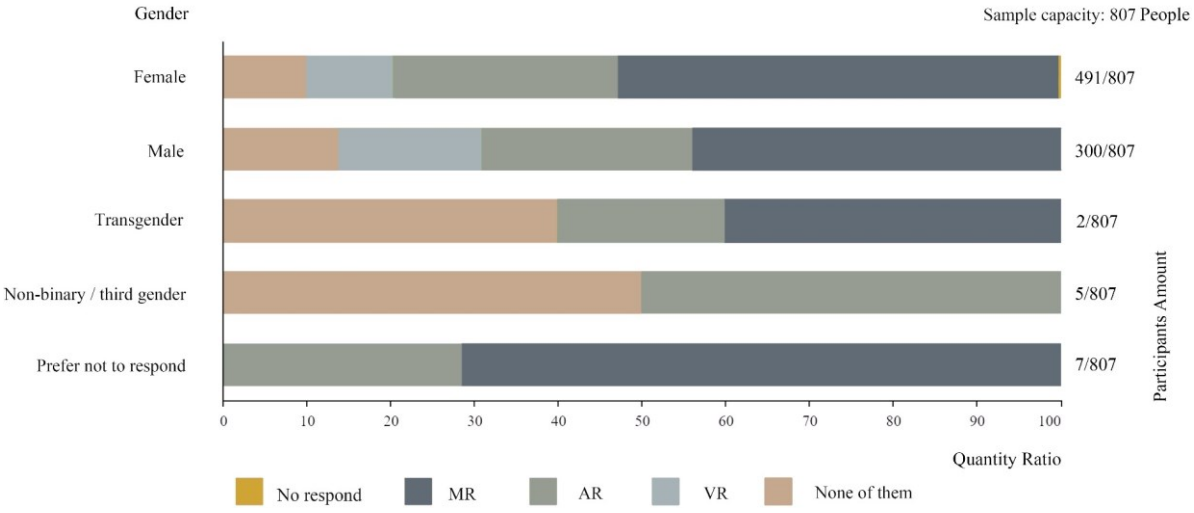


Figure 4.2 Gender versus XR preferences

Table 4.3 Gender and XR preferences Chi-square analysis

Items	Categories	Gender (%)					Total	χ^2	p
		Female	Male	Transgender	Non-binary	No response			
MR	No	47.34 %	56.42 %	100.00%	60.00%	20.00%	50.56 %	11.964	0.018*
	Yes	52.66 %	43.58 %	0.00%	40.00%	80.00%	49.44 %		
Total		488	296	2	5	10	801		
AR	No	86.89 %	76.35 %	50.00%	100.00 %	100.00 %	83.15 %	19.229	0.001**
	Yes	13.11 %	23.65 %	50.00%	0.00%	0.00%	16.85 %		
Total		488	296	2	5	10	801		

VR	No	69.88 %	68.58 %	50.00%	60.00%	80.00%	69.41 %	1.238	N.S.
	Yes	30.12 %	31.42 %	50.00%	40.00%	20.00%	30.59 %		
Total		488	296	2	5	10	801		
No XR	No	89.96 %	86.15 %	50.00%	60.00%	100.00 %	88.39 %	10.732	0.030*
	Yes	10.04 %	13.85 %	50.00%	40.00%	0.00%	11.61 %		
Total		488	296	2	5	10	801		
* p<0.05, ** p<0.01, *N.S.* p>0.05									

The results demonstrate a statistically significant correlation between MR, none of XR and gender ($p<0.05$) (Table 4.3). There is an extremely statistically significant correlation between AR and gender ($p<0.001$). There is no statistically significant correlation between VR and gender ($p>0.05$). This suggests a statistically significant difference in the attitudes and preferences towards MR and AR among consumer groups of different genders. On this basis, the numerical variance between gender on MR and AR has been calculated.

MR: 52.66% (F) > 49.17% (mean) > 43.58% (M) > 40% (non-binary)

AR: 23.65% (M) > 16.98% (mean) >13.11% (F) > 0.00% (non-binary)

No XR: 13.85% (M) > 11.66% (mean) > 10.04% (F) > 4% (non-binary)

Hypothesis 1 suggests to the stakeholders that *MR is more appealing to female consumers while AR is more attractive to male consumers*. *Males are less receptive than females regarding XR technologies. VR remains nearly unaffected by gender.*

H2. Age has significant associations with MR and AR; VR and No XR have no direct associations.

Figure 4.3 shows that a group aged between 18 to 64 prefers MR technology. MR and AR have extremely statistically significant differences with age ($p<0.01$), while VR and those who dislike XR show no statistical association with age ($p>0.05$) (Table 4.4).

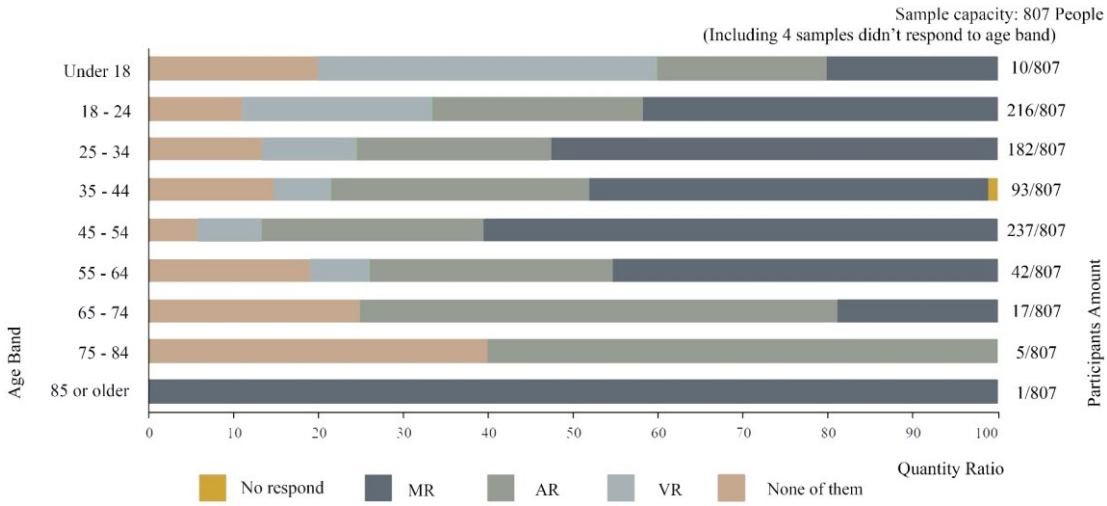


Figure 4.3 Age versus XR preferences

Table 4.4 Age and XR preferences Chi-square analysis

Items	Categories	Age (%)									Total	χ^2	p
		Under 18	18-24	25-34	35-44	45-54	55-64	65-74	75-84	85 or older			
MR	No	80.00%	58.26%	47.49%	50.00%	41.03%	54.76%	81.25%	100.00%	0.00%	50.56%	30.069	0.000**
	Yes	20.00%	41.74%	52.51%	50.00%	58.97%	45.24%	18.75%	0.00%	100.00%	49.44%		
Total		10	218	179	92	234	42	16	5	1	797		
AR	No	60.00%	69.27%	82.68%	91.30%	91.45%	90.48%	100.00%	100.00%	100.00%	83.19%	55.890	0.000**
	Yes	40.00%	30.73%	17.32%	8.70%	8.55%	9.52%	0.00%	0.00%	0.00%	16.81%		
Total		10	218	179	92	234	42	16	5	1	797		
VR	No	80.00%	68.35%	70.39%	64.13%	73.50%	66.67%	43.75%	40.00%	100.00%	69.26%	11.329	N.S.
	Yes	20.00%	31.65%	29.61%	35.87%	26.50%	33.33%	56.25%	60.00%	0.00%	30.74%		
Total		10	218	179	92	234	42	16	5	1	797		
NoXR	No	80.00%	88.99%	86.59%	89.13%	92.31%	80.95%	75.00%	60.00%	100.00%	88.46%	14.060	N.S.
	Yes	20.00%	11.01%	13.41%	10.87%	7.69%	19.05%	25.00%	40.00%	0.00%	11.54%		
Total		10	218	179	92	234	42	16	5	1	797		
* $p<0.05$, ** $p<0.01$, *N.S.* $p>0.05$													

Hypothesis 2 suggests the age band for *MR applicability based on consumer preferences as 18 to 64, exhibiting a peak between the 25 to 54 age range. Consumers who prefer AR are predominantly between the ages of Under 18 to 24, and their fondness decreases as their age rises.*

H3. Previous experience with XR has a significant influence on intent to use, purchase and experience.

85.7% of participants have not used XR previously, while 14.3% have experienced with XR technology. Figure 4.4 shows that among those who have experience in XR, more consumers used AR and VR, with less experience in MR. Consumers choose shopping as the primary intent of use (46.6%), followed by playing next-generation games (41.5%) (Figure 4.5).

Table 4.5 shows the associations between XR's previous experience (XRPE) and intent to use (IU), intent to purchase (IP), and intent to experience (IE). It demonstrates that a total of 6 items show statistically significant associations ($p<0.05$) with XR's previous experience, while the remaining 17 items have no statistically significant associations ($p>0.05$).

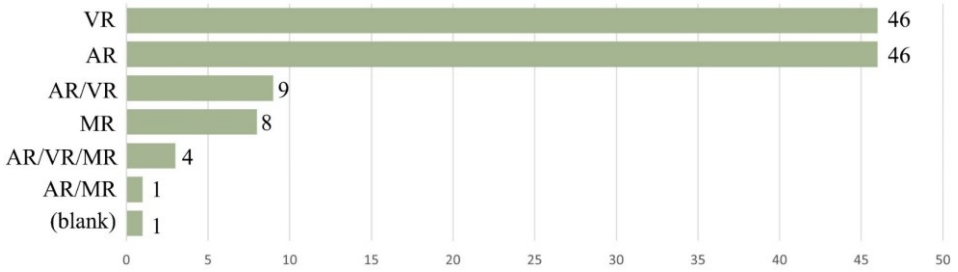


Figure 4.4 Extended reality previous experience (XRPE)

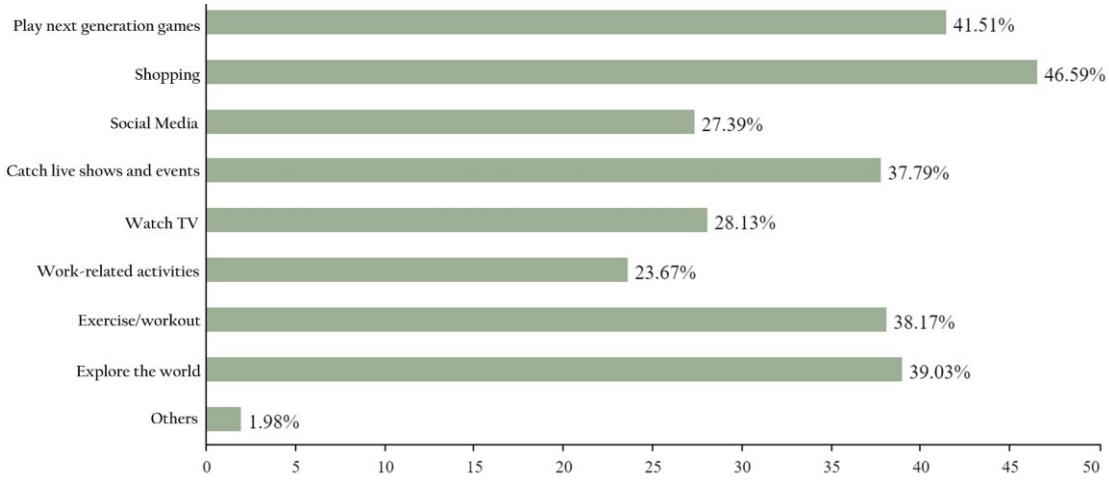


Figure 4.5 VR/MR Intent to use popularity rate

Table 4.5 Associations in XR previous experience with IU, IP, IE

Items	Categories	XRPE (%)		Total	χ^2	p
		Yes	No			
IU. Shopping	No	40.00%	55.67%	53.42%	9.722	0.002**
	Yes	60.00%	44.33%	46.58%		
Total		115	688	803		
IU. Live show	No	53.04%	63.66%	62.14%	4.723	0.030*
	Yes	46.96%	36.34%	37.86%		
Total		115	688	803		
IU. Exercise	No	51.30%	63.66%	61.89%	6.380	0.012*
	Yes	48.70%	36.34%	38.11%		
Total		115	688	803		
IP. Clothes	No	20.00%	32.41%	30.64%	7.144	0.008**
	Yes	80.00%	67.59%	69.36%		
Total		115	688	803		
IP. Furniture	No	43.48%	53.78%	52.30%	4.191	0.041*
	Yes	56.52%	46.22%	47.70%		
Total		115	688	803		
IE. Customisation	No	42.61%	54.22%	52.55%	5.323	0.021*
	Yes	57.39%	45.78%	47.45%		
Total		115	688	803		
* $p<0.05$ ** $p<0.01$						

Hypothesis 3 findings suggest that *consumers with previous experience used XR with the intention of shopping increased, and the intention of watching live shows and exercising decreased. Moreover, the probability of intention to repurchase clothes and furniture using XR devices is statistically positively correlated. Customisation is a statistically positively correlated factor of the intent to experience.*

H4. Extended reality previous experience has highly significant differences in attitude to use and perceived usefulness.

Attitude to use and perceived usefulness have statistically significant differences with previous XR experience ($p<0.05$) (Table 4.6). Users with experience with XR technologies show a more positive attitude towards use, with 87.83% interested in using them for shopping. Of those without previous XR experience, 70.51% were interested in using them for shopping (Figure 4.6).

Table 4.6 XRPE towards attitude to use and perceived usefulness Chi-square analysis

Items	Categories	Previous XR experience (%)		Total	χ^2	p
		No	Yes			
Attitude to use	Definitely yes	180 (26.28)	49 (42.61)	229 (28.63)	20.541	0.000**
	Probably yes	303 (44.23)	52 (45.22)	355 (44.38)		
	Don't know	107 (15.62)	6 (5.22)	113 (14.12)		
	Probably not	63 (9.20)	6 (5.22)	69 (8.63)		
	Definitely not	32 (4.67)	2 (1.74)	34 (4.25)		
Total		685	115	800		
Perceived usefulness	Definitely yes	155 (23.48)	32(28.32)	187 (24.19)	10.858	0.028*
	Probably yes	322 (48.79)	63 (55.75)	385 (49.81)		
	Don't know	85 (12.88)	9 (7.96)	94 (12.16)		
	Probably not	57 (8.64)	9 (7.96)	66 (8.54)		
	Definitely not	41 (6.21)	0 (0.00)	41(5.30)		
Total		660	113	773		
* p<0.05 ** p<0.01						

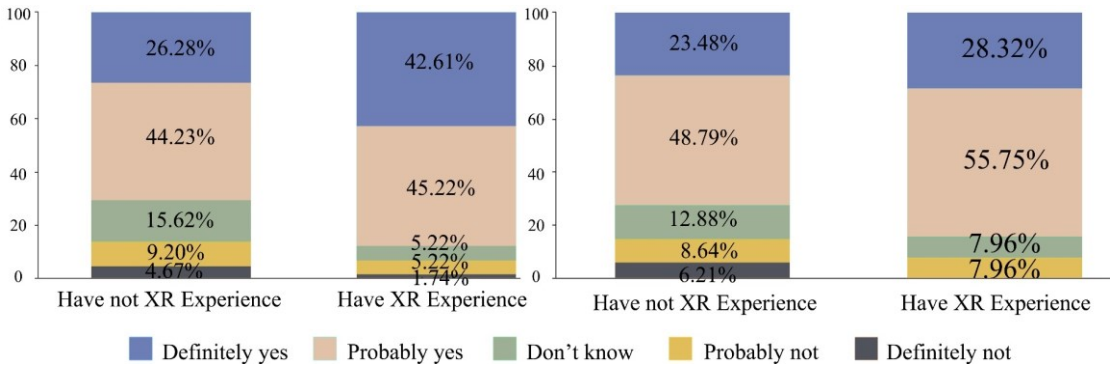


Figure 4.6 XRPE towards ATU (left). XRPE towards PU (right).

Hypothesis 4 shows that *consumers who have experienced XR are significantly more positive than non-experienced consumers regarding attitudes to use and perceived usefulness of the technology.*

H5. Extended reality previous experience has significant associations with AR, VR and No XR, and has no direct significant associations with MR.

Table 4.7 demonstrates the association between consumers with and without XR experience and their technology preferences. It is found that consumers' previous XR experiences have no statistically significant influence on preference for MR (p>0.05),

but AR, VR, and no XR users are statistically significantly correlated with their past experience with XR ($p<0.05$).

Table 4.7 XR preference and XR previous experience Chi-square analysis

Items	Categories	XRPE (N)		Total	X^2	P
		Yes	No			
MR	No	60	343	403	0.227	N.S.
	Yes	54	340	394		
Total		114	683	797		
AR	No	86	577	663	5.71	0.017*
	Yes	28	106	134		
Total		114	683	797		
VR	No	65	488	553	9.579	0.002**
	Yes	49	195	244		
Total		114	683	797		
No XR	No	108	596	704	5.296	0.021*
	Yes	6	87	93		
Total		114	683	797		
* $p<0.05$, ** $p<0.01$, *N.S.* $p>0.05$						

Hypothesis 5 indicates that *MR is a more stable preference compared to the other two technologies and less susceptible to past experiences. Also, after experiencing XR, approximately 5.26% of users preferred to shift away from it.*

The Association Between AR and MR on Intent to Use, Intent to Purchase, and Intent to Experience

More consumers prefer MR to AR in the general domain (Figure 4.7). MR is preferred for shopping, while AR is preferred for playing games (Figure 4.8). MR's intention to use is statistically positively correlated with shopping, social media, watching shows, work-related activities, and exercising. MR's purchase intention is positively correlated with clothes, shoes, groceries, skin care products, and customised jewellery. MR's experience intention is positively correlated with scene effects, sound effects, and workshops (Table 4.8). AR's intention to use has a statistically positive correlation with playing games but a negative correlation with work-related activities. Consumers' intention to use AR statistically positively correlates with buying shoes and using AR to experience personalised recommendations.

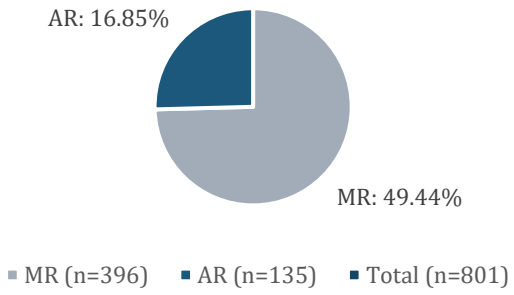


Figure 4.7 MR and AR user preferences

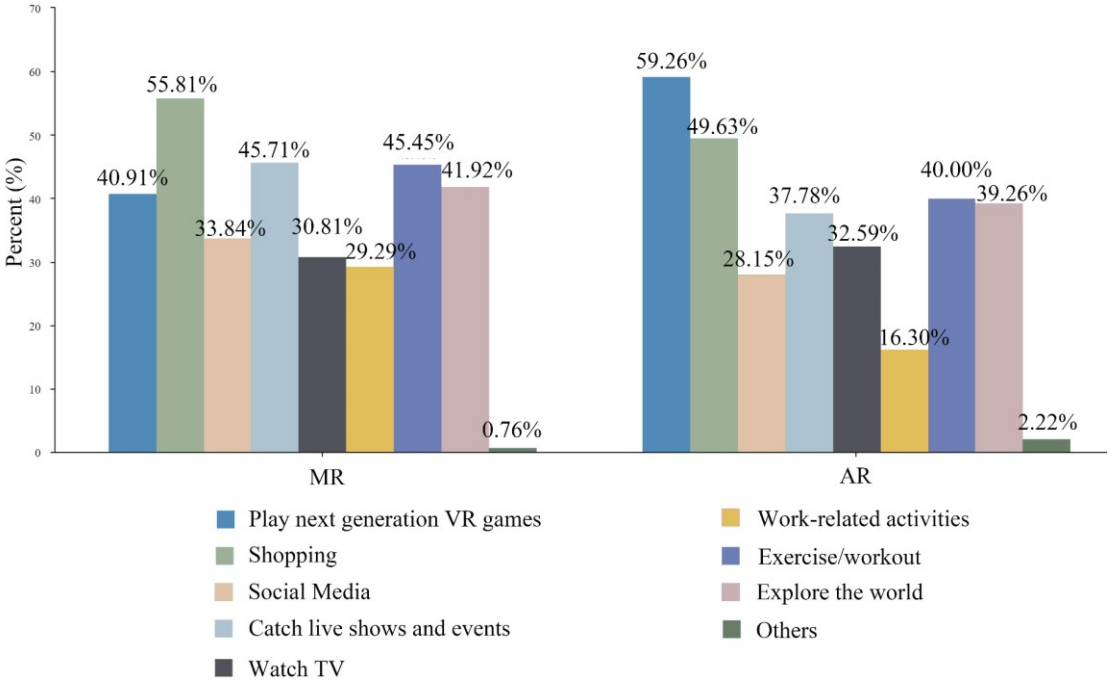


Figure 4.8 MR versus AR in intent to use

Table 4.8 Correlation in MR versus AR in intent to use, intent to purchase, and intent to experience

Items	Categories	MR (Pearson Correlation Coefficient)	AR (Pearson Correlation Coefficient)
Intent to use	Play next generation games	-0.011	0.163**
	Shopping	0.186**	0.029
	Social media	0.141**	0.007
	Catch live shows and events	0.163**	0.001
	Watch TV	0.057	0.044
	Work-related activities	0.133**	-0.077*
	Exercise/workout	0.145**	0.015
	Explore the world	0.058	0.002
	Others	-0.088*	0.007

Items	Categories	MR (Pearson Correlation Coefficient)	AR (Pearson Correlation Coefficient)
Intent to purchase	Clothes	0.152**	0.031
	Shoes	0.158**	0.087*
	Groceries	0.116**	0.007
	Furniture	0.058	0.025
	Skincare products	0.101**	-0.023
	Customisable jewellery	0.149**	0.031
	Others	0.002	-0.001
Intent to experience	Scene effect experience	0.208**	-0.029
	Sound effect experience	0.099**	0.050
	Customisation	0.028	0.048
	Personal recommendations	0.013	0.075*
	Interactive sessions	0.046	0.046
	Workshops	0.101**	-0.015
	Others	-0.021	-0.021
	* p<0.05 ** p<0.01		

The preference structure for intent to purchase is similar in MR and AR. However, the response rate for clothes, groceries, skincare products, and customised jewellery was higher in MR than in AR. The propensity to buy shoes was slightly higher in AR than in MR (Figure 4.9).

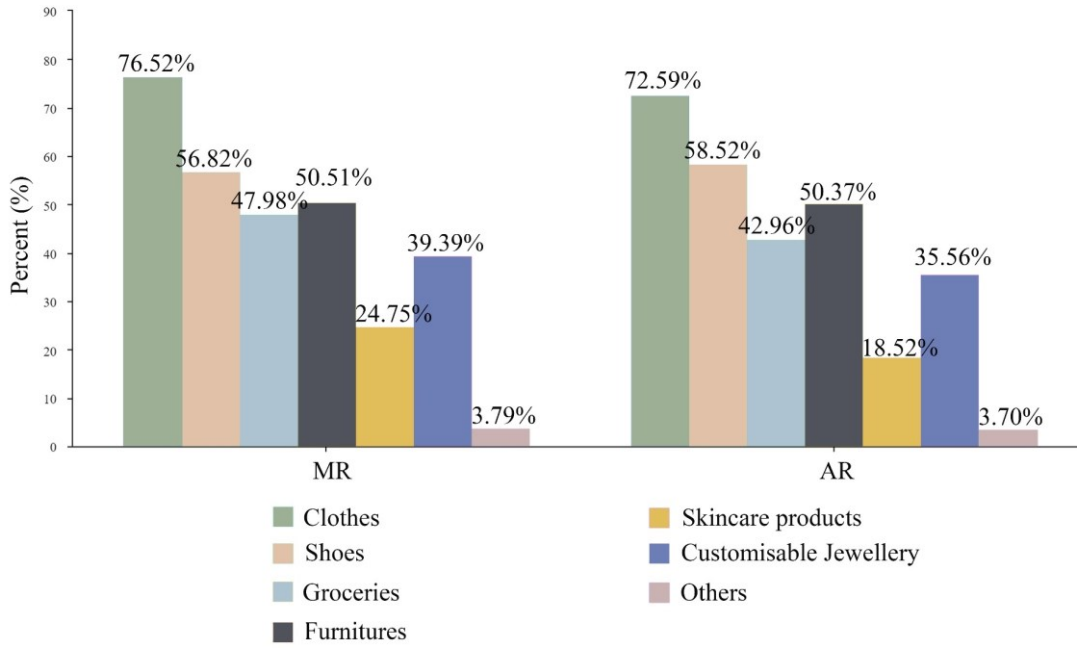


Figure 4.9 MR versus AR in intent to purchase

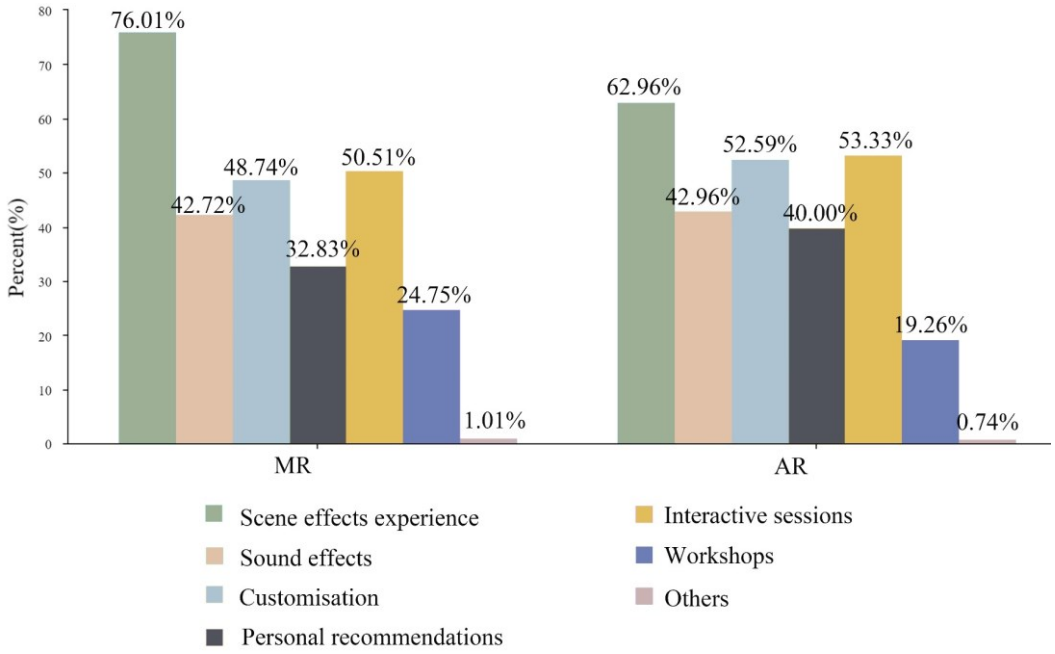


Figure 4.10 MR versus AR in intent to experience

The order of item preference for intention to experience is generally similar for MR and AR. Consumers who prefer MR consider scene effects to be essential than those who prefer AR. Consumers who prefer MR consider customisation and interactive features as the second most important (Figure 4.10).

4.6 Discussion and Limitations

Previous technology acceptance studies have discussed or compared AR and VR (Rese et al., 2017; Vrellis et al., 2020; Xi et al., 2024). This study is an initial attempt to identify customer preferences between wearable AR (MR) and mobile AR in retailing. The results provide a helpful step in the field of marketing towards enhancing customer experience through XR technology. MR has fewer studies and practices focusing on the retail market (see Section 2.2.5). This study found that the general public, with only 1.61% of consumers (n=807) having MR experiences. Of those 14.25% of consumers with previous XR experience, 11.3% have experience with MR, 52.2% have experience with AR, and 51.3% have tried VR. These further claim that mass adoption of MR experience to enhance customer experiences requires more practical guidance and theoretical support.

The study found that the potential consumer group adopting MR to purchase is between the age range of 18 and 64, but after 54 years, the consumer response rate sharply decreases. As such, 18-54 years is considered the primary target group, while 54-64 years is a possible age band range to try (Figure 4.11). For AR, the results aligned with other studies showing that users between the ages of 18 and 34 or 35 years are the major groups (Burke, 2002; Xue et al., 2020). The findings are summarised in a table split over two pages (For the full survey report, see Appendix A).

Extended Reality and Consumer Preferences Recommendations in Retailing				
Technology & Consumer Preferences	Demographics & Intentions	Classification	Suggestions	Interpretation
Mixed Reality (MR)	User Demographics	Gender	Female (52.7%) > Male (43.6%)	A statistically significant correlation exists between gender and MR preferences ($p<0.05$). Females (52.7%) significantly prefer MR technology than males (43.6%).
		Age	Aged 18-54	A statistically significant correlation exists between age and MR preferences ($p<0.01$). Consumers aged 18-64 prefer to use MR, while those aged 18-54 have a greater proportion.
	Consumer Intentions	Intent to Use	Shopping/Social media/Catch live shows/Work-related/Exercise	A statistically significant correlation exists between these use intentions and MR preferences ($p<0.01$). Consumer preferences (response rate): shopping (55.8%) > catch shows (45.7%) / exercise (45.5%) > social media (33.8%) / work-related (29.3%).
		Intent to Purchase	Clothes/Shoes/Groceries/Customisable jewellery/Skincare products	A statistically positive correlation exists between these five items and MR preferences ($p<0.05$). The response rate is: 76.5% of customers chose clothes, 56.8% for shoes, 48% for groceries, 39.4% for customisable jewellery and 24.75% for skincare products.
		Intent to Experience	Scene effects/Sound effects/Workshops	These three items are statistically positively correlated with MR ($p<0.05$). Consumer preferences (response rate): scene (76%) > sound effects (42.7%) > workshops (27.8%). Customisation. Personal recommendations and interactive sessions are not statistically correlated with MR. The customer preferences (response rate) are as follows: 48.7% of customers chose customisation, and 50.5% for interactive sessions.
Augmented Reality (AR)	User Demographics	Gender	Male (23.7%) > Female (13.1%)	There is a statistically highly significant correlation between gender and AR preferences ($p<0.001$). Males (23.7%) significantly prefer AR technology than Females (13.1%).
		Age	Under 18-34	There is a statistically significant correlation between age and AR preferences ($p<0.01$). Consumers aged under 18 to 34 significantly prefer to use AR, while aged under 18 to 24 have a greater proportion.
	Consumer Intentions	Intent to Use	Play games	Playing games has a statistically positive correlation with AR ($p<0.01$). AR has a statistically negative correlation with work-related ($p<0.05$). Shopping, social media, catching live shows/TV, exercising and exploring the world have no statistical correlation with AR ($p>0.05$). Consumer preferences (response rate): Play games (59.3%) > Shopping (49.6%) > Exercise (40%) > Explore the world (39.3%) > Catch live shows (37.8%).
		Intent to Purchase	Shoes	There are a statistically significant correlated with AR purchase for shoes ($p<0.05$). Skincare products have a negative correlation with AR, which is not recommended.
		Intent to Experience	Personal recommendations	Personal recommendations has a statistically positive correlation with AR ($p<0.05$), with a 40% response rate. Consumer preferences (response rate) for other not statistically correlated items: scene effects (63%), interactive sessions (53.3% %), customisation (52.6%), and sound effects (43%).
Virtual Reality (VR)	User Demographics	Gender	Female (30.1%) ≈ Male (31.4%)	There is no statistically significant correlation between gender and VR preferences ($p>0.05$). There is no significant difference between females (30.1%) and males (31.4%) in preference for VR technology.
		Age	N/A	There is no statistically significant correlation between age and VR preferences ($p>0.05$). There is no significant difference between different age bands in their preference for VR technology.

XR Previous Experience	With XR Experience (14.3%) (n=115)	XR technology		MR (47.4%) > VR (43%) > AR (24.6%)	For MR, previous experience has no statistically significant differences in user preference (p>0.05), and users before and after use have not shown differences in preferences (retention of 47.4%). For AR, previous experience has statistically significant differences in user preference (p<0.01), and users who prefer it decrease (retention of 24.6%). For VR, previous experience has highly statistically significant differences in user preference (p<0.001), and users who prefer it decrease (retention of 43%).
		Intent to Use	Shopping/Live Show/Exercise		There is a statistically significant correlation between consumers who had XR experience and intent to use XR for shopping (p<0.01), catching live shows and exercise (p<0.05). Of consumers who have experienced XR, 60% chose to prefer to use them for shopping, 47% chose to catch a live show, and 48.7% chose to aid exercise.
		Intent to Purchase	Clothes/Furniture		There is a statistically significant correlation between consumers who had XR experience and intent to use XR for purchasing clothes (p<0.01) and furniture (p<0.05). Of consumers who have experienced XR, 80% chose to buy clothes, and 56.5% chose furniture.
		Intent to Experience	Customisation		There is a statistically significant correlation between consumers with XR experience and intent to use XR for experiencing customisation (p<0.05). Of consumers who have experienced XR, 57.4% chose to experience customisation.
		User Retention	5.3% of users might not be retained		5.3% of users who have had XR experiences have become disinterested in any XR technology after use.
	Without XR Experience (85.7%) (n=688)	XR technology	MR (49.8%) > VR (28.6%) > AR (15.5%)		For users who have not had an XR experience, 49.8% intend to try MR, 28.6% intend to try VR, and 15.5% intend to try AR.
		User Retention	12.7% of users might not try XR		12.7% of users who have not experienced XR indicate they prefer not to try MR, AR or VR.
Dislike XR	User Demographics	Gender	Male (13.9%) > Female (10%)		There is a statistically significant correlation between gender and dislike of any XR technology preferences (p<0.05). Among those who dislike XR (MR/AR/VR) technology, males (13.9%) have a statistically significant dislike of XR than females (10%).
		Age	N/A		For users who dislike XR, there is no correlation between age and XR preference (p>0.05).
	Consumer Intentions	Intent to Use	Shopping		12.8% of consumers are not interested in using XR shopping.
	Previous XR Experience	With & Without previous experiences	11.7% of consumers dislike XR		For all experienced consumers, 11.7% of consumers are not interested in using XR.
Data collection in 2022, surveys were distributed in the United Kingdom and China with 807 respondents.					

Figure 4.11 XR development consumer model, preferences, and retail typology recommendations

There could be limitations regarding XR's previous experience and user intentions, as items not significantly related to XR's previous experience potentially encompass areas and content that have not yet been developed and adopted in the marketplace. Considering the unknown impact of the differences between the apps that respondents have experienced, the results of this report are applicable for businesses to understand consumer preferences and the demographics of potential customer groups. Companies should conduct further investigations into the impact of previous experiences with specific technologies on certain types of apps based on development needs before committing to investments.

Another limitation is that the options provided by consumer intentions (IU, IE, IP) are limited and not fully inclusive of all fields of consumption, product categories, and experiential features in the markets. Therefore, researchers can benefit from referencing and expanding more options. Further in-depth analysis of consumer demands through qualitative methods is beneficial for obtaining more actionable insights and developing MR applications.

4.7 Conclusion

This chapter defines the market development directions and consumer models for XR technologies and validates the feasibility and user preferences for MR in future retail (see Appendix F Section 01). It compares the respective benefits and disadvantages of MR and AR in the retail market and explores their uses. This study identifies the significance of adopting MR as a medium amongst the XR technologies and answers RQ1. Building on these findings, the age range of the consumer participant group targeted for the following studies is between 18-54 years. Based on the retail industrial ROI and consumer preference considerations, high-value customised jewellery is used for the retail category for the subsequent pilot studies. The scene, sound effects, and workshops will be considered integral to the design features in the ideation and design development of the MR UI system.

4.8 Contribution Summary

This chapter has addressed two research gaps in Section 2.6 (p. 65):

Research gap 2: Lack of research on XR technologies (VR, MR, AR) in retail with user acceptance and consumer demographics.

Research gap 3: Lack of comparison between MR and AR retailing, including consumer intent to use, experience, and purchase.

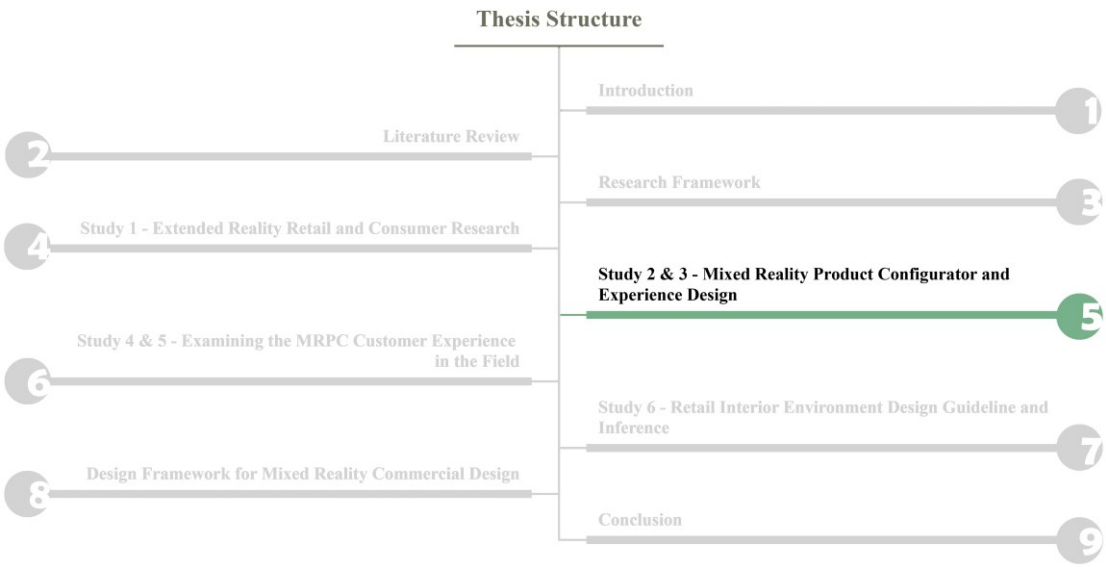
It answers research question 1:

What is the feasibility of, and user preference for, mixed reality adoption in the retail industry?

Review of the contributions made in this chapter:

- Established consumer model, preferences, and retail typology recommendations for extended reality development.
- Established the significance and consumer acceptance of MR in retailing and define the pilot sector scope that is in jewellery market.
- The findings contribute to the ideation of the MR purchase system framework design in the next stage (see Figure 3.12, p. 99).

5 Study 2 & 3 – Mixed Reality Product Configurator and Experience Design



5.1 Introduction

This chapter identifies the design requirements, design methodology, and market implementation challenges for producing a product mass customisation user interface (UI) in MR and designs a prototype application, the ***Mixed Reality Product Configurator (MRPC)***. The chapter answers the research questions through two studies. Study 2 undertook 2D MR UI prototyping using a mixed methods approach (n=15), iterating the 2D UI design and proposing a toolkit for rapid commercial MR prototyping – MRPaperPro. Study 3 uses qualitative semi-structured interviews (n=26) to identify the significance of an MRPC customer experience for brick-and-mortar retailing. It iterates the 3D MRPC application design and addresses prospective retail stores and consumer genres that might adopt the MRPC. Based on the findings from Studies 2 and 3, the output of MRPC design specifications is presented in Section 5.6.

5.2 Research Background

5.2.1 Product Configurator for Mass Customisation

In commercial design, consumer research is an indispensable strategy for design and development. Consumer shopping patterns are categorised into two fundamental motivations: buying for a specific goal and pleasure-seeking (Childers et al., 2001). This represents two different types of consumers, pragmatic and hedonistic. This results in different types of e-tailing consumers shopping in different ways. Researchers believe that online shopping is target-oriented and not concerned with the experience (Gilly and Wolfinbarger, 2000). Similarly, one study suggests that 69 per cent of online consumers already have a specific purchase intention (Feeley, 2023). It also depends on the product category, digital technology, and consumer typology. For low-value products, consumers may be willing to spend considerably fewer attempts to complete their purchase goal (Hennigs et al., 2015). Whereas, with high-value products, consumers may consider premium pricing, so they could potentially spend more time and anticipate a higher quality experience and service (Hennigs et al., 2015). Web-based product

configurators are an example of considering purchase goals and pleasure-seeking, and there are plenty of commodities that already use configurators to support the online customisation of personalised products, such as furniture, jewellery, cars, and shoes (see also p. 37). Product configurators refer to a range of activities that allow the mass customisation of specific consumer needs to provide product variety (Forza and Salvador, 2006). Users who use product configurators are both goal-oriented and experience-oriented (Addis and Holbrook, 2001). They are interested in visualising and personalising their experience, and they also have buying goals; therefore, they devote more time to completing the configuration of a product (Alford et al., 2000). However, with the development of XR technology, using immersive headsets for shopping appears to be the future direction of innovative retail in mass customisation (MC).

Despite their multiple benefits, one MR headset issue, as stated in the literature review, is that day-to-day users have not adapted to prolonged use of MR technology. One reason for this is neck strain and pain from wearing heavy equipment, along with eye strain. In addition, the current field of view of these headsets is narrow, thus limiting the content that can appear in view. There are also safety concerns when using them in public areas, such as the hazard of users immersing themselves in virtual content and ignoring the real environment when using them in an environment that is not designed for this purpose (Thomas and Holmquist, 2021). Therefore, the design of MR applications should consider these factors, such as comfort, field of view, and distance, to ensure that users can experience immersion without becoming excessively disconnected from reality when using them in public environments. In addition, the hazards of charging cables and the surrounding environment can be reduced by planning a suitable usage area.

Although current studies propose four types of MR UI layout design (Object-centred UI, User-centred UI, Object-user UI, and User-object UI) (Li et al., 2022), I suggest that a comprehensive consideration of the usage location is essential before development. For example, in commercial public spaces, using an object-centred UI (that is UI positioned in front of the object) design may require users to physically approach and walk towards objects. When users lack extensive MR experience, safety issues may increase during use. Therefore, I recommend that for commercial MR UIs, until they are adopted on the mass market, user-centred UI design (UI positioned in front of the

user) should be employed in combination with physical space planning. This approach can help to minimise the safety risks associated with user immersion by limiting unnecessary movement and establishing clear physical boundaries within the MR environment. This chapter focuses on a user-centred UI design, designing an MR product configurator system as a test prototype.

5.2.2 Rapid Prototype Techniques for AR and MR

Conducting usability prototype testing before developing 3D interfaces can significantly lower the costs associated with 3D development (Walsh et al., 2013). This multiple prototype testing, that is iteration, is common in the design and development process, and design iterations usually produce higher-quality designs and more new concepts (Wynn and Eckert, 2017). Iterative processes in which users are involved in the design, rather than just testing the system or providing feedback at the end of the design process, can incorporate the designer's output into the user's needs (Walsh et al., 2013). A participatory design, that is users are part of the design process, enables new concepts to be brought to the design during prototype iterations and refining and accelerating the development of the MR system.

This section reviews the available prototyping techniques and identifies the research gap, which is that existing prototype testing methods do not meet the specific needs of the MRPC design. Therefore, a rapid paper prototyping tool has been designed that can be tailored for commercial MR UI testing. Figure 5.1 classifies existing AR and MR prototyping technologies by considering four dimensions: physical and digital modalities, time cost, ease of production, and fidelity. Prototype testing techniques encompass physical, digital, and hybrid approaches. Physical techniques, such as sketching, paper, and sticky notes, due to their low visual precision, have considerable discrepancies, which are under the category of low-fidelity prototypes. High-fidelity models with significantly greater precision closely resemble a real environment; and digital techniques, exemplified by sophisticated software such as Unity, enable its creation. Hybrid techniques blend physical and digital components using digital equipment to produce three-dimensional sketches. For instance, these techniques involve scanning sketches for viewing through VR HMDs, crafting clay models for

panoramic viewing by playing with digital tools, and transforming sketches into videos. Unlike traditional 2D prototyping, 3D MR UI prototyping involves the simultaneous consideration of visual and interactive fidelity, as it requires substantial interaction.

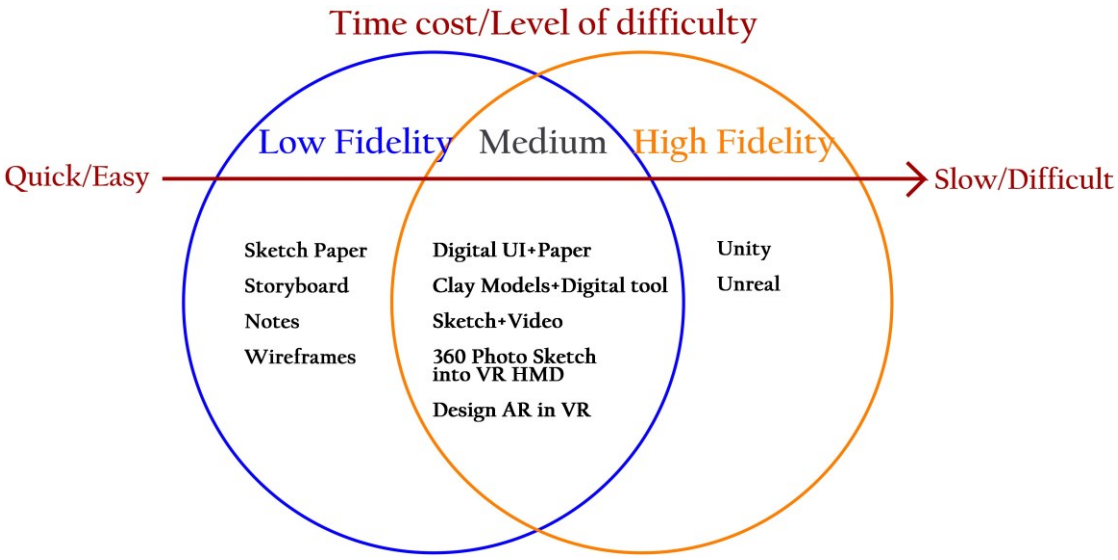


Figure 5.1 AR and MR prototype techniques

Table 5.1 Comparison of AR and MR rapid prototype techniques

MR and AR prototype tools	Fidelity	Production time	Visual effects	Interaction	Tool types
AR Paper Prototype (Freitas et al., 2020)	Low	Quick	Sketchy	Low	notes
PapAR (Lauber et al., 2014)	Low	Quick	Sketchy	Low	paper sketches
Augmented Sketch (Vasquez, 2019)	Low	Quick	Sketchy	Low	digital sketches, photos
MRPaperPro (Jin and Fagan, 2024)	Mid-high	Medium	Vivid	High	paper-printed, digital UI
Pronto (Leiva et al., 2020)	Medium	Medium/ High	Vivid/Sketchy	High	digital sketch, animation
ProtoAR (Nebeling et al., 2018)	Low	Medium	Sketchy	Mid-high	clay, digital tools, app

Table 5.1 presents a comparative analysis encompassing several representative rapid prototype testing methods within AR and MR. These are categorised into six tool types: sticky notes, paper, digital sketches, UI design software, clay models, and AR prototyping software. AR Paper Prototype (2020) employs sticky notes to swiftly display product information (Freitas et al., 2020), while PapAR (2014) utilises an overlay of translucent paper-on-scene imagery to convey interface details (Lauber et al., 2014). This type of approach makes it more suitable for use in information displays and

less robust for hedonic experience displays. Pronto (2020) employs sketches and video recordings to facilitate user interaction (Leiva et al., 2020). Analogous to this display effect is Augmented Sketch (2019), which entails photographing the physical world and superimposing sketch representations to elicit MR effects (Vasquez, 2019). Also, its usage necessitates the prompt retrieval of pertinent photographs from participants from an album by the host. Another type is ProtoAR (2018), which adopts clay to sculpt 3D models in conjunction with UI sketches, capturing and inputting them into the ProtoAR application to view in 360◦ (Nebeling et al., 2018). Pencils Before Pixels (2008) uses similar materials, such as clay, bricks, and paper to create spatial experiences (Baskinger, 2008).

The benefits of these methods are that users can view panoramic objects or environments in 360º. However, these methods may not provide the user with the benefit of co-designing with interdisciplinary designers. In addition, commercial development may involve substantial model-making components or sketches to produce merchandise. Commerce development will emphasise product outcomes to achieve its purchasing purpose. These prototyping cases are mainly designed for AR, which utilises smartphones or tablets to interact with the user, while VR offers AR effects that require the use of controllers. It is difficult for designers to observe the body performance of users directly in an MR context from their contact behaviours with these tools. Also, users with VR vertigo conditions may be limited in the prototyping stage. Therefore, a research gap is identified when designing an MR UI prototype and iterating the design (see also p. 65).

To satisfy needs, I designed a prototyping toolkit, MRPaperPro, which contributes to developing MR content that mediates between information-oriented and entertainment-oriented approaches. Facilitating the development of affordable, readily accessible, medium-high fidelity tools, it is suitable for multidisciplinary stakeholders. Distinct from other tools, this tool balances visual precision and interaction behaviour. In a commercial context, visual precision (product and UI design) is an essential form of information input for consumers to evaluate purchases and make decisions.

5.3 Research Question and Objectives

RQ2: How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments?

RQ2 Objectives in this chapter attempt to address:

- **RQ2_OBJ1:** Designing a participatory rapid paper prototype method for usability testing of MR commercial applications to iterate system design. (Research gap 4)
- **RQ2_OBJ2:** Define the standpoint and user requirements for the MR product configurator and design a user-centred user interface. (Research gap 5)

To fulfil the research objectives, studies 2 and 3 are conducted in this chapter.

Study 2 (RQ2_OBJ1) bridges the gap of suitable commercial MR UI rapid prototyping by designing an MRPaperPro toolkit, which provides a lean and effective way for interdisciplinary designers and consumers to co-design and collaborate. By utilising this tool, three rounds of 2D UI design iterations are completed prior to 3D system development.

Study 3 (RQ2_OBJ2) iterates 3D MRPC design through stakeholders' (consumers, retailers, XR experts, UI/UX designers, architects) feedback on the MRPC. It demonstrates its significance in brick-and-mortar stores and for target groups of consumers and retail stores.

After design iteration, the final MRPC design outcome will be demonstrated in Section 5.6 to respond to RQ2.

5.4 Methodology

5.4.1 Research Design

This chapter consists of two studies: while Study 2 uses a mixed methods approach to conduct prototype testing, Study 3 uses a semi-structured interview method. A prototyping method based on user evaluation is an essential aspect of interactive system

development and aims to identify usability problems in UI design (Nielsen, 1994; Rubin and Chisnell, 2011). Semi-structured interviews can reveal hidden aspects of audience perspectives and help researchers to identify in-depth issues, which is a common and flexible qualitative method (Kvale and Brinkmann, 2009). The combination of two methods aims to design a user-centred MRPC system to meet consumer demands in retailing. Through prototyping, it iterates the MRPC's design and uses interviews to identify consumer demands and stakeholders' insights. Therefore, the MRPC design plan will be presented based on the results of two studies at the end of this chapter.

Study 2: 2D MRPC Prototype Testing

Based on the online configurator design (see also Sections 2.3.2 and 2.3.3) and the findings of customer preferences for relative experience (see Section 4.6), a prototype of an MR jewellery configurator was ideated. Due to not being a brand-based app, it focuses on ergonomic design and functional features. However, there is no suitable rapid prototyping tool for MR retail UI design. Hence, an MR paper prototype toolkit, MRPaperPro, is designed (see also Appendix F, Section 04). This study has two goals: 1) using MRPaperPro to iterate 2D MRPC's UI design and understanding MR store environment experience preference, and 2) evaluating MRPaperPro as a prototyping design toolkit.

Study Two used quota sampling because users should represent various demographics (nationality, gender, age) to address the research aim of globalised consumers. It aims to test system usability, so test content does not need to be projected onto a population for precise estimation. 2D ideation was iterated during this study, and 3D MR apps were built into MR development software.

The following will introduce the design approach of the MRPaperPro toolkit. The design goals of this toolkit are to achieve:

- *Testing MR shop environment perspectives.* MRPaperPro prototyping provides users with contexts in a real-world environment. In this session, interior designers can accomplish an A/B test of a consumer's interior design demands and collect consumers' preferences for physical space and spatial interaction behaviours.

- *User interface usability and design.* Based on the flow design and aesthetics of the interface, evaluate and identify logistical fluency, navigation and task usability of the system through users' flow of operations. UI designers can obtain UI feedback and aesthetic comments through live communication.
- *Provision of participatory design and innovation.* In participatory design, product and UX designers capture consumers' expectations for mass-scale customised product design. Designers discover a generation of repetitive user behaviours and innovative interaction behaviours from observation.

Physical testing is often time-consuming and expensive, and designers usually aim to resolve as many issues as possible through simulation before developing physical prototypes (Wynn and Eckert, 2017). MRPaperPro constitutes a technological approach for conducting mixed reality prototypes and usability testing for design deployment during the early to middle stages, particularly within the retail industry. It is designed to efficiently tackle early- and mid-stage MR interface design iteration issues at a lower cost. The method emphasises embodied user responses and participatory design within prototype assessment. The proposed technology predominantly incorporates multi-layered paper and tangible 3D models, enabling users to experience a simulated MR in-store customisation experience by replacing widgets with pinching actions. The first layer is an environmental atmosphere simulation, situating users with a contextual reference for their interaction environment. The second layer encompasses interface design visuals, such as web page graphics and product information. The third layer comprises tactile and 3D conceptual models (Figure 5.2).

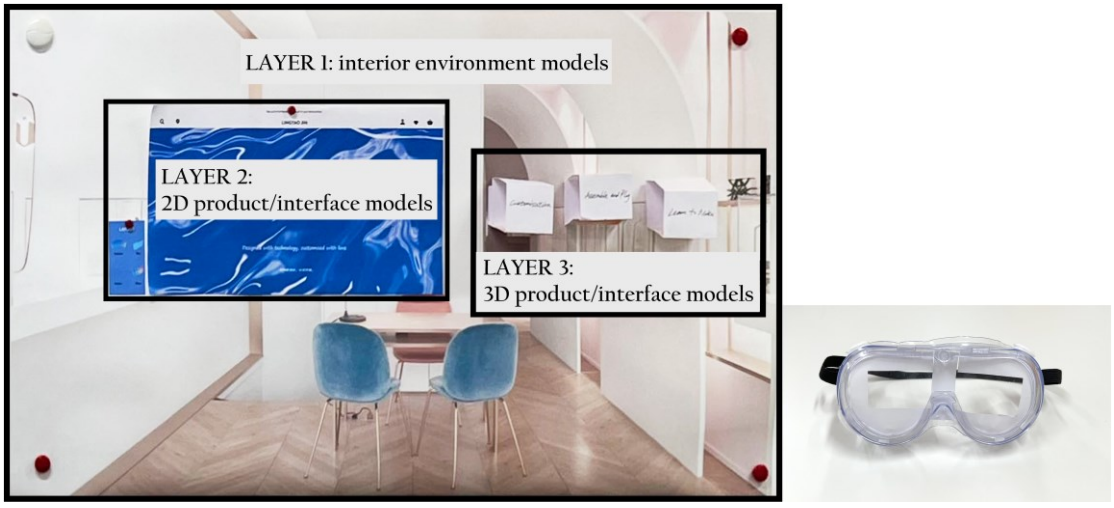


Figure 5.2 MRPaperPro hierarchical display (left). Simulation of HMD field of view (right)

Due to the tactile nature of MR, responsive reactions (sounds and colours) are triggered by pressing buttons. Consequently, certain buttons can be designed as boxes with two sides, simulating touch-responsive behaviour. Following button presses, the experimenter flips the box to orient the responsive surface towards the user. The main interface utilises magnets as movable attachment tools, affording users the flexibility to reposition the interface in line with their requirements, thus simulating gestures such as dragging and pinching. Small components can be affixed with clay on the back to stick onto the canvas to mimic customisation operation (Figure 5.3). This heightened flexibility enables real-time communication between designers and users, thus facilitating swift collaboration in shifting or modifying UI layouts.

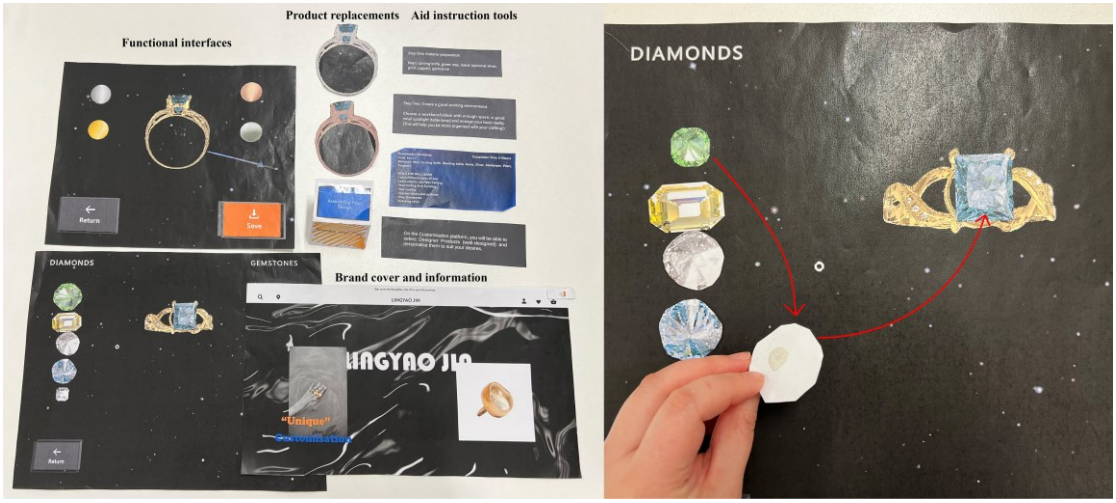


Figure 5.3 MRPaperPro subset of design aid tools (left). Parametric portable components (right)

To design ergonomic UI perspectives, the technique also proposes the preparation of a spectacle that mimics the same field of view ratio as MR HMDs, so as to simulate the UI and spatial range that one would naturally observe. Application hardware will be implemented in Microsoft HoloLens 2 HMDs. This particular HMD features a field of view with a display ratio of 4:3, a diagonal of 52°, a vertical measurement of 29°, and a horizontal measurement of 43° (Skarredghost, 2021). For participant experiences, experimenters should prepare experimental spectacles designed to simulate HoloLens 2 or other HMDs they intend to use, maintaining a 4:3 viewing area while obscuring surplus portions.



Figure 5.4 Experiment environment preparation

Furthermore, it is preferred to conduct testing on a vertical whiteboard instead of a horizontal tabletop, owing to the inherent orientation of HMDs (Figure 5.4) because under HMDs, users' heads and eyes are generally aligned straight ahead. In contrast, traditional smart devices such as smartphones or PCs prompt users to tilt their head downward when reading. A table traditionally serves as the physical interaction platform for conventional UIs. These steps are essential for emulating the consumer in-store experience and provide the UX designer with considerations for user-headset and user-retail worker interaction modes.

Study 3: 3D MRPC Iteration and Evaluation

This study iterates the MRPC in 3D software and intends to collect data from interviews: 1) To identify the significance of MRPCs grounded in brick-and-mortar stores compared to traditional online and physical channels; 2) To explore the requirements of mass MRPC adoption for brick-and-mortar retail; 3) To identify applicable consumer and retail store genres.

The thesis readership includes CEM stakeholders, who should be invited to provide insights from different fields before design. The sampling strategy uses simple random, snowball and quota sampling. Retailers use simple random sampling as there is no limitation to brand genres and retailers' knowledge of MR. UX designers and XR experts are contacted via snowball and quota sampling, as these groups are difficult to

access, and their expertise is needed for the scope of the study. Consumers are recruited by quota sampling to include the perspectives of customers of various ages and genders. They should have experience in online shopping, including consumers who are online-oriented, offline-oriented and both.

5.4.2 Data Collection

Study 2: 2D MRPC Prototype Testing

Prototyping was conducted from July to December 2023. Participants are briefed on MR, a method to engage in paper prototyping (10 minutes). The experimenter begins to record both video and audio data. Data collection includes four steps: 1) Using paper prototyping to test MRPC UI usability (20–30 minutes). 2) Using semi-structured interview questions to ask users about their expectations of the MRPC experience (20–30 minutes). 3) Ask participants to complete a questionnaire to respond to the MRPC prototype design (10 minutes). 4) Ask questions to collect MRPaperPro toolkit feedback (20 minutes).

MRPaperPro was used to complete the above steps one to three. It used a mixed methods approach to construct the experiment, including a storyboard, paper prototyping, semi-structured interviews and a questionnaire. Prior to commencing the experiment, participants needed to attain a relatively consistent level of cognitive understanding, comprehending the experiential flow and usage method of the MR user interface. The experiment includes explanatory storyboards. Participants were allocated time to peruse these, ensuring their grasp of the operational procedure and the shopping process they might encounter in practical scenarios. Following this, participants were introduced to the 'think aloud' [22] method before beginning prototyping, with

[22] Paper Prototyping: How to Create & Usability-Test Simple UI Prototypes. Nielsen Norman Group (2021). https://www.youtube.com/watch?v=OlbdIXLunt4&t=596s (Accessed in March 2025).

participants describing the reasons for their actions and thoughts (McDonald et al., 2012; *Paper Prototyping*, 2021). The experimenter only informed users of the situation when they produced unexplored interfaces, such as "We do not have this interface or functionality yet. You can tell me what you expect to see" or "Nothing happens here". The experimenter used neutral language during prototype testing to avoid prompting participants' behaviour. After completing this prototyping test, the participants completed a questionnaire and an interview. After three method iterations (Figure 5.6), the finalised MRPaperPro workflow was established, as shown in Figure 5.5.

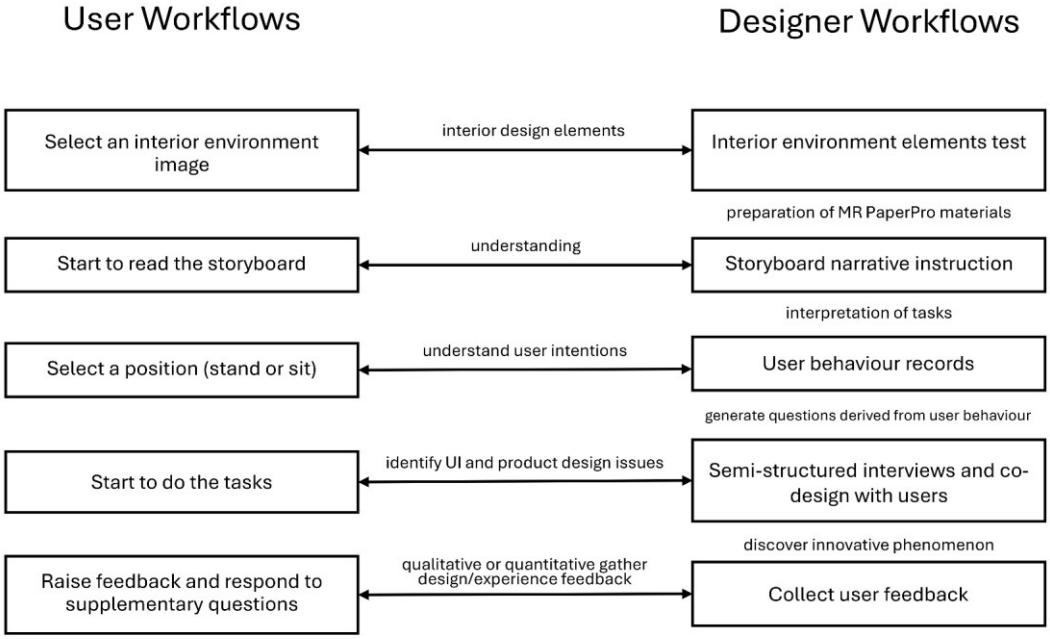


Figure 5.5 Workflows of MRPaperPro toolkit

The MRPC system includes gestures, such as pinching, tapping, zooming, shifting and rotating. To facilitate the assessment of these interactions through paper prototype testing, this method needs to prepare product images of different sizes and with UI interfaces to represent the zooming function. Before a prototyping test, the researcher provided two images representing two typologies of retail interior environments as the first layer of the paper prototype to mimic the environment in which customers shop. These images were intentionally chosen according to the designer's research goals, factoring in interior furnishings, colours, dimensions, and layout. Prior to each prototyping cycle, users were informed of the need to hypothetically enter a brick-and-mortar shop to use this HMD and select a preferred scenario from amongst those on offer.

Study 3: 3D MRPC Iteration and Evaluation

Interviews were conducted in October 2023. In-depth interviews took about an hour remotely, and a video of the MRPC's operation was played to showcase its operation. Table 5.2 shows the semi-structured questions. The interview included three steps. The participants were asked non-MRPC-related questions (approximately 25 minutes), followed by playing the video of MRPC (3:15 minutes), and then asked questions related to the MRPC-related questions (approximately 30 minutes).

Table 5.2 Semi-structured interview questions for stakeholders

Stakeholders	Data goals	Interview Questions
Consumers	3)	How much time do you typically spend shopping per week (both online and offline)? How much time would you be willing to spend on shopping per week? What categories of products do you usually buy online? What categories of products do you usually buy in-store? How do you allocate the proportion of online shopping and in-store shopping?
	1)	What do you think are the pain points of current offline shopping? What do you think are the pain points of current online shopping?
	2)	Do you have MR or AR experience before? How do you think product customisation affects your decision-making? Can you please describe the advantages and disadvantages of this app? What factors might prevent you from using this app in physical shops? Do you have any suggestions for improvement of the app in terms of visual effects, functions, and interaction methods?
Retailers	3)	How long has your shop been established? What is your shop size? What is your shop's business scope, including customer types, product types, and operating formats? What is the biggest challenge your brand/shop is currently facing? What methods have you used or will you use to increase customer connections, attract new customers and build shop image? How do you rank these factors that influence consumer purchases and experience? Store environment design (shop layout, lighting, colours, signage, merchandise display), Product design (product style, colours, styles, materials), Social factors (number of salespeople in the shop, salespeople's dress, other customer influences, privacy), Quality of merchandise, Quality of service (customer service attitudes, professional knowledge, affective value provision)
	2)	What are the advantages and disadvantages of using this app for in-store purchasing? Do you have any suggestions for improvement for the app? What challenges affect your use of this technology or app in-store?
XR Experts	2)	What are the reasons you think the MR has not yet emerged as a bigger market in the retail industry? What factors do you think would make mixed reality design more inclusive for public domain access?

Stakeholders	Data goals	Interview Questions
		Can you please describe the advantages and disadvantages of the MRPC system? Do you have any suggestions for improvement for the MRPC system? What key performance indicators might be relevant when using this app in a physical shop?
XR UI, UX Designers, Architects	2)	What is the most important aspect of MR UI/UX/interior environment for shopping? What is the most overlooked aspect of MR UI/UX/interior environment for shopping? What are the advantages and disadvantages of using this app for in-store consumer experience? Do you have any suggestions for improvement of the MRPC system in terms of visualisation, function, interaction, and interior environment design?

5.4.3 Data Analysis

Study 2: 2D MRPC Prototype Testing

Video data and transcripts were imported into NVivo 12, and questionnaire data were imported into IBM SPSS software for analysis. After each round of prototyping, the data were analysed to modify the MRPC design (see Appendix B of the iterative process). In round three of prototyping, the method was considered saturated, and prototyping was halted. The semi-structured interview questions were: 1) Why did you choose this store background? 2) What are the disadvantages of UI design? 3) What can be improved in UI design? The questionnaire design and the Cronbach's alpha reliability of each scale are shown below, which indicates scales with good reliability (Table 5.3). The question for MRPaperPro evaluation was "Please describe three advantages and disadvantages of using this paper test".

Table 5.3 Questionnaire design and reliability of Study two

Construct	Measurement Variables	Adapted References	Cronbach's α
Perceived Usefulness (PU)	PU1: Using the MRPC shopping improves my purchase performance. PU2: Using the MRPC shopping enhances my effectiveness on the purchase. PU3: Using the MRPC shopping makes it easier to do my purchase.	(Davis, 1989; Rese et al., 2017; Venkatesh, 2000);	0.98
Perceived Ease of Use (PEU)	PEU1: Interacting with the MRPC system is often frustrating. PEU2: The MRPC system is rigid and inflexible to interact with. PEU3: My interaction with the MRPC system is easy for me to understand. PEU4: It is easy for me to remember how to perform tasks using the MRPC system.	(Davis, 1989; Huang and Liao, 2015; Kim and Forsythe, 2008);	0.68
Perceived user interface design (PUID)	PUID1: The layout of the MRPC app is user-friendly. PUID2: The computerised instruction provided by the MRPC user interface is clear. PUID3: The layout of the MRPC user interface is in good structure. PUID4: Overall user interface design of the MRPC user interface is satisfactory.	(Cho et al., 2009)	0.84
Behavioural Intent to use (BIU)	BIU1: Assuming I had access to the system, I intend to use it. BIU2: Given that I had access to the system, I predict that I would use it.	(Ajzen, 1991; Rese et al., 2017)	0.72

In each cycle of prototype testing, five participants were recruited, which is a reasonable number of participants to identify problematic issues (Nielsen, 2003). After each round of prototyping, the design features were iterated according to the videos. The questionnaire used a 5-point Likert scale: 1-strongly disagree, 3-neutral, and 5-strongly agree (Likert, 1932). The questionnaire result showed no significant improvements in the results of Cycle C (Table 5.4). Therefore, the 2D prototypes were considered saturated, and 3D models were built (UI iteration process see Appendix B).

Table 5.4 Questionnaire scores result in three iterations

Cycle	PU (Mean)	PEU (Mean)	PUID (Mean)	BIU (Mean)	Overall Score (Mean)
A (n=5)	2.87	3.40	3.80	3.30	3.34
B (n=5)	4.30	3.50	3.90	3.80	3.88
C (n=5)	4.07	3.40	4.15	4.30	3.98

MRPaperPro evaluation was coded with two themes: advantages and improvements. In Cycle C, no new suggestions for improving MRPaperPro were made. Therefore, this design method is considered data saturation.

Study 3: 3D MRPC Iteration and Evaluation

Data sets contained approximately 21.9 pages per participant, and transcripts were imported into NVivo for thematic analysis. When data are repeated significantly, the theory is considered sufficiently comprehensive to reach saturation and explain the phenomenon being studied (Strauss and Corbin, 1990). Thematic analysis used three-level coding divided into five steps (Braun and Clarke, 2012). First, video recordings are transcribed, and the dataset is read. Step two identifies initial codes, organises the data inductively and generates subcategories. Step three involves analysing and comparing codes to identify themes. Step four reviews themes and codes within the overall dataset by generating thematic maps. Fifth, define and describe themes and write examples and quotes.

5.4.4 Participant Demographics

Study 2: 2D MRPC Prototype Testing

Participants were targeted between 18 and 54 years old, demonstrating a strong interest in MR (see also p. 117). The participants' average age is 31.13 years. Three participants had design-related backgrounds, namely A3, C11 and C12. Participant A5 (C13) was a returning participant with a computer science background (Table 5.5). The benefit of having the same group of participants across iterations is the consistency of evaluation and the ability to assess design modifications directly (Carlson et al., 2020). However, the primary goal of this study is to identify new app design requirements and improve design through participatory design iteration. To avoid a learning effect (that is, participants improve performance as learning occurs as they become familiar with procedures and tasks) from the same group of participants (MacKenzie, 2013), as well as to cover a more diverse group of users and different perspectives. Different participants were recruited for cycle A and cycle B design iterations. Only one participant from cycle A was invited to the cycle C iteration to compare the effects of the design iteration improvement. None of the participants had previously used or had background knowledge of MR, while two participants had previous VR experience. The study was conducted with ethics approval from the University Ethics Committee.

Participants signed a consent form before participating. Recruitment was voluntary, and refreshments were provided to participants during the activity.

Table 5.5 Participant demographics of Study two

Cycle	Participant code	Gender	Ethnicity	Age	Occupation	Highest Education
A	1	Female	UK	27	Student	Postgraduate
A	2	Male	Belgium	51	Researcher	Postgraduate
A	3	Female	China	30	Associate Lecturer	Postgraduate
A	4	Male	India	28	Student	Postgraduate
A	5	Male	India	29	IT professional	Postgraduate
B	6	Male	Malaysia	22	Student	Undergraduate
B	7	Male	China	22	Student	Undergraduate
B	8	Female	Italy	21	Student	Undergraduate
B	9	Male	UK	18	Student	Attended college
B	10	Female	India	24	Student	Undergraduate
C	11	Male	Bangladesh	53	Associate Lecturer	Postgraduate
C	12	Female	Spain-UK	51	Graphic designer	Undergraduate
C	13	Male	India	29	IT professional	Postgraduate
C	14	Male	China	24	Student	Postgraduate
C	15	Female	Arab	38	Student	Postgraduate

Study 3: 3D MRPC Iteration and Evaluation

The 26 participants included consumers (n=10), XR experts (n=7), XR UI/UX designers and architects (n=2), and retailers (n=7). Table 5.6 shows the demographics of consumers, experts, and designers. The average consumer age is 36.4 years. XR experts include different age groups, from academics to industry. XR designers have done related work for more than three years. Retailers aged 29–35 years comprised four participants, and those above 45 years formed three participants (Table 5.7). The University Ethics Committee approved the study, and all participants signed a consent form. Consumers were volunteers and not provided with any incentives; retailers, designers, and experts were given a £15 Amazon voucher as compensation.

Table 5.6 Demographics of consumers, XR experts, and designers of Study three

Interviewee	Code	Gender	Geography	Age	Occupation	Highest Education
Consumers	C1	Female	China	41	Engineer	Undergraduate
	C2	Female	China	30	Administrator	Undergraduate
	C3	Male	China	54	Manager	Postgraduate
	C4	Female	China	34	Researcher	Postgraduate
	C5	Female	China	50	Business management	Postgraduate

Interviewee	Code	Gender	Geography	Age	Occupation	Highest Education
	C6	Male	UK	25	Banker	Postgraduate
	C7	Female	UK	37	Manager	NVQ
	C8	Female	UK	21	Student	Undergraduate
	C9	Male	UK	39	Construction	H&D in construction science
	C10	Male	UK	33	Teacher	Postgraduate
XR Experts	E1	Male	Malaysia	26-34	PhD researcher	\
	E2	Male	Singapore	35-44	Postdoctoral	\
	E3	Female	UK	45-54	Senior Developer	\
	E4	Male	Italy-German	26-34	PhD researcher	\
	E5	Male	China	26-34	PhD researcher	\
	E6	Male	UK	Above 55	Professor	\
	E7	Male	German	26-34	PhD researcher	\
XR UI/UX Designers, Architect	D1	Female	India	26-34	UI, UX designer	\
	D2	Female	Italy	35-44	Architect, UI, Interaction	\

Table 5.7 Retail shop profiles of Study three

Retail Shop Profiles	Retail shop 1 (R1)	Retail shop 2 (R2)	Retail shop 3 (R3)	Retail shop 4 (R4)	Retail shop 5 (R5)	Retail shop 6 (R6)	Retail shop 7 (R7)
Shop type	Independent space	Open space in a mall	Independent space	Independent space	Independent space	Independent space	Independent space
Shop dimension	Approx. 25 m²	Approx. 12 m²	Approx. 20 m²	Approx. 20 m²	Approx. 12 m²	2 floor approx. 15 m² per floor	A house of 3 floors, approx. 75 m² per floor
Retailer gender	Female	Female	Male	Female	Male	Female	Female
Retailer age	30	35	46	29	Above 55	Above 55	29
Customer age group	18-58	30-50	30s	20-50	18-70	20-75	25-35
Customer type	White-collar	White-collar	White-collar	Wholesale clients	No Target	No Target	White-collar
Product materials	Precious metal, pearl, clay	Jade, Woven	Crystal. Jade, Wood, Woven	Costume jewellery	Precious metal, Stone	Precious metal, Stone	Precious metal, Stone
Year Established	3 years	3 years	Over 10 years	3 years	44 years	12 years	5 years
Usage of digital technology	E-commerce and physical	E-commerce and physical	E-commerce and physical	E-commerce and physical	Online platforms for marketing only	E-commerce (since 2023) and physical	E-commerce and physical
Geography	UK	China	China	China	UK	UK	China

5.5 Findings

5.5.1 Study 2: 2D MRPC Prototype Testing

This section will explain the results of 1) using MRPaperPro to iterate 2D MRPC's UI design and understanding MR store environment experience preference, and 2) evaluating MRPaperPro as a prototyping design toolkit.

1) 2D MRPC's UI Design Iteration and MR Store Environment Preference

Figure 5.6 interprets the experimental workflow of the three cycles of MRPaperPro testing. The three prototyping cycles include two themes, and eight subcategories are generated. The following will interpret the theme on UI design and store environment experience preferences.

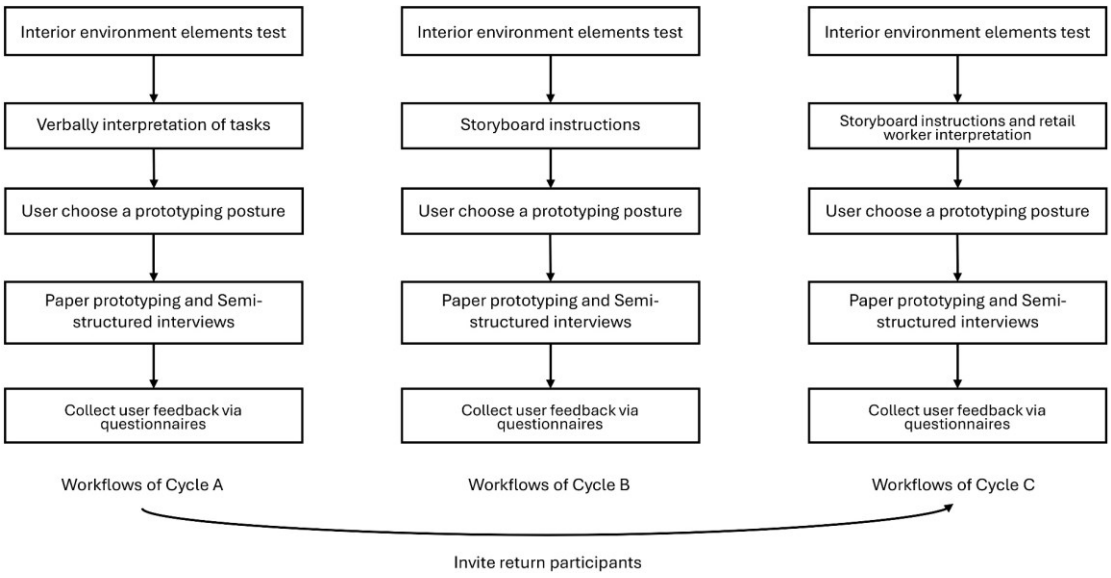


Figure 5.6 Three cycles of pilot workflow iterations

UI Design Iteration

The UI design iteration includes visual design, functionality, natural interaction gestures and ergonomics. Based on the online configurator, Cycle A designs an MRPC with a customisation function, enabling personalised alterations to an existing product, such as replacing the stone, changing the product's material and ring thickness and adding

gemstones, sizes and shopping carts. Figure 5.7 captures the original UI design and a participant moving the interface.

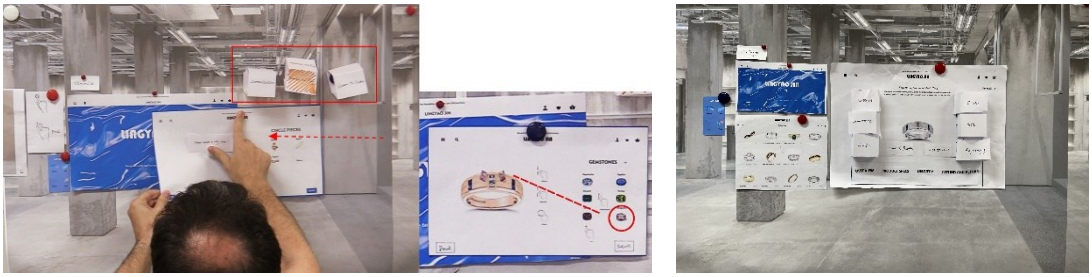


Figure 5.7 Paper UI movement and alternate product components

Participants provided improvement comments on the layout position, that the main customised page could be shown in the vision centre, and the UI should show the brand style. Microsoft HMDs development guidelines also indicate that pure white can be excessively bright and discomforting for users, while black will appear transparent (Vitazko et al., 2022). The interface colour was amended to a dark colour. A participant commented on the importance of UI design for shopping:

> *"It is good to have a nice web layout because it kind of brightens your day and makes it a bit, subconsciously makes you continue going to that website [...] If the headset was to make it more engaging or easier for me to shop physically, then I would probably do more shopping in person" (A1, Female, 27).*

Cycle B improvements include amending the layout, adding an interface from two to three panels and adding a plane and 3D objects. The paper prototypes encouraged the participants to imagine new interactions without having experienced the equipment. Apart from designed gestures, the participants developed new interaction gestures, such as swiping their palms to unfold and collapse the interface. There were other extensions, such as virtual game animations for image symbolism and interaction means (virtual agent). Other suggestions include separating stone and diamond to different sides, adding engraving and package options, amending product texture, removing thickness, adding assembly for more freedom in design and adding special effects that cannot be found in reality.

In Cycle C, participants gave opinions on product design, such as amending and engraving typographic display positions (Figure 5.8), adding extra diamonds and UI instruction text. A participant suggested that the layout could be improved thus:

> *"But keeping them focused on one product or one page, it's going to be better. So three (screens), it's good [...], but I don't think we have to go back" (C15, Female, 38).*



Figure 5.8 Sketches' engraving position on the product (left). Mimics the hand movement (right)

Furthermore, participants elaborated ideas for other future retail purposes of the application, such as the baking sector for customised memorial cakes (B6) and the toy manufacturing sector for customised toys (A2).

MR Store Environment Experience Preference

Subcategories related to the store environment include colour tone (interior style), layout (product display, seating area), lighting (illuminance) and usage posture (standing, sitting). Referring to shop layout and colour tone, one participant stated:

> *"(monochrome tone shop) It felt, in a way, more accessible. It felt good just to walk around and have a look before I talk to an agent and do that immediately. Very intimate with an expectation to go and sit. So, if I'm not ready for an interaction yet here, I feel like I'm just looking around. And it's also very clearly displayed, so I like things which are organised and there it kind of feels cosy. And I'm a little bit suspicious. I feel I'm a little bit manipulated, almost" (A2, Male, 51).*

Six participants chose a seated position, while nine decided to stand during their experiences. This suggests that stores should prepare seats and standing space. The experimenter measured the participants' arms' stretch distance to the UI from 50 cm to 80 cm. Therefore, the UI design chose the maximum value as the UI starting point distance to meet the minimum needs.

2) Evaluating the MRPaperPro as a Prototyping Design Toolkit

The advantages of using MRPaperPro include it being inexpensive, handy, fast and re-readable, with fewer space constraints and no background knowledge needed. Disadvantages of this technique include the need for participant imagination, lack of virtual embodiment and waiting for replacement. Some evidence is shown below.

- **Repeat and re-read.** This method enables participants to easily repeat and re-read content when they intend to return to previous content.

  > *"I can feel what I am touching and what I am doing, and also in virtual [use], there is no written instruction. So here I can read the instructions again and again" (C13, IT).*

- **Handy and fast.** The papers are easy to access and quick for doing tasks.

  > *"You don't need to [do anything] other than arranging some tools … You can have your paper. It's very handy. You can make it immediately" (C11, designer).*

- **Fewer space constraints.** This toolkit is less constrained by the testing environment, so designers do not need to put much effort into arranging space.

  > *"You don't have to get any specific space to do this research. You don't need to set up a room differently, very separate to do this, you can even do it in a public space. You don't need much isolation, you just need your participants to get engaged with those things to have engagement, and that's all" (C11, designer).*

- **Require imagination.** This method needs participants to have certain knowledge or imagination of using MR.

  > *"The participant needs to be imaginative to think about why they are communicating with this paper website in reality. The participant, himself or herself, should imagine that I am pressing this, and there is a screen that is then coming down, or coming up, then I'm going from that to another screen. I am looking for these options here. She has to imagine with these papers" (C11, designer).*

- **Lack of virtual embodiment.** The toolkit lacks 3D visualisation or immersive effects.

  > *"I'm not getting virtual satisfaction from this paper" (C13, IT).*

In summary, this prototyping toolkit is applicable as a participatory design for developing MR for interdisciplinary design, which allows designers to exploit their work. However, designers must have certain auxiliary abilities to aid users in

understanding and conceptualising the role of paper prototypes. It also suggests that designers should be familiar with procedures to minimise discontinuities when replacing parts. There are some limitations designers should be aware of, such as MR headset interactions, including remote ray-targeting and proximity direct taps, which cannot be reflected within paper prototyping. Finally, where circumstances permit, designers can multiply the number and angle of whiteboards to mimic interface tilt angles in space.

5.5.2 Study 3: 3D MRPC Iteration and Evaluation

The interview results are structured in three parts (see Section 5.4.1 and Table 5.2): 1) To identify the significance of MRPCs grounded in brick-and-mortar stores compared to traditional online and physical channels; 2) To explore the requirements of mass MRPC adoption for brick-and-mortar retail; 3) To identify applicable consumer and retail store genres.

1) Significance of MRPC for Brick-and-Mortar Retailing

Table 5.8 summarises consumer interview results, which code the differences between the three channels. Consumers with a high proportion of online shopping identified the advantages as time-saving and convenience and the disadvantages as a lack of perceived product size and haptic experience. To bridge customer pain points (that is, barriers and obstacles in CX), design requirements need to include 1:1 3D product dimensions and virtual product fitting. C1 represents a group of online shopping customers:

> *"I'm usually quite busy at work, so I'm not willing to spend a lot of time shopping in offline shops, browsing, or choosing. I think online is more convenient" (C1).*

The advantages of shopping in physical shops are building a relationship with the retail assistant and the tactile experience. The disadvantages include perceiving insufficient information on products available in the shop, small information panels, queuing, inconvenience of carrying products and pressure from assistants. Participant C1 described the MR offline shopping channel as combining the advantages of both online

and offline shopping, including the convenience of virtual fitting, time-saving and the ability to touch the texture of products.

> *"Then, I don't have to try it on myself. Maybe I can see what the texture is like [...] If I'm online, you can only see the model's match, but you can't see the details of the clothes' texture. I feel that it is a little combination of online and offline. I think this will be better, so it meets the kind of online look where you can see what the model wears, and then what is the effect, how it actually looks and feels, and then it saves you time. It feels like saving yourself the trouble of trying it out" (C1).*

One participant stated that MR could provide more options, such as available to buy in-store and delivery, and was concerned about the headsets queue.

> *"Because I actually have done that before, like in the sense that I go to the store, I see the products. I know that I want them, but I don't buy them in the store. I order it through my phone or through the Internet in my house [...] because I don't want to carry all those things [...] I want, or the salesperson tells me there are more colours, but we don't have them in stores, then yeah, it could be interesting to see them [...] My concern with that is that I don't wanna queue, and if there aren't too many people using the headsets and there's a queue waiting for them, then that's definitely not ideal" (C8).*

Another participant commented on one of the significant aspects of brick-and-mortar stores:

> *"I will speak to the makers or store assistants or retailers out there and pick their brains about it, then read some information. I'm quite dyslexic, so I avoid reading at all costs, so to speak" (C9).*

Table 5.8 Three retail channels' benefit and pain point codes

	E-commerce Channel	MR Brick-and-Mortar Channel	Brick-and-Mortar Channel
Benefit	• time-saving • convenience • price and promotion • elaborate price information • available stock • less time pressure	• detailed price information • assistants' knowledge • recommendations • social avoidance • work independently • less time pressure • increased engagement • sense of immersion • increased satisfaction • accelerated decision-making • strength of ideas communication • uniqueness • creativity and attractiveness • preview outcomes • larger product information display interfaces • knowledge acquisition • efficient customisation • virtual fitting • direct fulfilment of needs • design freedom • sustainable customisation display methods	• assistants' knowledge • building a relationship • clear communication • tactile experience • try on and trial products • recommendations
Pain point	• lack of haptics • waiting for assistant service • perceived product size • lack of experience • picture embellishment	• learn to use duration • comfort • environment accessibility • system accessibility • cost • slower decision-making • queue for HMDs • privacy • product fidelity	• product information display size • lack of fitting images • lack of efficiency • unwilling to use a fitting room • crowded • fitting room waiting • limited options • no stock • product comparison difficulty • inconvenience of carrying purchases • insufficient information • employee pressure • efficient communication • sustainability of supplies for customised effect displays

2) Requirements of MRPC Mass Adoption for Brick-and-Mortar Retail

The analysis is based on four fields of stakeholder insights, and four themes with 574 concept codes produced. It includes the retail interior environment (see Section 2.4), system development (see Section 2.3), marketability (see Section 2.5.1), and management strategy (see Section 2.5.2). These themes use a hybrid thematic approach with inductive and deductive coding (Fereday and Muir-Cochrane, 2006). They are mainly data-driven, inductive studies based on textual data that extend the findings of existing studies and align with some existing theories (see Section 2.5.2).

Retail Interior Environment

The shop interior environment is crucial for the accessibility of MR and attractiveness in brick-and-mortar shops (see also Section 2.4.3). XR experts, interior designers and UI designers mainly described how the environment affects the usability of MR during use. Consumers interpreted how the environment affects the sensory nature and attractiveness of their experience. Retailers, on the other hand, mainly paid attention to the design of interior environments and the factors influencing sales.

By combining the stakeholders' findings, 24 interior design factors are identified, which include traditional store design and MR-related environment concerns. Lighting emerges as the most critical factor, accounting for 16% of references to interior environment factors, followed by shop layout (9%) and product display (9%), space dimensions (8%), safety environment (7%) and environment acoustics (6%). These are followed by a sense of attractiveness (5%), surrounding distractions (5%), environment quality (5%), traffic flow design (4%), privacy (3%), décor style (3%), interior colour tone (3%) and separate isolated space (3%). Shop hygiene, temperature, security, and window display each account for 2%. And, visual order, matching product and interior, environment comfort, functional partition, signage, and weather conditions each account for 1%. Experts, retailers and consumers explained lighting's impact from perspectives of technical usability, product display, and colour temperature on perception:

> *"Especially with the HoloLens one, we had the problem that sometimes there's too much light in the room. And especially if you're looking at some very bright things, the display is not good enough [...] and another problem*

> *is if there's not enough light, then for AR things the tracking will not work very well" (E4).*
>
> *"Lighting is very important because you have got to make everything sparkle and shine. So we get through lots of light bulbs" (R6).*
>
> *"I think it's also important to experience the lighting in the shop. Some shops feel very cold and uncomfortable, so it's better to choose warmer lighting" (C2).*

For shop layouts, retailers considered more difficult-to-access layouts to ensure merchandise security (R5). Interior designers emphasised layouts for leading traffic flow and spatial navigation (D2), and that product display layout could affect the visual order and UI design layout (D2/R4/5/R6/R7). XR specialists considered the importance of clear layouts for AR to recognise locations and provide correct information (E4). Spatial dimensions include shop dimensions and the space available for movement when employing MR (D2/E1/E4). The safety environment involves setting space boundaries to resolve conflicts in the physical environment (E7). Surrounding environment distractions come from the behaviour of other shoppers, gaze from space users, communication noise, music, HMD speaker noise, and lighting distractions (E1/E2/E4).

System Development

System development refers to the design, development, and deployment of the MRPC, which evaluates existing functionality, improvements, and future developments. Subcategories codings include considerations of function design (mentioned by 49.3%), UI design (33.2%), product design (4.3%), privacy policy (2.8%), user experience (9.5%), and back-end development (1%).

Under *function design*, virtual fitting (18.3%) is the most frequently mentioned, followed by preview design results (6.7%), learn-to-make tutorials (6.7%), and co-design (5.8%). Also mentioned are comparison products, video instructions for use, and learning to make videos, at 2.9% each. Adaptive fitting, handcraft skills, measuring the size, product resizing, visual aids, and shareability follow at 1.9% each. Lastly, real-time pricing, multi-angle presentation, sound assistance, UI comfort, favourite function,

audio reading, interactive gestures, packaging customisation, self-image avatar, and UI teleportation each have a 1% mention.

The *UI design* includes extensive product information (12.9%) and a simplistic UI style (10%). This is followed by ease of use, usability, usefulness, UI navigation, mental effort, multi-screen, scene effects, animation elements, and gamification with shopping tasks, which account for 5.7% each. *Product design* includes product fidelity (44.4%), jewellery (product) designers' delivery methods (model-making) should be accessible (33.3%), and 3D product visualisations (22.2%). *Privacy policy* includes considering general data protection policy and the impact of mall policy (for shops in a mall), each accounting for 33.3%; methods of storing information and online purchase terms and conditions policy, each accounting for 16.7%. *User experience design* includes non-verbal service experience (46.7%), sustainable product customisation experience (26.7%), event-based theme experience (13.3%), and customer psychology experience (1.3%).

MRPC provides a manual virtual fitting function. However, experts and consumers raise the possibility of adaptive fitting as an improvement. An XR expert suggested:

> *"The advantage is that you can overlay virtual items. In the real world, unless I can put it on my hand and actually see it on my finger, then I think it's kind of not really using the full potential of XR. So, then, if we are going to do that kind of machine vision, where I can track my finger and put a ring on it in that kind of detail. I think that's going to take a few years to realise" (E5).*

Retailers consider the ability to preview design results to be cost-reducing. Retailer R4 stated:

> *"Clients often come up with really wild and imaginative ideas, like wanting something like a rainbow black. But with this (MRPC), you've already set up a pretty comprehensive framework for them to play around with. So they're like, oh, this is actually my own jewellery that I've made as well. Because I've taken this kind of order before to give people to do custom, they feel that they have a lot of ideas, and they'd throw in all sorts of ideas and then you get this version, he felt oh it's good, and then maybe after a few days, he felt that, hey, there is a new idea and asks for changes. From a designer's perspective, time is also money, so constantly making revisions isn't ideal" (R4).*

Derived from the above suggestions, the design features identified in prototyping remain unchanged, and some new features are added. New features include comparing customised products, where the MRPC sets up two comparable products to minimise customer decision-making difficulties with multiple options. UI comfort was designed according to ergonomic studies. Other functions include real-time pricing, sound aids, learn-to-make tutorials, visual aids, and brand-related special effects, which are also added to the system. Since this MRPC demo is not brand-based, I chose some open-access resource animation as a brand-related effects display (see Section 5.6.1). Some mentioned functions, namely co-design (multi-user mode), adaptive fitting, audio reading, product resizing, shareability, gamification with shopping tasks, and self-image avatars, were unable to be developed in this research due to technical limitations.

Moreover, comments on the MRPC's ease of use, usability, usefulness, and mental effort will be tested by user feedback for its evaluation (see Section 7.5.2). The concern that product designers' delivery methods (model-making) should be accessible will also be discussed with product designers and manufacturers (see Section 8.3).

Marketability

Marketability refers to the possibility of and factors influencing the MRPC's mass adoption in the retail market. Considerations for the marketability of MR include perceptions of MRPC (15.3%), hardware issues (14.5%), demand motivations (14.2%), investment (13.8%), affective motivation (10.9%), potential benefits (9.8%), social factors (9.5%), public cognition (9.1%), and consumer behavioural impacts (2.9%).

Perceptions of MRPC include factors such as mental effort, eye fatigue, technology acceptance, perceived complexity, perceived quality of MR services and perceived irreplaceability, and shape marketability. *Hardware issues* are problematic and mentioned in many aspects, including accuracy, battery charge speed, battery life, frame rate, HMD appearance, field of view, glitches, price, recycling sustainability, resolution, size, wear comfort, weight, intraocular distance, motion sickness, processor speed, resolution, technology accessibility, and technology usability. *Investment* includes consideration of hardware needs and software investments by retailers, long-term costs, profits, availability of HMDs, demand-driven, availability of basic apps,

HMD depletion and preservation, HMDs quantity, city size and demographics, HMD production ability, product category and effort, profit margin, and product categories being sustainable.

Potential benefits are stakeholders' speculative opinions on its future possibilities, such as customer retention, identifying problems before manufacturing, reducing logistics, saving time on pickup, saving space, and unlimited locations. *Social factors* that influence MR's marketability include consumer brand consciousness, loyalty, brand image, service quality, trust, HMD accessibility in shops, and the impact of market self-regulation. *Public cognition* (consumers and retailers) includes stakeholders' cognition for technology penetration, usage value, trust in the brand and the technology, social acceptability, perceived experience value, familiarity, effort to use, camera privacy, and sustainability of energy consumption. Consumer *demand* and *affective motivations* are shown in Table 5.8, and *consumer behaviour impact* includes different desires for the location of use (at home and in-store), in-store dwell time, and return to use.

Management Strategy

Management strategies are divided into before launch (52%) and during usage (48%). Before launch, strategies include shifts in retail business mode and reduced storage space and expenses. Training of assistants shifted from traditional Photoshop skills to operating MR, ensuring sustainable trade manufacturing to enable timely merchandise supplies. Pop-up events could be used as a speedless marketing method. To coincide with geo-policies and collect shopper product preferences through MRPC, a designer suggested:

> *"This is what the people want, and so they can, with concern, maybe get the idea off of the customer and then take it to the manager or something, and then they can discuss, is this what we should be selling instead? [...] It's going to be better as well because you can actually see what people find interesting, and so you can use that as a way to draw customers in instead of assuming what people like" (D1).*

During usage management, the strategy includes keeping HMDs hygienic, providing incentives for use, on-the-spot production, onboarding complexity, system maintenance and frequency, updating app functions and databases, and retailer share screen devices.

On the other hand, system maintenance is affected by the application framework of the back-end build during system development.

3) Prospective Retail Store and Consumer Genres on MRPC Adoption

Analysis of retailers identified the following **retail store genres** with prospects of investment and adoption on MR.

1) ***Retail associated with high-end brands or high-profit products.*** The investment cost of HMDs is a major challenge for the mass retailing of MR. 73% of the participants (n=26) emphasised that the price of the equipment affects their investment and purchase. Consumers highlighted this approach as a way to consider purchasing a high-end, long-lasting product with an accompanying good environment. 57.1% of retailers underlined that this approach is currently more relevant for product types that are highly profitable due to investment costs and returns. In addition, there is a need for more available application resources in the market. *"If the profit margin is not high enough and the population is not large enough, it's not going to support our entire team's operation"* (R7); *"If I'm a small-time investor, I don't have the resources to get somebody to build an app or build something for me, so there has to be some sort of software needs to exist"* (E2).
2) ***The retail settings of product category, price range and brand image are relevant to MR image.*** 28.6% of retailers stated it depends on the product category, and 57.1% believed it should align with the brand image and price range. R7 describes the specificity of the high-end jewellery stones inspection instrument. Therefore, the price range of the jewellery decides retailers' usage of MR. MR suits fine jewellery but not ultra-luxury jewellery. *"For gemstones, things like clarity, fire and cut really need to be examined using specialised tools, like a professional loupe. These details are mostly relevant to high-end or luxury jewellery, which is why the price tends to be quite expensive. Brands that operate with a lower price point, say under £2,000 or £3,000, can't offer that level of service".*
3) ***Retailer demographics relate to an investment in and acceptance of mixed reality technology.*** Retailer age impacts on MRPC acceptance, with 57.1% of retailers in the 29-35 years age range (R1/2/4/7) showing higher acceptance of the technology and 42.9% of retailers aged above 46 years showing lower acceptance (R3/5/6).
4) ***Retail shops situated in geographic areas with high technology penetration and high urbanisation.*** Retailers interpret the urban scale to correlate with customer consumption patterns that impact on investment. Seven participants commented on technology penetration and urbanisation in the acceptance of technology (R2/R3/R7/E2/E6/E7/D2). Consumer C5 (50-year-old, lives in

Beijing) also commented on the correlation between technology penetration and acceptance. *"I don't play games much, and I'm not particularly great with tech stuff either. But after seeing how you handled it, I found it pretty easy to use. I think it's because of your product design and development of this idea, straightforward, not complicated. Even kids and elderly wouldn't find it hard. Nowadays, you see lots of older people who are pretty good with smartphones, I'm kind of in the middle. [...] I think it's mostly just the popularity of electronic devices. That kind of stuff is everywhere".*

5) ***Product design and environmental experience-oriented retailing.*** The inductive results show that 57.1% of retailers prioritise perceived product design and environmental design over service quality as being more acceptable to MR (R1/R2/R4/R7). On the other hand, 42.9% of those who prioritise service quality over product and/or environmental design have a negative attitude towards MR (R3/R5/R6).
6) ***Business modes relate to the following three types (a/b/c).*** Four modes were identified from seven retailers: a) A production model where the retailer cooperates with factories and operates in a front-end and back-end manner. b) Retailers who possess their own design department and manufacturing line. c) Independent artisanal designers who run businesses from design and production to sale. d) Finished merchandise sourced directly from the supplier. Among the retail modes applicable to MRPC are the first three, capable of manufacturing customised products. Participant R1 (Mode C) describes the reason that matches the business: *"When a client describes a colour very imaginatively [...] It might come across as a different feeling in the person, so when you're doing semi-customisation, and both the individual and the merchant are taking a risk [...] The time spent on this process is a time cost lost. So if there is a solution to make the guest's expression more concrete, or for the designer to understand the guest's situation, to be able to more clearly express what kind of alteration or customisation the designer can bring to the client, I think it's a better bridge of communication".*
7) ***Retail brands that offer product customisation as a service can use MRPC as a futuristic sustainable solution.*** Providing brands with a sustainable customisation display approach through using MRPC as a futurism method to reduce plastic wastage. Participant D1 describes a customisation experience in a chain shop: *"This is a laser thing on a plastic card, which is like where we can do this laser thing. So they are using plastic for that, but they are not doing it on the metal ring, so those plans when that sheet will get filled, they will just throw it away and then they will take another sheet to display and show it to you. In that way, they will use a lot of plastic to showcase to customers how the alphabet is going to look on your ring. But if I get another option of just deciding on an interface, I will get a demo of the product and how it is really going to look. I think that's a more sustainable way for the future, also that does move towards a futuristic and sustainable solution to anything".*

Consumer genres for the prospective use of MR product customisation were identified as follows:

1) ***Consumers who seek the uniqueness of products.*** Aligning with prior studies (Michel et al., 2009), 30% of consumers emphasise the importance of product uniqueness, and repeat customisation behaviours emerge in purchases based on such needs. *"Because I like customising most of my things […] If I design it for myself, it would be my unique design. So I like to be that unique person when you buy a product"* (C6).
2) ***Experiential consumption and novelty-driven consumers.*** Similar to the previous study, novelty drives consumers to mass adoption (Schreier, 2006). 50% of consumers emphasised experiences as an important reason to go in-store or to reduce waiting time. *"100% It has to be experience-led because everything is cheaper online, so it has to be. They have to get an experience out of it; otherwise, it's just not worth doing [...] Something felt social, something exciting, and something different"* (C9).
3) ***Acquisition of knowledge and information-based consumers.*** Consumers perceive the MRPC approach as a channel for acquiring knowledge in practice, which aligns with previous study findings (Jiang et al., 2015). *"For example, that ring you just had, I think the top seems to be too complicated, I want it to be minimalist, and then what kind of that base is it going to be [...] so here in the process it expands knowledge again and you know how to make this thing"* (C5).
4) ***Consumer motivation and demand to commit to memorable purchases.*** Consumers shop for products with symbolic meaning over public festivals, or relationship-driven customers shop for products with added significance (Vaibhav and Roshan, 2020). One participant mentioned, *"I think a couple can just decide their things together. It's based on the relationship"* (D1).
5) ***Fashionistas with a willingness to create and participate in design.*** This aligns with the concepts of co-creation and being participatory (Kohler et al., 2011). Consumers are endowed with a strong willingness to participate and engage in creative thinking, with confidence in their design ability or high satisfaction with the products they design in participation. A participant suggested that *"Even if I want something, even if it may be a very ugly design in the eyes of others or professionals, as long as I like it, it feels unique and special to me, and I still like it"* (C1); *"I like to get my hands dirty, I like to engage, I like to design, and I have some confidence in my aesthetics"* (C5).
6) ***Services optimisation-oriented consumers.*** Consumers prioritised the MRPC's ability to simplify the in-store purchase process regarding time-saving, product satisfaction, purchase efficiency, and communication. In addition, consumers indicated that the assistant can offer refined quality and customised service by manipulating on their behalf. *"So because he was using*

Photoshop to do that, he was going to use a laser technique to embed on that bracelet, but the character which was designed, he was just asking me, do you need these, and after like 10, 20 times of changing that character, I felt that, okay, do whatever you want [...] (With MRPC) I can choose the character or give an example of what I need, and I think that will be a better experience than in-store" (D1).

7) ***Social avoidance and work independence consumers.*** Consumers perceive that the MRPC enables them to escape from socialisation pressures, and users who are inclined to complete purchases independently show a high level of interest. *"I usually stroll in this kind of shopping mall, and I don't want a salesperson to follow me to introduce things. I don't like these kinds of other people to greet you or whatever. If I can have this technology and be able to explore and find the answer myself, I am still looking forward to it"* (C3).

5.5.3 Summary of Studies 2 and 3

This research uses fine jewellery as a market pilot for commercial systems. Developers may change the product categories, but these recommendations can still be beneficial regarding functionality, design considerations, and management strategies. In addition, although Study 3 identified 24 store interior design factors, these factors have yet to be verified in real stores. It includes comprehensive store design considerations, but key factors that impact on the MR experience in a brick-and-mortar store are uncertain. Consequently, it leads to a fieldwork study (see Chapter 6).

After the app iteration from the interview results, with testing on the HMD, a few amendments were made according to the designer's design skills. These include adding a hand menu, adjusting the interface angle, adjusting model assets, adding an interface reset, redeploying the UI position, and adding visual aids instructing on replacement of a diamond's position. The iteration process includes three rounds of 2D paper prototyping and two rounds of 3D prototyping in the HMD (see Appendix B). The holistic design specifications are elaborated below according to apparatus, parameter settings, functionality, and ergonomic layout (see also Section 2.3.2 Online configurator, Section 5.5.1 Prototype testing, and Section 5.5.2 System development).

5.6 Outputs: Design Specification of the Mixed Reality Product Configurator

5.6.1 Apparatus

To implement the Mixed Reality Product Configurator (MRPC), the software used was Unity 2019.4.1.8f1, Visual Studio 2019 Community Edition, and Mixed Reality Toolkit 2.6.1 (MRTK), and the hardware used was Microsoft HoloLens 2. Some open resource models (rings, cartoon special effects, diamonds) were retrieved from the Unity Asset Store. HoloLens 2 is a standalone computer that does not need to be connected to an external computer. For the retail context, this interaction method is accessible to customers and supports natural interactions in retail. Other alternative MR HMDs are introduced in Section 2.2.5 (Table 2.2). Figure 5.9 shows the tracking relationship between the app development software's camera and the hardware's camera.

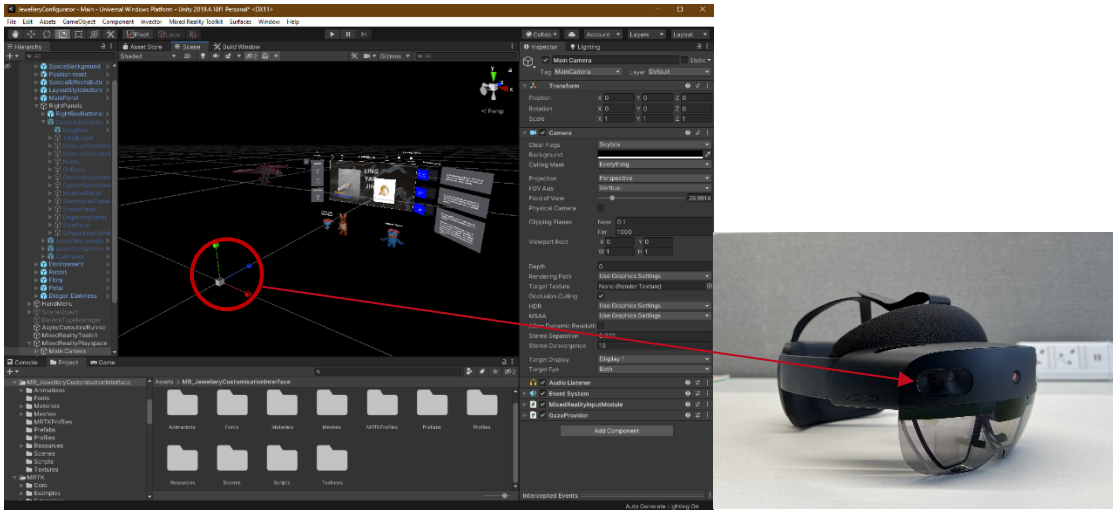


Figure 5.9 Camera positions in Unity and HoloLens 2

5.6.2 Natural Interaction Behaviour

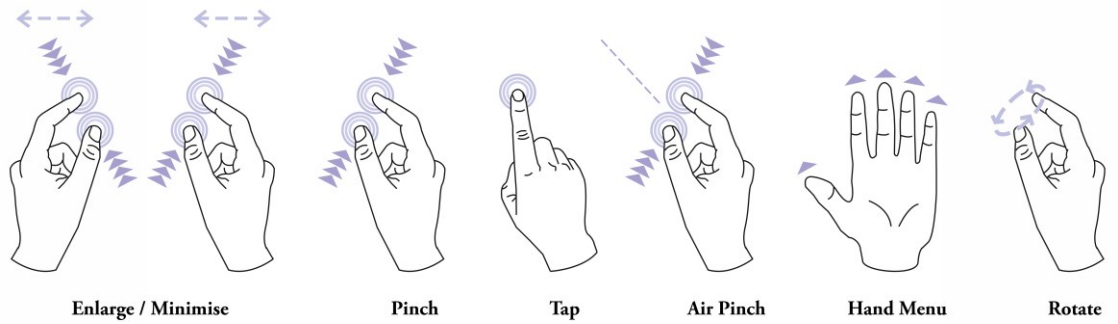


Figure 5.10 Natural interactive hand gestures in MRPC. Adapted from MRTK

Figure 5.1 illustrates MRPC gesture implementation (Microsoft Learn, 2021).[23]

- **Enlarge and Minimise.** Customers need to pinch the virtual product with both hands to scale the product inwards or outwards. The virtual product is displayed in 3D, and the initial effect is a magnified size of the product to facilitate users' locating it. Therefore, customers try on the product to scale it down to the appropriate size and configure it to enlarge it to view product details.
- **Pinch.** Proximity pinches the virtual content to select the object and then drags the object to change its position.
- **Tap.** Users can tap buttons to trigger functions at a close distance. For example, tap the shopping cart widget to open a new window. Tap on the save icon to store the current configuration parameters.
- **Air pinch.** When a user points to a distant object, a ray appears, and at a certain distance, the user can pinch to select an object and drag it. When the user moves position or height (standing, sitting) or intends to compare the effect of a virtual product from a distance, the Air pinch can grab and move the virtual object.
- **Hand menu.** Users unfold a single palm (left or right) to the sightline (within visible range of the HMD camera), and then a small hand menu panel emerges. It contains two buttons: position reset and come over. Keeping the hand unfolded, the user taps one of the buttons with the other hand to trigger a response.

[23] Microsoft Learn. https://learn.microsoft.com/en-us/hololens/hololens2-basic-usage (Accessed in March 2025)

- **Rotate.** The user can rotate the virtual object by twisting the wrist after selecting a virtual object for a 360° perspective of product details.

5.6.3 Product Configuration Parameters

The parametric basis of configurators was derived from Section 2.3.2 and was extended based on the results of Studies 2 and 3. Chapter 4 identifies some key design features, which are jewellery, customisation, scene effects, sound effects and interactive sessions. These consumer requirements drive the MRPC function design. The MRPC involved customisation, assembly and learning platforms. The customisation and assembly each include six same design functions for a ring product: including A) ring mount materials, B) gemstone types (shape and colour), C) engraving, D) ring size, E) shape (ring mount textures and adding extra stones), and F) gift packaging (Table 5.9). Figure 5.11 illustrates the engraving platform in a mockup retail environment. Consumers are allowed to view the final design effect instantly, which mimics the actual product after customisation.

Table 5.9 MRPC parameter design

ProductType	**Platform**	**Parameters**					
		A	B	C	D	E	F
Rings	Customisation	Materials (n=4)	Gemstones (n=10)	Engraving (n1≤4/n2=2)	Size (n=12)	Shape (n1=4/n2≤2)	Gift packaging (n=4)
Rings	Assembly	Materials (n=4)	Gemstones (n=10)	Engraving (n1≤4/n2=2)	Size (n=12)	Shape (n=4)	Gift packaging (n=4)

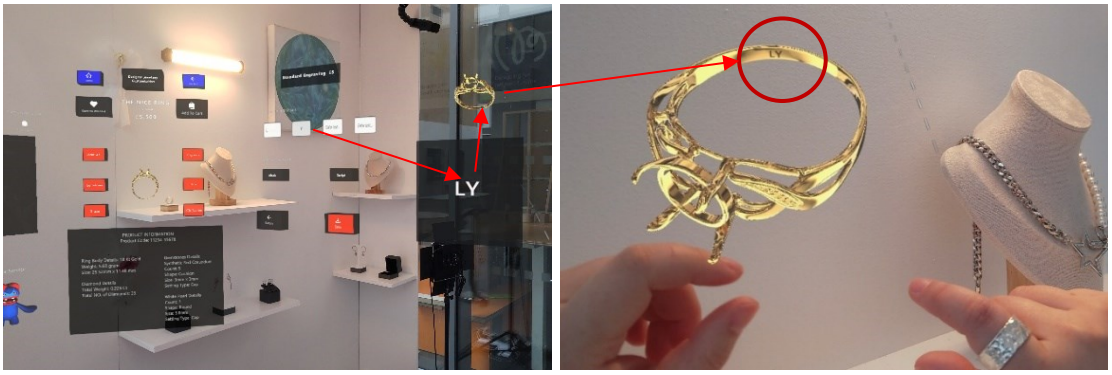


Figure 5.11 Screen capture of the MR Product Configurator of the engraving platform (left). Engraving effects on the ring (right)

5.6.4 Function Design and Workflow

Fundamental requirements were extracted from online configurator platforms and refined to build new features based on the findings from studies 1, 2, and 3 (see Appendix B). Figure 5.12 demonstrates a video of the MRPC app, Table 5.10 elaborates on MRPC design features, and Figure 5.13 illustrates partial effects.

Figure 5.12 QR code of MRPC app demonstration

Table 5.10 Function design, characteristics and requirements

Attribute	Design Function	Description	Characteristic	Demand Improvement
Functional	Material	Change the manufacturing material of the ring mount.	Optional with e.g. silver, rose gold. Pinch a material that overlaps the ring to replace it.	a) Customers can instantly try on the customised product on their hand, whereas online retail cannot. This helps customers find products that suit their skin tone. b) Display a single product physically, which reduces storage space. c) Shareability d) Ability to compare both physical and virtual products.
	Gemstone	Change the stone in the ring.	Customisation: users can change stones in designated places and quantities. Assembly: users can add more stones and move stone positions on the plain ring mount. The spacing between stones has been preset.	
	Engraving	Capable of engraving four letters and two font settings.	A panel on the right shows enlarged letters/symbols for enhanced readability. One product shows the input letters, and users can view the personalised effect instantly.	
	Size	Select the size of the ring mount.	Customers with known sizes can choose directly, and for unknown sizes, they can ask retail assistants for advice.	
	Shape	Change the texture of the ring. Add extra diamonds.	Texture such as matte or embossed. Customers can add extra diamonds in preset places.	
	Gift packaging	Select packaging for products.	Enable to match products and packaging at the same time.	Strengthen consumer decision-making and judgement capabilities by providing information.
	Comparison (dual products)	Two virtual product displays are shown together.	It has an adjustable virtual product and an additional saved product effect. Users can compare the two designs.	

Attribute	Design Function	Description	Characteristic	Demand Improvement
	Shopping cart	With product effect, parameter content and price.	The shopping cart provides an informative interface that gives the user an overview before making final decisions.	
	Position reset button	Reset all changes and movement of the interfaces.	Position reset restores initial interfaces when changing to the next customer or when interfaces are messy.	Increase the mobility and flexibility of 3D interfaces.
	Come over button	Summon the app to come in front, in sight.	When the customer moves position or height, the button allows interfaces to teleport to the default horizontal sightline.	
	Pin button	Interfaces follow head movement.	Allow the entire app to follow the user's movement wherever the user goes.	
	Interface mobility	Interfaces can move position.	Allow users to manually move interfaces to a new position.	
	Instruction text	Instruction notes are shown next to the feature panel.	Instruction notes are shown to guide users to the next step.	Aid UI usability and navigation in usage.
	Sound aids	System beep	When the user successfully selects and drags a product, the system beeps to inform the user that the action was successful.	
	Video	Showcase information on brand news and the jewellery production process.	On the Learn to Make platform, customers can watch the manufacturing processes and follow crafts in workshops.	Provide additional information to suit users' interests.
Experiential	Visual aid	Gamification pointer to indicate replacement.	When users pinch a parameter object to approach a replacement object, a gamification sign (a sword) appears, it points the location of the replacement when detected within the recognisable boundary.	Enhance gamification, playfulness, and immersion values that cannot be experienced in a physical environment or online.
	Picture cursor hovers	Two images are shown at the same cursor position.	When one finger points to a flat image, the current image shows a different image. When the finger is lifted, the original image is resumed to display multiple information.	
	Special effect	3D animated characters and dynamic scenes.	Special effects panels and 3D animated characters will display dynamic atmospheric scenes when tapped, such as floating snow.	

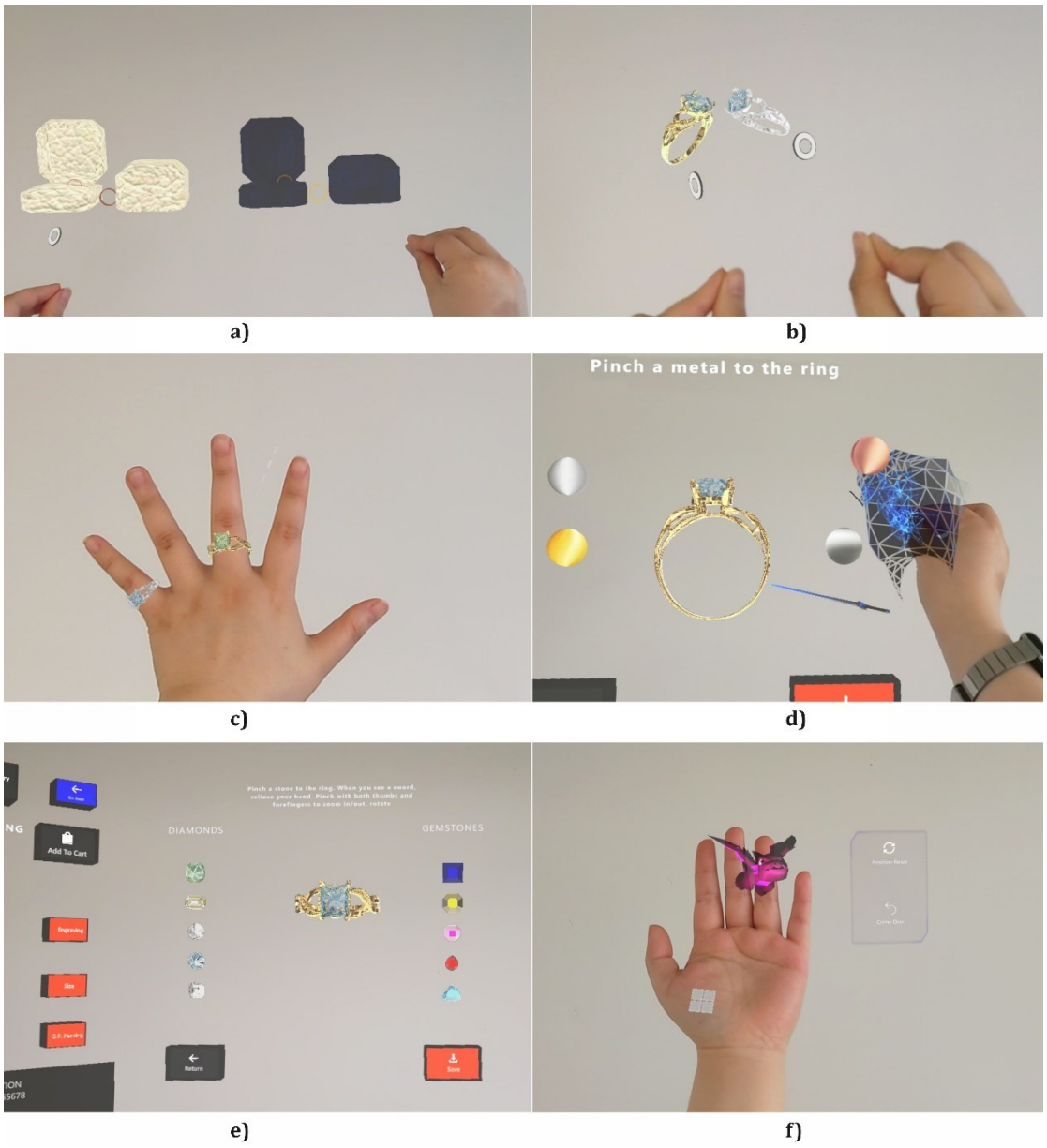


Figure 5.13 a) Compare packaging; b) Compare customisation products; c) Virtual fitting; d) Changing material with visual aid; e) Stone parameter platform; f) Hand menu

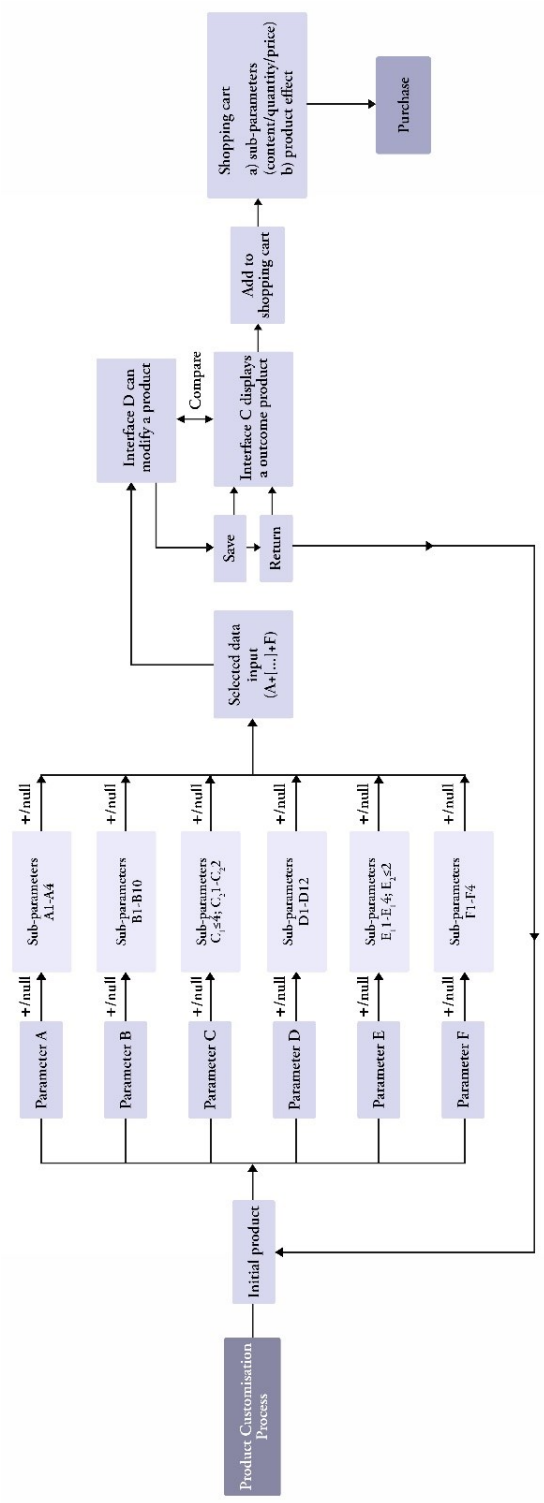


Figure 5.14 MRPC configuration workflow

Figure 5.14 illustrates the customisation workflow. The initial product is a branded design product, and users can select (+) to change the product configuration or retain the initial configuration (null). All altered configuration parameters are stored and

displayed in interface C, while interface D can continue for configuration. Hence, users can compare the parameterisation of two virtual products in parallel. Extensive options tend to delay the consumer's decision-making, and therefore the design sets up two product comparisons.

5.6.5 Layout and Distance

The UIs contain four panels (one aid and three main panels) demonstrating the above features. The ergonomic UI design is as follows (Figure 5.15), and Figure 5.16 shows the rendering from a front view. Four ergonomic suggestions are listed below.

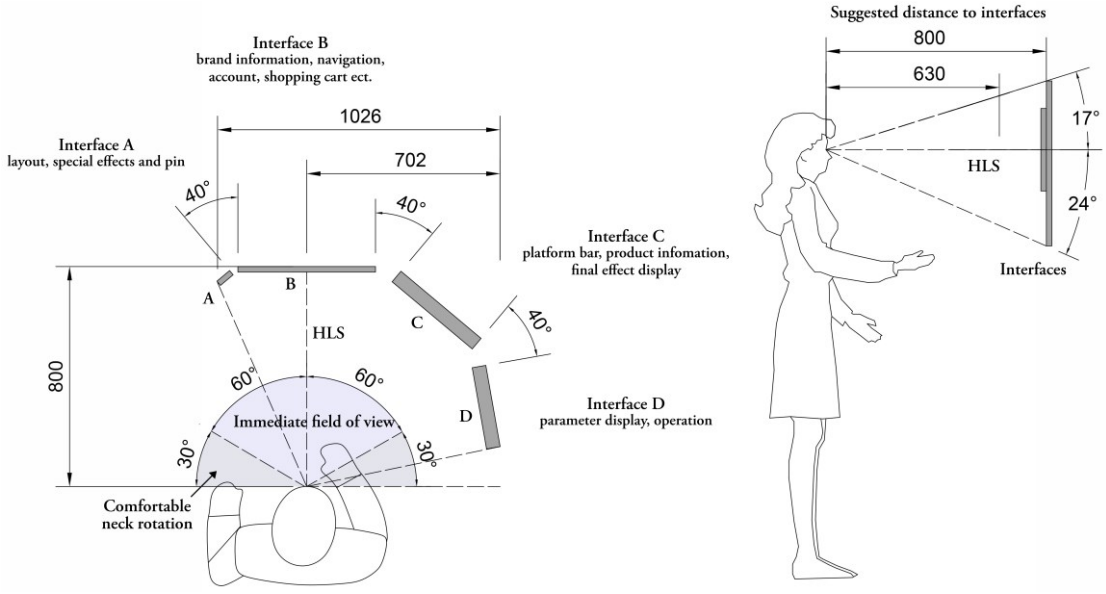


Figure 5.15 MRPC ergonomic dimensions from top and side perspectives

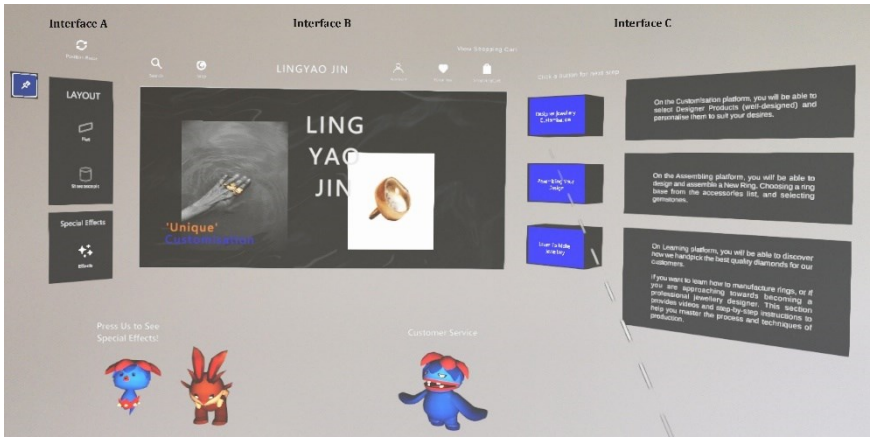


Figure 5.16 MRPC Interface positions in HMDs in a frontal perspective. Screen capture

- ***A distance of 630–800 mm from the user interface to the horizontal line of sight.*** To fulfil the needs of the majority of users, the measurement is based on the average height of an adult male (Europe), which is 183 cm, with an arm span of 1,600 mm, single-side of 800mm (Le Corbusier, 2000). Considering the 4:3 optical field of view (FOV) of HoloLens 2, if the distance is closer than 800mm, multiple interfaces will not be fully displayed in the FOV, and scaled-down interfaces may lead to low readability. Furthermore, viewing a screen below 500mm is prone to near-vision fatigue (Rempel et al., 2007). The ergonomic eye-to-screen distance is 500–990mm, whereas the average is between 630 mm and 740 mm (Jaschinski, 2002; Jaschinski-Kruza, 1991). Hence, a comfortable range for use modes that accommodates tangible and remote rays is 630–800mm. In order to gain a wider FOV, the multi-interface design for HoloLens 2 is recommended to be 800mm from eye to interface. Figure 5.9 shows the application camera set to ensure that the distance remains constant at each launch.
- ***The overall length of the interfaces is less than 1,600mm and less than 800mm unilaterally, with eyes as the centre point.*** Based on the average arm span (using 183cm height), this is compatible with users being able to reach the interface with one outstretched arm (Neufert, 1970). The MRPC has an overall length of 1,026mm, which is an adaptable dimension. According to the need to distribute three primary interfaces, this dimension remains a moderate (no too narrow or wide) value. Although larger display users perform better at completing space tasks (Tan et al., 2003), the longer the length, the more space it needs to occupy. Therefore, the interface length can be reasonably trimmed down if space is limited.
- ***The interface position of height should be at the horizontal line of sight of users.*** The interface position of width is within 90° of the user's horizontal line of sight on each side. Ergonomic studies recommend that the screen be 5°–25° lower than the horizontal line of sight (HLS) when viewing the screen with the naked eye, considering eye comfort, neck comfort, and user preference (Allie et al., 2005). The optimum vertical line of sight angles is +25° to -30° (Kress, 2020). As a physiological aspect of a force on the cervical spine from flexion, neck load is 10–12 lbs to HLS (0°), and lower neck flexion to 15° is 27 lbs, and the greater the head angle, the more is cervical spine pressure (Tanaka et al., 2020). Therefore, considering the additional weight of the HMD that the user's cervical spine needs to sustain, and considering the additional weight of the HMD that the user's cervical spine needs to support, the vertical field of view (FOV) of interfaces is set to HLS (0°), and the interface length within angles of +25° to -30°. Limited literature discusses the angle setting in multiple screens in a horizontal FOV. Other studies suggest that a human's immediate field of view is within 60° on each side of the HLS, and the natural neck rotation angle is within 90° (Denker, 2016). In light of these theories, a pilot test of interface

angles of 35°, 40° and 45°, and setting a 40° angle as the horizontal FOV, presents a natural encircling shape and allows users to turn their heads to see the interfaces comfortably.

- ***Reserve one side space for retail assistants, and do not let consumers get lost in virtual content***. In a standard retail environment, consumers may require in-store retail assistant service during use. The assistant could stand in the reserved position to minimise interference with the user during service. Leave spaces for consumers to notice the real-world situation.

5.7 Discussion

This chapter addresses the challenges of integrating MR into retail combined with CEM stakeholder perspectives. It emphasises the importance of ongoing communication among designers, retailers and software developers to create collaborative, mutually beneficial solutions. By highlighting the key obstacles and design requirements to MR adoption in retail, it explores the issues that stakeholders need to collectively fulfil the potential of MR for mass customisation in the future. The study presents the MRPC design, which forms the basis for the possibility of MR's mass customisation application development in the marketplace and answers RQ2.

This study emphasises the potential advantages of using high-value products as a market pilot for MR commercial systems. It uses high-value categories, jewellery retail, as an example, to provide MRPC commercial application design recommendations. However, several technical issues based on consumer requirements remain unresolved and undeveloped. For instance, co-design (allowing multiple users to interact across different devices), integration of payment methods, text-to-audio capabilities, product reviews, finger size measurement, and adaptive product fitting. I suggest that researchers and developers develop these functions further. Consumers also highlighted the importance of consistent interaction gestures across different MR shopping apps in the retail market. For shareable fitting photo requirements, positional discrepancies exist between the fitting effects seen by the human eye and those captured by device cameras. This means that a virtual fitting screen capture image cannot display the correct product position on one's body. Therefore, it is suggested that *software engineers* develop these functions and address these barriers when considering

developing MR commercial systems. ***Retailers*** and ***product managers*** can consider adding some of the recommended apps' functions in regard to their brand demands and business scale (see Section 5.5.2, System Development).

In addition, the findings identify issues that should be addressed when designing and developing. For example, system ease of use needs to be investigated before launch, along with learning time to use, including speed of onboarding for customers and retail assistants. The MRPC has iterated its UI design, prioritising ergonomic comfort and ensuring a less negative user experience. UI design also considers the speed of decision-making, setting comparable product numbers to minimise customer decision-making difficulties. It is also suggested that product designers deliver high-quality modelling product fidelity and follow with developers and designers in setting accurate light reflection parameters to align with real-world conditions when integrating models into Unity. ***UI, UX designers, product designers*** and ***product modelling technicians*** should collaborate when developing an MR shopping system to ensure interaction content, MR product delivery effects and MR technology usability are aligned with customers' needs (see Section 5.5.2, System Development).

It is also recommended that ***UI designers*** communicate with ***interior designers***, considering the physical environment's influence on customer experiences, such as pedestrian traffic flow, spatial dimensions, and colour schemes (see Section 5.5.2, Retail Interior Environment). This means improving store environmental accessibility, including specific designs for the space where the MR system will be used to maximise customers' perceived MR access to use (such as usage floor area, bystander privacy, and safety boundary) in complex business environments. MR UI designs may overlap with shop walls if the UI is too far apart. If the UI is overly long or wide, and given the limited field of view of HMDs, moving shoppers around will require more space and might clash with the movement of other shoppers. Therefore, UI designers may consider employing adaptive interfaces to use the commercial environment or designing UI size and interaction movement distances according to the stores' interior layout. Additionally, virtual content should be carefully curated to avoid information overload caused by excessive use of colours or overly complex, content-rich designs (Tatzgern et al., 2016). To enhance usability and aesthetics, UI designers should thoroughly

evaluate the interface's colour scheme and ensure compatibility between virtual product colours and the real environment.

Finally, ***companies*** and ***product managers*** should comprehensively read through and evaluate the factors according to their business scale, target consumer types, ROI, and risks in order to plan their brand strategies. First, they can assess whether their business is suitable for investing in MR-based purchasing. Subsequently, to understand current technology challenges, customer usage demands and motivations, and other marketability factors (such as policy and ethics) that should be considered (see Section 5.5.2, Marketability). Then, developing management and marketing strategies includes stages of pre-development, during usage, and planning for a long-term operation mode (see Section 5.5.2, Management Strategy). Furthermore, product managers and design teams can develop tailored brand goals based on consumer genres. For consumer genres 1/2/4/5, MR apps can focus on designing entertainment-oriented interactions and experiential engagement. For consumer genres 3/6/7, MR apps can deliver utility-oriented experiences aimed at quick purchases and optimising in-store services (see Section 5.5.2, Retail Store and Consumer Genres).

5.8 Conclusion and Limitations

This study uses jewellery as a pilot retail industry and application development prototype, and the findings can benefit similar fashion retail industries. Some of the findings can be generalised to apply to MR business development, that is, the retail store genres are based on a consideration of the state-of-the-art retail market, economy, and MR technological stage. Investors and those seeking investment can use this recommendation to guide their decisions. Additionally, the study addresses general considerations for store environments, system development, marketability, and management strategies that relate to MR-based business development; however, these scopes and factors require additional sub-studies to investigate how they can be converted into implementation approaches. Notably, some of the recommendations associated with mass customisation limit their general applicability to other retail categories and MR purchasing applications. For instance, the system design suggestions

associated with MC, and the consumer genres 1/4/5 are limited to the scope of the MC retailing.

Another limitation is that retail shops involved are all independent small to medium-sized businesses within the jewellery industry, suggesting that future research could explore a wider range of product types and include large-sized chain-brand retailers for comparison. Moreover, retailers and consumers were introduced to the MRPC concept through pre-recorded videos without an in-person experience with MR. Although this method can involve diverse participants, their perceptions might have been impacted without experience. Future research could benefit from installing MR experiences in brick-and-mortar shops, allowing retailers to observe customers using the MRPC experience for some time in-store and subsequently gain deeper interview opinions.

On the other hand, retailers, XR experts and designers emphasise the importance of the store environment from their perspectives. This suggests a need to integrate the MR store environment experience from a holistic perspective and integrate MR system interaction and physical space. These design factors and challenges have not been validated in a real market. Therefore, the next chapter will conduct market fieldwork to observe real-world MR usage, explore the physical environment and interaction with consumer behaviour and develop solutions to these issues.

5.9 Contribution Summary

This chapter has addressed two research gaps pointed out in Section 2.6 (p. 65):

Research gap 4: Absence of design recommendations and practices for mixed reality parameterised configurators for mass customisations in retail.

Research gap 5: Lack of a participatory rapid prototyping approach to aid rapid iterative testing of early-mid MR commercial systems.

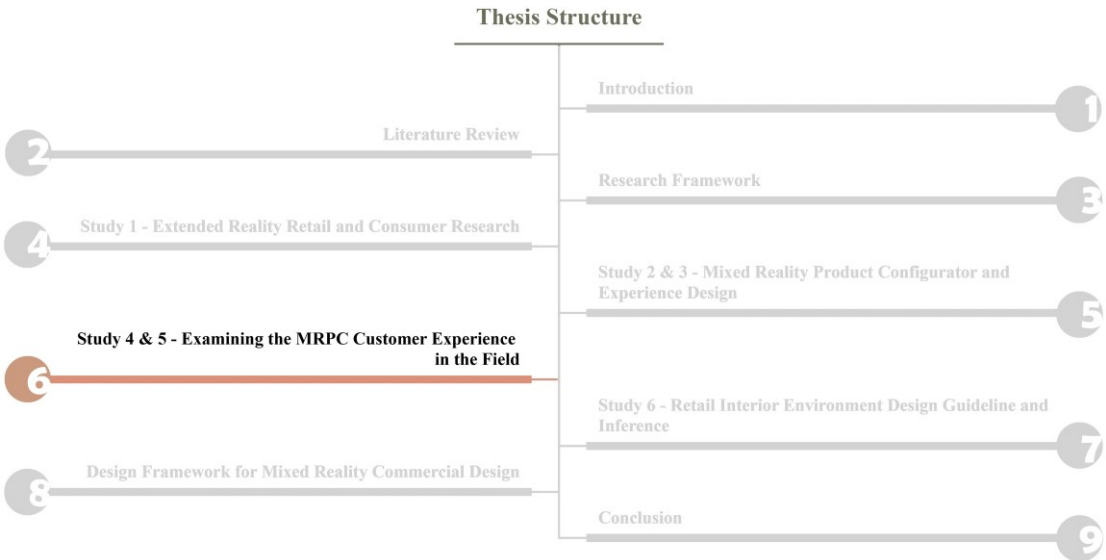
It answers research question 2:

How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments?

Review of the contributions made in this chapter:

- Provided an early participatory MR prototyping toolkit (MRPaperPro) for UI, UX, and interior designers to conduct rapid, affordable prototypes in retail commercial design development.
- Defined the significance of adopting MRPC in brick-and-mortar retailing, compared with online or traditional in-store channels.
- Made recommendations for system development, store environment design, marketability, and management strategy, thus helping stakeholders understand potential challenges in implementation.
- Defined prospective retail store genres and consumer genres suitable for adopting MRPC to guide retailers and managers.
- Design and develop a Mixed Reality Product Configurator for brick-and-mortar stores as a prototyping system documentation to aid designers and developers.
- This outcome provides the tools (ergonomic interfaces) for the next stage of field trials, thus enabling the evaluation of the integration between interfaces and the physical environment. And, framing the scope of the MR design factors observation (see Figure 3.12, p. 99).

6 Study 4 & 5 – Examining the MRPC Customer Experience in the Field



6.1 Introduction

The chapter identifies the challenge in the customer experience journey between traditional versus MR brick-and-mortar stores and addresses the shift of consumer behaviour during two sessions of 6-day observations. This study addresses the knowledge gap by using grounded theory with triangulation to empirically investigate the implementation of the MR Product Configurator app in a traditional fashion retail shop. It derives several managerial and design implications for implementing MR shops. This study proposes a theoretical framework for MR customer experience based on 68 consumers who have tried an MR headset. The framework depicts the quality of user experience, current challenges, and achieving long-term success. By addressing the gaps in these factors, the practical implementation of MR retail may enhance its quality of experience for pragmatic aspects.

6.2 Research Background

6.2.1 Customer Experience in Brick and Mortar Stores

Customer experience (CX) defines the multiple stages of cognitive, affective, behavioural, sensory and social responses generated by the customer over the entire purchasing journey (Trischler et al., 2018). These stages establish contact during the interaction between the service and the served, termed touchpoints (Lemon and Verhoef, 2016). Positive experiences increase profits by improving the performance of touchpoints, leading to higher conversion rates and increased customer loyalty and advocacy (Homburg et al., 2017). The use of AR and MR in retail and user experience is growing, producing benefits such as improved sales turnover (the total amount of products sold during a specific period of time) by expanding omnichannel (Tan et al., 2022b), sales conversion (turning potential customers into purchasing customers) by accelerating the time consumers spend evaluating purchase alternatives (Sihi, 2018). It also provide possibilities in engagement and interactivity (Yim et al., 2017), shareability and customisation (Kumar et al., 2024), decision-making comfort (Hilken et al., 2017), and virtual try-on (Yim and Park, 2019). These technologies are reshaping consumer

behaviour by bridging gaps between traditional and online shopping (Schultz and Kumar, 2024). Practitioners are unclear about the behavioural shifts consumers experience when transitioning from traditional in-store shopping to MR environments. In particular, the MR experience quality is an important customer experience scale in brick-and-mortar stores (Chang and Horng, 2010). As a result, Study four responds to compare customer journey experiences between traditional and MR formats to gain insights into how consumer behaviour shifts in response to MR technologies, aligning with changing customer expectations and needs.

6.2.2 Service Experiences and Experience Satisfaction

Brick-and-mortar shop experience offers added value for customised service through in-store service and atmosphere experience. Ford and Etienne (1994) classified in-store service into three categories: courteous, personalised and manipulative (Ford and Etienne, 1994). Of these, MR's in-store service corresponds to the criteria for personalised service. Personalised service refers to interactive engagement, where retailers build customer rapport through quality interactions (Ford and Etienne, 1994). Retail service assistants need to be attentive, insightful and responsive to interpret non-verbal customer behaviour and anticipate the social content that will occur (Ford, 2001). Non-verbal categories of customer service experiences have been divided into four categories: proxemics, which focuses on space and distance; kinesics, which focuses on body carriage and movement; oculesics, which focuses on eye movements; and vocalics, which focuses on linguistic tones and intonations (Gabbott and Hogg, 2000). McKechnie et al. (2007) suggested that influenced by non-verbal behaviours, customer experience satisfaction results collected using questionnaires alone may be inconsistent with actual repurchase behaviours (McKechnie et al., 2007).

MR customised experience is a genre of innovative retailing where retail assistants cannot provide timely insight and responsiveness without guidance and awareness. As well as the unwillingness of organisational leadership to afford the employee MR technology training cost (Salman and Ahmad, 2023), all of these challenge the market implementation. Therefore, the exploration and classification of customer non-verbal behaviours in MR environments can help retailers understand the factors contributing

to consumer experience satisfaction. By summarising the behaviour of users and users' companions using MR headsets, this study attempts to outline training considerations for retail assistants to enable them to initiate the service. Existing studies have not addressed these issues, therefore, using qualitative observation to explore shifts in non-verbal behaviour can be a practical and in-depth approach.

6.2.3 Brick and Mortar Store Atmosphere Design

Intentional design of retail environments can influence consumer sentiment and thus increase purchase probability (Kotler, 1974). Mehrabian and Russell (1974) proposed a stimulus-organism-response (S-O-R) theory that connects environmental stimuli, affective response and behaviour variables in research in environmental psychology (Mehrabian and Russell, 1974). Some research has investigated a variety of studies on environmental stimuli, including the classification of atmosphere cues (Turley and Milliman, 2000), multisensory experiences and customer dwell time (Kim, 2001; Spence et al., 2014), and multiple retail touchpoints in the customer journey (Roggeveen et al., 2020). There are also several retail atmosphere studies on utilising experimental designs for precise measurements to understand their impact, for example, colours (Babin et al., 2003; Crowley, 1993; Wu et al., 2013), lighting (Birren, 1982; Nakamura and Karasawa, 1999), sound (Andersson et al., 2012; Helmefalk and Hultén, 2017; Yalch and Spangenberg, 2000), shop layout (Ballantine et al., 2010; Spies et al., 1997), product display (Ross et al., 2023) and crowding (Ballantine et al., 2010).

However, these cues have been studied in the context of traditional retail shops. No studies identified the ambient factors that are critical or create barriers to usage for users in MR brick-and-mortar shops. More work needs to be accomplished to elucidate how these factors influence specific MR shopping behaviours. Similarly, AR research has primarily focused on online purchases, with limited studies exploring its employing physical stores (Attri et al., 2024). For example, in the catering industry, AR enhances consumer confidence in food choices and improves overall dining satisfaction (Batat, 2021). Offering VR experiences in physical stores allows consumers to engage with the technology without investing in expensive HMDs and increases in-store traffic and touchpoints (Farah et al., 2019). Nevertheless, retailers currently lack strategies for delivering these technologies to customers (Farah et al., 2019), because they lack

knowledge of consumer behaviour. Based on current in-store experience, some critics argue that immersive technologies serve more as attention-grabbing tools rather than viable in-store solutions (Javornik, 2016). Since they are costly and primarily benefit brand awareness, the ROI remains limited (Bonetti et al., 2018). The financial risk of adopting immersive technologies stops many retailers from implementing them (Perkins Coie, 2018). Therefore, researchers should develop strategic approaches for practitioners to transform MR and VR from engagement tools into effective in-store purchasing solutions.

All these insights help to clearly pinpoint the research gap, which will be addressed in this study. In particular, it is unclear which factors in integrating MR applications directly into traditional retail shops affect the quality of the consumer experience and state how interventions can effectively reduce barriers. Some studies have highlighted the significance of efficient delivery of services to increase consumer satisfaction (Poushneh and Vasquez-Parraga, 2017). However, there is still uncertainty about specific aspects which might improve the efficiency, accessibility and satisfaction of consumers using MR technology. Many studies focus primarily on control experiments or remote questionnaires, which use precision experiments to explain the MR impacts but lack insight into the actual barriers faced by real retail stores (Zhang et al., 2023; Zimmermann et al., 2023). Before MR mass adoption in brick-and-mortar shops, the impact of MR applications on the retail environment should be constructive, accessible, and inclusive. They should be able to simultaneously support customers, users and shop assistants in the spaces without interference from each other, to create an MR in-store environment with a high-quality experience. Studying customer behaviour in natural retail environments can help to capture the complexity of real-world behaviour, thereby reducing the differences between test users and actual consumers.

This chapter draws on the theoretical framework of the SOR behavioural model and constructs a new MR customer experience model in physical stores using grounded theory, which remains a gap in the theoretical research on omnichannel marketing. Compared with previous studies, study five provides the first holistic perspective on the factors influencing customer behaviour and perception in implementing MR HMDs

(wearable AR) in physical stores. Previous studies have mainly focused on the pragmatic and hedonic value exploration of AR e-tailing (Jiang and Lyu, 2024), the impact of features of AR technology (vividness, novelty, interactivity, immersion, product presence, and perceived realism) on customers' positive behaviours and purchase intentions (Attri et al., 2024; Daassi and Debbabi, 2021b). Study five recommends an elaborated taxonomy of factors involved in the MR in-store experience journey, expanding the service range in external stimuli (interior environment and MR system) and the organism that is space users (user, user companion, retail associate and co-present third-party customers). It identifies distinct considerations for MR experiences that are different from AR, which can help firms anticipate user behaviour before the experience occurs and intervene through design to enhance customer intention to continue using.

6.3 Research Question and Objectives

RQ3: What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops?

RQ3 Objectives in this chapter attempt to address:

- **RQ3_OBJ1:** To compare customer experience frameworks in traditional and MR brick-and-mortar shops. (Research gaps 1 and 6)
- **RQ3_OBJ2:** To investigate the barriers to accessibility of Mixed Reality Product Configurators in brick-and-mortar stores and the associated design solutions. (Research gap 7)

Study 4 (RQ3_OBJ1) utilised the naturalistic observation approach to gather field data. To address the gap in understanding MR user dwell time, satisfaction, and shopping enjoyment, traditional CX will be used as a comparison case. The study contributes to the following by comparing behaviours in customer experience: 1) Reveals the differences between traditional and MR physical shops of customer experience procedures. 2) Addresses the shifts in customer behaviours between traditional and MR physical shops concerning dwell time, sentiment, and space allocation. These contributions facilitate a better understanding of consumer behaviours in the MR shop

among stakeholders, which can drive an essential step in the generalisation and implementation of the MR shop as one of the omnichannel retailing.

Study 5 (RQ3_OBJ2) conducted fieldwork through triangulation to explore customer experience behavioural patterns and retailer perspectives of MR shops, combined with questionnaires and a shop owner interview. This study proposes an MR user experience (UX) theoretical framework, which depicts the interplay between the physical environment, the virtual setting, and the space users. Addresses the challenges and benefits of traditional brick-and-mortar shops for implementing MR UX and suggests methods to improve them. The study contributes to the following: 1) Identify the user experience quality when using the MRPC in traditional retail brick-and-mortar shops. 2) Address the challenges of implementing the MRPC in traditional brick-and-mortar retail shops. 3) Provide managerial recommendations to similar retail shops to address the barriers to MRPC transaction methods for achieving long-term success.

6.4 Methodology

6.4.1 Research Design

This chapter consists of two studies, whereas Study 4 utilises a naturalistic observation method, and Study 5 uses a participant observation method. Observations as methods facilitate abductive theory development by describing and analysing user behaviours in a natural setting (McKechnie et al., 2007). The studies adopt grounded theory as a methodology, which conducts fieldwork and structured coding methods to generate theories of emerging phenomena (Glaser and Strauss, 1999). This methodology develops new concepts and early ideas through exploratory research (Homburg et al., 2017). Whereas MR technology integrated brick-and-mortar retail research is still in its infancy, and the nature of this innovative retail channel and customer responses are not yet well understood, grounded theory is appropriate for the aims of the study.

Sampling Strategies

Retail shops – including both independent and chains – used simple random sampling to be representative, ensuring that each group has a probability of being selected. An online map service was used to plot a list of jewellery shops in the UK using a search for "jewellery shops" in the cities of London (metropolitan, densely populated city, technology centre) and Lancaster (a non-metropolitan city, low population density, non-technology centre) (Perkins Coie, 2020). By randomly selecting coded numbers, recruitment took place through emails, brand websites, social media and in-store, inviting fifteen retail shops to participate in the research experiment. Some retailers recommended new shops, which were added. From June 2023 to November 2023, fourteen shops refused as well as did not respond, and one independent pop-up fashion shop accepted the invitation. Various factors may potentially influence this phenomenon, such as large chain brands having their own design and development departments, retailers unfamiliar with MR technology and unconfident in trying, MR not matching the brand niche, shops not having extra space for experiences, and retailers' degree of interest in technology (Perkins Coie, 2020).

The pop-up shop's name is non-disclosure and confidential. It is located on a high street in London, UK, and lasted three months (October to December). The shop is a standalone pop-up with independent spaces on two floors. Data collection took place on the ground floor (39 m^2) and lower ground floor (50 m^2) (Figure 6.1). The shop operates as a hybrid brand collection, and its brands are drawn from emerging independent designers and trendy fashion brands. It sells a range of jewellery, apparel, and bags but mainly focuses on jewellery and apparel. One brand's apparel collection includes unisex clothing, while the other brands focus on womenswear. The jewellery brands contain a wider range of unisex, genderless jewellery.

Pop-up shops can be categorised into different types, which have been reviewed in Section 2.4.2 Pop Up Store Typology for Mixed Reality. Short-term standalone retail stores have fixed or mobile space with an indoor structure, known as a premium pop-up experience (Yu et al., 2018). This genre is similar to long-term stores but with a short contract. Adopting MR as a purchasing tool is appropriate for premium merchandise regarding current cost and return. Therefore, standalone pop-ups fit the demand of the

study. The study was performed during non-holiday promotions and local events to reduce the impact of external factors.

Participant sampling was conducted using a combination of quota and convenience sampling rather than pre-recruitment. The sampling strategy and measures to minimise bias are as follows: a) It is impossible to estimate the total number of customers entering the shop daily, and it is less likely to get all invited customers involved. Therefore, random sampling cannot be applied. b) The convenience sampling population represented the probable end-user group. Including participants who do not intend to use MR shopping in the test is less useful for actual market adoption. c) The non-involved population was asked for reasons for not taking part, including lack of time, 3D vertigo and disinterest. No differences were found between the demographics (gender and age) of the time unavailable group and the demographics of the subjects. This reduces the bias from subject selection. d) By asking participants about their usual level of interest in XR, no significant differences were found between the data of significantly interested (n=3) and general interest participants. Thus, this reduced the subjective influence of bias in participant selection by the experimenter. Recruitment was promoted through posters at the shop and the shop's social media. The study was approved by the University's Ethics Committee. All retailers and participants signed a consent form before participating in the study, and participation was voluntary, with no incentives offered.

Observation Design

This exploratory study aims to better understand user behaviour and the environmental impacts of directly integrating MR into traditional brick-and-mortar shops to provide theoretical and empirical insight. As this is an emerging phenomenon, the study uses mixed methods triangulation as the methodology and grounded theory as the strategy. Triangulation attempts to collect data on a single topic using multiple tools (Bonoma, 1985). Grounded theory emphasises the generation of new, empirically driven theories by making explicit the process of theory generation through a series of structured procedures (Glaser and Strauss, 1999; Goulding, 2002). The triangulation approach to grounded theory reduces the analytical bias of a single researcher in a study by using qualitative and quantitative multiple data collection methods to obtain answers to the

same research question (Clark and Ivankova, 2016). This study uses participant observation methods, unstructured interviews with retailers, and quantitative questionnaires to develop a novel theoretical framework.

Many existing studies measuring shop atmosphere use laboratories to enable researchers to better control variables. However, rigidly controlled unnatural environments for participant behaviours and natural environments could have different reactions amongst respondents. Observation techniques are an effective way of focusing on the experiential process rather than the outcome, thus helping readily identify improvement areas of experience delivery (McKechnie et al., 2007; Wilson, 1998). To understand consumer behaviour in natural environments and to minimise observer bias, fieldwork triangulation with grounded theory was decided upon as the most appropriate method for the aims of this study.

The research triangulation design structure is shown in Section 3.5.5, see Figure 3.9. The data collection for Study 5 was derived from observation notes, video recordings, questionnaires, and retailer's interview transcription. The researcher played the role of a retail assistant to participate in the user experience. The questionnaire design adopted the User Experience Questionnaire (UEQ)[24], a widely used assessment tool for evaluating user experience (Schrepp, 2015). This study used UEQ to assess the MRPC experience in a brick-and-mortar shop. A total of 26 questions include three dimensions (Pragmatic, Hedonic, and Attractiveness) with six factors: attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty (Laugwitz et al., 2008). The interview questions for the shop owner are: 1) What do you think are the advantages or concerns of using this technology and kind of app? 2) Do you have any other suggestions or expectations? 3) Apart from the jewellery in testing, what other products do you think would be suitable for this headset, and why?

[24] User Experience Questionnaire. https://www.ueq-online.org/

6.4.2 Data Collection

The studies were conducted between 3rd–14th November 2023 in a fashion pop-up shop on the London high street in the UK. Studies 4 and 5 were six consecutive calendar days for each, including one weekend and four weekdays, respectively. Observations were made between 11 am and 7 pm, the shop's opening hours. The studies were conducted during non-holiday promotions and local events to minimise the influence of external factors. Some uncontrollable factors could not be avoided, as the overall number of daily visitors to the shops in Study 5 plummeted due to weather factors of heavy rainfall and traffic factors of public transport suspension.

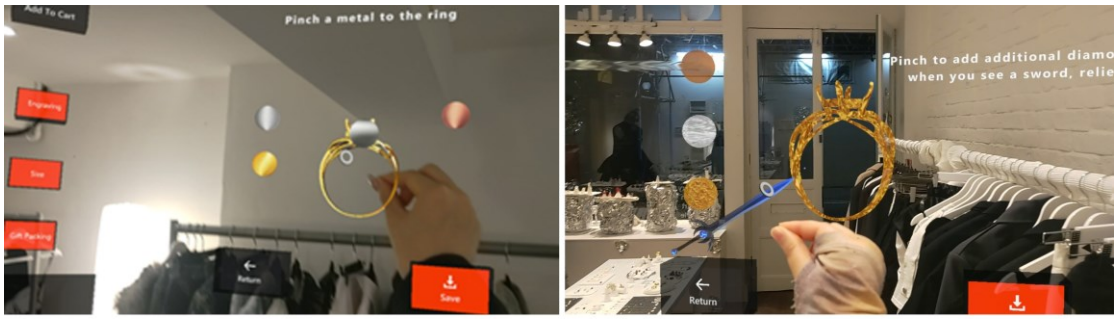
The pop-up shop had two floors. In Study 4, the researcher conducted naturalistic observations by the till on the ground floor. In Study 5, the researcher used participant observation to instruct customers when accessing the system. A booth was set up on the LG floor of the shop, and participants were asked to use the Mixed Reality Product Configurator (MRPC) after their regular navigation and browsing of the shop (see also p. 158, Outputs: Design Specification of the Mixed Reality Product Configurator). Activities were conducted one-on-one, with the experimenter standing beside and across from the user during the experience and instructing the user verbally and through gestures. The experimenter did not connect an external monitor device to observe the user's shopping interfaces.

No task or time limit was allocated to the user. Customer experiences stopped when the customisation was finished or added to the shopping cart. The average completion time was 5:00 minutes, the minimum time was 1:55 minutes, and the maximum time was 11:27 minutes. No users reported vertigo during use. After users completed the experience, they were asked to complete a questionnaire. After six days of testing the MR in-store experience, the retailer was invited on the final day to engage in the experience, and an interview was conducted to obtain perspectives on the retailer's observation throughout the six days and the MR experience. Figure 6.1 shows that participants have MR experiences on different floors. Figure 6.2 captures a screenshot of the user experiencing the MR customisation in the HMD on a different background.



a) b)

Figure 6.1 a) A customer experienced the MRPC from an HMD on the shop's ground floor. b) A customer tried on a virtual ring on the lower ground floor



a) b)

Figure 6.2 a) Use platinum to replace the golden product material in the MRPC. b) change the ring mount texture

6.4.3 Data Process and Analysis

Study 4 collected data, including observation notes and videos. The framework of the observation notes included weather, time of entry, time of exit, gender, group, individual, age, and relationship. Study 5 used various tools, including adoption videos, observation notes, questionnaires, and interview scripts with retailers. Study 5 collected 68 valid responses, including 45 videos, 68 questionnaires, and an interview recording of the retail shop owner. The shop has one retailer and one employee. The study only requires data from the retailer, as retailers have ownership of investment and decision-making authority.

The data analysis comprises a total of five stages. 1) Transcribing and organising qualitative data, consisting of six days of observation notes of Study 4. Also, Study 5

includes 68 users plus 1 retailer's recordings into 3 to 11 pages of transcripts per person. The quantitative data were digitised, and responses were reversed to be sequentially consistent. 2) The qualitative data (transcription, videos, and notes) were imported into NVivo and analysed based on the grounded theory process. 3) Quantitative data were analysed by importing them into the quantitative statistical software SPSS. 4) Data triangulation was compared and interpreted cross-sectionally. Given the multiple interpretations possible in the coding process, triangulation was able to compensate for and verify the validity of the results from the single perspective of only one researcher. 5) Comparison of Studies 4 and 5 to generate customer experience maps. 6) Define the findings and describe the evidence.

Qualitative data used NVivo 12 for analysis. From the 45 videos (n=68), one video was randomly selected from each of the day, with 6 videos reserved for data saturation testing. Qualitative data analyses proceeded according to the constant procedure of grounded theory's three stages of coding, in the order of open coding, axial coding, and selective coding. Constant comparisons were made with the content to find similarities and differences in the data and to generalise and generate a theoretical framework (Glaser and Strauss, 1999; Hammersley, 1990; Strauss and Corbin, 1990). Finally, theoretical saturation was examined to reach qualitative rigour. It is defined as there continues to be an increasing number of repeated codes, but no new codes appear, so the theory is considered saturated (Glaser and Strauss, 1999; Urquhart, 2022).

The quantitative data were imported into IBM SPSS 29 for statistical analysis. The scale was tested for reliability, and Cronbach's alpha value was 0.932, implying a high reliability. In the validity test, the KMO value was 0.798, meaning the datasets have good validity. The study results are primarily based on qualitative data on customer usage behaviour, with user-reported UEQ questionnaires and retailer interviews supplementing the interpretation in order to increase the robustness of the results.

6.4.4 Participant Demographics

Study 4: Naturalistic Observation

Table 6.1 shows the visitors for Study 4, where 1,191 customers were observed over the six days. Visitors are divided into groups and individuals, and each column is separated by gender. The shop has a greater number of female customers than male customers. The female customer group is about 9.23 times more than the male, and individual females are about 6.23 times more than males, but there is almost no significant difference from the mixed gender group. Weekends have more visitors than weekdays.

Table 6.1 Observation of visitor numbers in six consecutive days in Study four

Date (3-8th Nov. 2023)	Group (Number of groups)			Individual (Number of individuals)		Number of visitors
	Female groups	Male groups	Mix groups	Females	Males	
Friday	45	0	12	37	5	166
	Total population: 124			Total population: 42		
Saturday	79	4	43	58	10	343
	Total population: 275			Total population: 68		
Sunday	50	5	27	63	13	289
	Total population: 213			Total population: 76		
Monday	27	1	16	40	5	148
	Total population: 103			Total population: 45		
Tuesday	29	2	18	38	6	152
	Total population:108			Total population: 44		
Wednesday	14	1	13	32	4	93
	Total population: 57			Total population: 36		
Total	120	13	129	268	43	1191

Study 5: Participant Observation

Table 6.2 reflects the participant demographic profiles for this pop-up shop during the six-day period. Overall, there were 446 visitors, with 68 visitors accounting for 15.3% of those who participated in the study. In other words, for every 6.5 customers, 1 person opted to participate. Two of the participants had previous experience with MR and worked in related IT fields, while the remaining participants had no previous MR experience. To examine the customer experience of the MRPC against the benchmark, the study used G*Power (a tool to compute statistical power) to estimate the quantitative

required sample size, which was 36 (based on a medium effect size, Cohen's d = 0.5, α = 0.05, power = 0.90). The actual sample size collected was 68, which increases the statistical power and reduces the standard error, enhancing the robustness of the results. Qualitative analyses with this sample size are saturated, so the results are considered capable of some degree of generalisation (Hennink and Kaiser, 2022).

Table 6.2 Visitor and participant numbers on six consecutive days in Study five

Date (9-14th Nov. 2023)	Number of visitors	Number of Participants (%)
Friday	55	15 (27.3)
Saturday	56	10 (17.9)
Sunday	191	18 (9.4)
Monday	39	9 (23.1)
Tuesday	52	8 (15.4)
Wednesday	53	8 (15.1)
Total	446	68 (15.3)

Table 6.3 reflects the participant demographic profiles for this pop-up shop for 6 days. 82.3% of participants were younger than 35 years, and the majority had a Bachelor's degree or higher level of education (90.9%). Participating shoppers' occupations included 32 careers, with 60% employees, 35.4% students, and 4.6% unemployed. Nationalities were distributed across 21 countries, with the four countries with the highest proportion of participants accounting for the United Kingdom (20.9%), China (20.9%), the United States (14.9%) and France (10.5%), and the rest of the countries (32.8%).

Table 6.3 Participant demographics of Study five

Participant demographics		**N (%)**	**Total (%)**
Gender	Female	46 (67.7)	68 (100)
	Male	22 (32.4)	
Age band	18-25	37 (54.4)	
	26-35	24 (27.9)	
	36-55	7 (10.3)	
Education	Below Bachelor's Degree	6 (9.1)	
	Undergraduate	31 (47.0)	
	Postgraduate	29 (43.9)	

6.5 Findings

6.5.1 Study 4: Comparison of Traditional and MR Customer Experience

A comparison of the results of the two studies identified differences in customer experience behaviours between traditional and MR-oriented approaches in offline shops. Four themes will be addressed: consumer experience mapping, dwell time and MR duration of use, customer sentiment and spatial area in use.

Customer experience mapping depicts a holistic perspective on general customer behaviour from end-to-end in an experience in a time sequence (Lemon and Verhoef, 2016). Customer experience and journeys are primarily applied to marketing and service design, which is divided into three general stages: pre-purchase, purchase and post-purchase (Kalbach, 2020; Lemon and Verhoef, 2016). These three stages consist of awareness, consideration, engagement, purchase, retention and advocacy, which are structured in the horizontal axis of the MR customer experience mapping (Sashi, 2012). These customer engagement stages form the customer engagement cycle (Sashi, 2012). In this cycle, the awareness stage is when the customer discovers the brand, product, or service. The consideration stage occurs when the customer becomes interested in the brand's product or service. During the engagement stage, customers interact with retail workers and other customers, where interaction satisfaction may appear before or after the purchase process (Sashi, 2012). Customer retention is due to long-term overall satisfaction or highly positive sentiment (Sashi, 2012). Customer satisfaction positively impacts retention (Gustafsson et al., 2005). Satisfied customers may interact with others on social networks to spread their positive experiences with products, services, and brands, and advocate for the brands (Sashi, 2012).

The longitudinal axis is formed by the customer experience process, including actions, touchpoints, key performance indices (KPIs), pain points, and possible solutions (Holz et al., 2024; Homburg et al., 2017; Ivey-Williams, 2016; Kranzbühler et al., 2019; Rudkowski et al., 2020). Touchpoints are verbal (namely, advertising) or non-verbal (namely, product use) events that customers perceive or consciously associate with a brand (Homburg et al., 2017). Customer service and experience KPIs emphasise the

value of using data to improve customer experience and company financial results (Patti et al., 2020). They include numerous usable metrics, such as perception-based metrics (customer satisfaction, trust, loyalty, sentiment), operational metrics (average response, duration of use, dwell time), and outcome-based metrics (retention, conversion rates) (Patti et al., 2020). Pain points are obstacles or challenges encountered during the customer journey (Holz et al., 2024).

This study aims to compare the differences in the customer experience journey in two retail scenarios. Customer experience mapping helps to identify the complete customer engagement cycle. The dwell time, MR duration of use, and sentiment are aligned with the metrics based on short-term MR studies. Additionally, based on the MRPC UI layout design and the stakeholders' concerns about footprint in the interviews (see Sections 5.6 and 5.5.2), spatial analyses of the users' behaviours using this application have been added to this study.

Customer Experience Map

Figure 6.3 summarises 12 days of comparative observations depicting the differences in customer experience between traditional and brick-and-mortar shops integrating MR. The MR service enhances the customer experience by addressing pain points throughout multiple stages of the traditional brick-and-mortar transaction process. For example, during the purchasing phase, some customers seek to semi-customise products and ask retailers to contact the designer for remote ordering. MR customisation apps streamline this process by offering a self-design communication approach. Additionally, after engaging with MR, customers advocated for the brand by sharing their in-store experiences on social media. By engaging the customer in the design increases touchpoints, promotes communication with retailers and lengthens dwell time. Participant P8 mentions the MR sales method and real-time pricing information during the engagement process of product customisation: *"If I design a ring, can you actually make it? [...] Yeah, so cool! Also, there is a price. Is that like accurate?"* Therefore, in addition to differences in customer experience, sales and production modes need to align closely with it to ensure a cohesive experience.

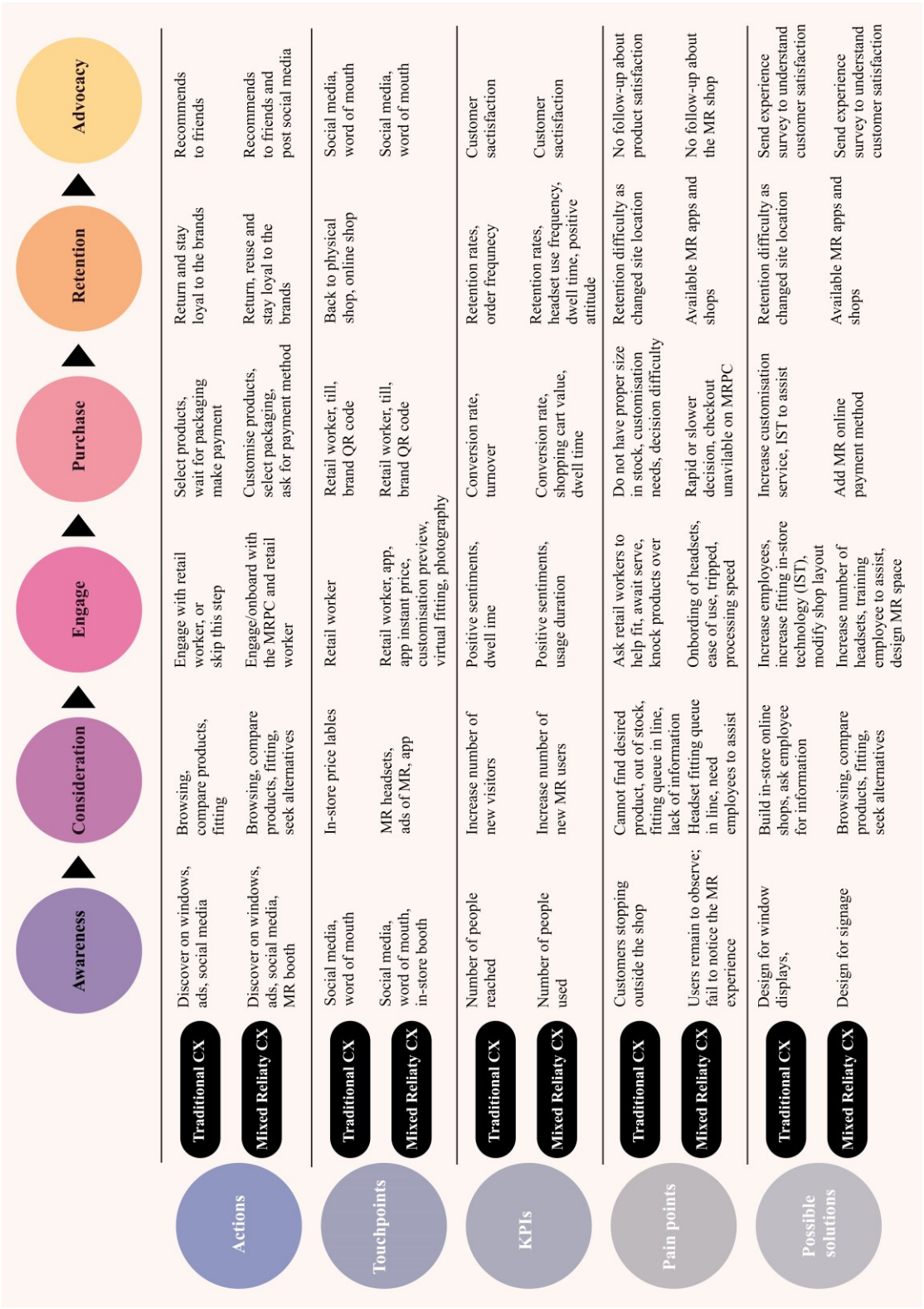


Figure 6.3 Comparison of customer experience mapping in traditional and MR shops. Adapted from Sashi, 2012; Ivey-Williams, 2016; Homburg et al., 2017; Patti et al., 2020; Holz et al., 2024.

Dwell Time and Duration of Use

Based on the calculation of the overall dwell time of customers (groups and individuals) from entry to exit, it was found that the average in-store dwell time of customers was 4:12 minutes. 8.97% of customers (groups and individuals) dwelled for ten minutes or more in-store, and 91.03% of customers (groups and individuals) dwelled for less than 10 minutes in-store. Customers who spent more than 10 minutes in the shop groups account for 8.72%, and individuals account for 31.94%. Customers who stayed in the store for less than 10 minutes in groups accounted for 91.74%, while individuals accounted for 68.06%. For those who remained in the shop for more than 10 minutes, by relationship-oriented, friends cohorts accounted for 10.17%, couples accounted for 4.84%, and family groups (with children) accounted for 1.18%.

The average duration of use for all customers (individual and group) using MRPC was 5:00 minutes, with the average duration of use for group customers 5:00 minutes and for individual customers 5:32 minutes. Among group customers, the average duration of use was 5:15 minutes per person while companions waited on the sidelines and an average of 7:27 minutes for users whose companions were shopping or fitting.

The above results indicate that the average length of in-store dwell time in this shop is short, with the majority of customers leaving within ten minutes. Individual shoppers stay longer than group shoppers, and peer-oriented shoppers who came with peers are the dominant group for long dwell times. The adoption of MRPC may increase the possibility of dwell time beyond general physical browsing for customers who intend to use MRPC. Similarly, the average duration of use is longer for individual customers than for group customers, and the usage purpose of waiting for companions (7:27 minutes) is notably higher than the average duration of use (5:00 minutes).

Sentiment Analysis

Performing a sentiment analysis using transcripts of customers using MRPC and employing manual labelling rather than traditional machine learning sentiment classification methods. The manual process consumed more time but allowed the semantic information of the contextual text to be fully utilised, resulting in higher

accuracy for implicit sentiment analysis (P. K. Jain et al., 2021). Four types of sentiment were identified: positive, negative, neutral, and confusion. Positive emotions, such as P13 stated: *"I think I'm pretty happy with my AR experience"*. Negative emotions, such as technical stability issues, P14 stated: *"Maybe I messed it up, lost. It seems to be moving too much for me to grab things"*. For neutral emotions, P19 mentions the lagging (slow responses) nature of the technology: *"Because it's also lagging a little bit, but it's cool"*. P21 was confused about usage because it forgot its operating method: *"So should I pinch one of the pitchers or one of these blue screens?"*

79.17% of customers produce positive sentiment, each experiencing an average of 6.9 times positive sentiment while using the MRPC. 54.17% of customers respond with neutral sentiment. 3.75% of customers produce negative sentiment, with each customer producing an average of 2.3 times negative responses. 4.17% of customers feel confused while using the MRPC, with an average of 1.7 times of confusion per capita. MR users' companions (both using the MRPC and non-users) sentiments were identified as positive, negative, and neutral emotions. When observing users accessing the MRPC, 46.15% of companions expressed positive sentiment, while 7.69% showed neutral sentiment, and 7.69% showed negative sentiment, respectively.

Positive sentiment correlates with the quality of the user intent. User intentions are categorised into five types: successful intentions, unsuccessful intentions, invalid intentions, unconscious intentions, and repeated intentions. Successful intent is when the user completes intended actions successfully, and unsuccessful intent is when the user fails to complete the intent. Invalid intent is when the user tries to perform a task using an invalid action, such as a self-created gesture undetectable by the hardware. Unconscious intent is the action triggered by accidental touch, such as moving the interface without awareness. Repeated intent is when users attempt to complete an action unsuccessfully and repeatedly retry. Among users coded into successful intentions, an average of 15.2 times successful intentions per capita were generated. Comparably, unsuccessful intentions occurred 9 times per capita, invalid intentions 2 times per capita, unconscious intentions 1.8 times per capita, and repeated intentions 6.5 times per capita.



a) b)

Figure 6.4 a) Customers prefer to use the MRPC in a seated position. b) Behaviours of customers and companions acting on MRPC access

The results illustrate that successful attempts and the positive sentiments of users are positively influenced. The success rate of users is 1.69 times higher than the unsuccessful rate. Positive sentiment (79.17%) was generated significantly more than negative sentiment (3.75%) when the user engaged in use. Companions were also influenced to generate positive sentiments, namely, laughing, taking photographs, and being curious about the sights of users while observing. Negative sentiments were derived from waiting time, awaiting comfort (standing, sitting), and emotional reactions to observing the user using barriers such as urge, impatience, and prodding by their companions. Figure 6.4 illustrates the behaviour of users and companions, sentiments, and usage posture.

Spatial Analysis

A key distinction in the customer experience is the consideration of spatial boundaries. While in traditional customer experience, customers focus their full attention on interacting with the real world, MR shopping demands attention to both the virtual and real worlds, with users interacting with digital elements through natural gestures. This shift in interaction emphasises the need for physical space design to cater for users in different usage postures, such as standing, sitting and walking. Notably, 1.47% of users unintentionally touched physical products, while 1.47% accidentally kicked tables during use. Therefore, ensuring a safe, accessible environment and optimising MR's spatial footprint is crucial for customers and retailers. This highlights the significance

of an overall holistic design approach, which means that designing not only the MR interface but also the space is vital.

Below are analyses of the footprints of the three modes of standing, sitting and walking. Since the participants were not selected using a random sampling method, the calculated distance travelled based on their height or walking range may not be fully representative. To address this, the study recorded footfall in the user's spontaneous gait and calculated it based on the normal distribution interval of height. A study investigated the normal distribution of height for men and women in North America, Europe, East Asia, and Australia, illustrating that a range between 157.6cm to 186cm is the majority of the population's height range (Jelenkovic et al., 2016). Therefore, a space accommodating a height of 186 cm can meet most people's needs. However, in shops with limited space, it is acceptable to design areas using an average male height of 178 cm, sufficient for most females and average-height males. Therefore, a reasonable space area should match customer height ranges between 178 to 186 cm. The calculation uses step length, which is the distance between the initial point of contact (heel) of one foot and the initial point of contact of the other foot (Murray et al., 1964). Female step length approximately equals height by 0.41 and male by 0.415 (Murray et al., 1970; Pratama et al., 2012). To accommodate all genders, use male step length for calculations, as it is generally longer. The step length of the 186 cm male is 77.19 cm, and the 178 cm male is 73.87 cm.

Figure 6.5 shows the number of steps taken from the user's standing position as a midpoint. 50% of users remained stationary at the origin, while 1.47% of participants moved to the quadrant points of -2 and 2.5. Therefore, removing the two extreme values is sufficient to satisfy 97.1% of the users. Users were initially positioned in the centre, with the horizontal axis allowing for two steps to the left. This suggests that a rectangular space with a 2:4 ratio is necessary for accommodating walking movements. A walking area of 148–154 cm by 296–310 cm meets the needs of most customers wearing HMDs and using the MRPC. The users were preset to stand in the centre of the field, and the horizontal axis was set to two steps to allow the left side to take one step. Therefore, a space ratio of 2:4 is required for the floor space occupied by the walking posture. The walking area should be designed with boundaries for floor areas of narrow

148×296 cm or moderate 154×310 cm, which is adequate for most customers accessing MRPCs.

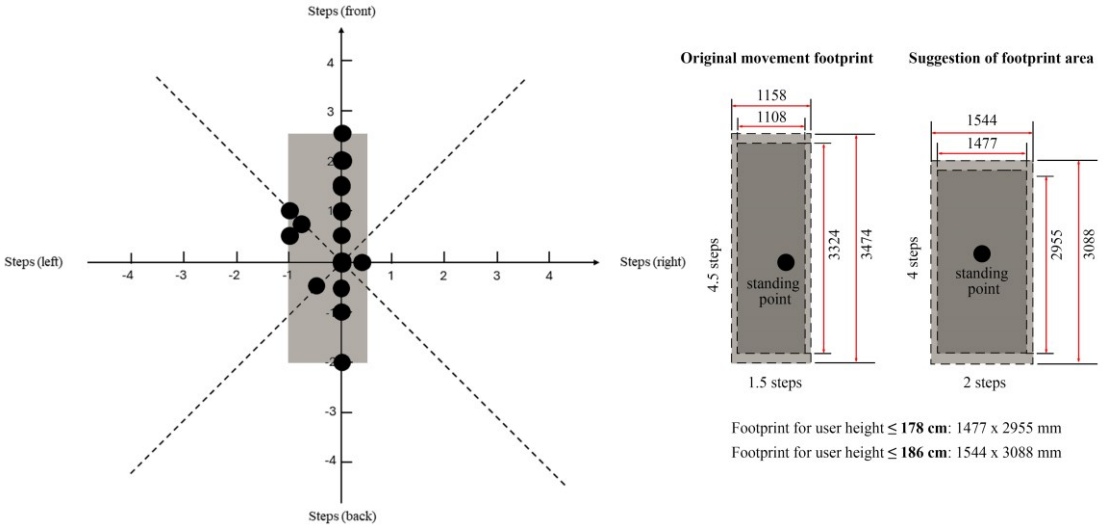


Figure 6.5 User movement range during testings (left). Recommendations for floor plan of walking (right)

6.5.2 Study 5: Mixed Reality Customer Experience Barriers in Stores

The study results will be explained by qualitative and quantitative results, respectively. In the qualitative results, two parts of findings are elaborated on: 1) the MR retail brick-and-mortar store customer experience model and 2) the shop owner interview findings. In the quantitative results, a statistical analysis will be presented regarding the feedback of the UEQ questionnaire.

Qualitative Results

1) MR Retail Brick-and-Mortar Shop Customer Experience Model

Open coding enables data conceptualisation and categorisation by integrating the labelling of the original statements. Initial concepts were conceptualised through axial coding, and then subcategories were summarised inductively as main categories through selective coding. A total of 101 initial concepts, 36 subcategories, and 6 main categories were identified through structured coding. The theoretical model introduces main categories and subcategories (Figure 6.6). The main categories include two external stimulus attributes (interior environment, MR system) and four organism

attributes (retail assistant, MR headset user, co-present customer, user's companion). The MR customer experience model is introduced below by reporting evidence from three parts (main categories): interior environment attributes, MR system attributes and organism attributes. Along with subcategories will also be interpreted (see Appendix C definitions of the theoretical model).

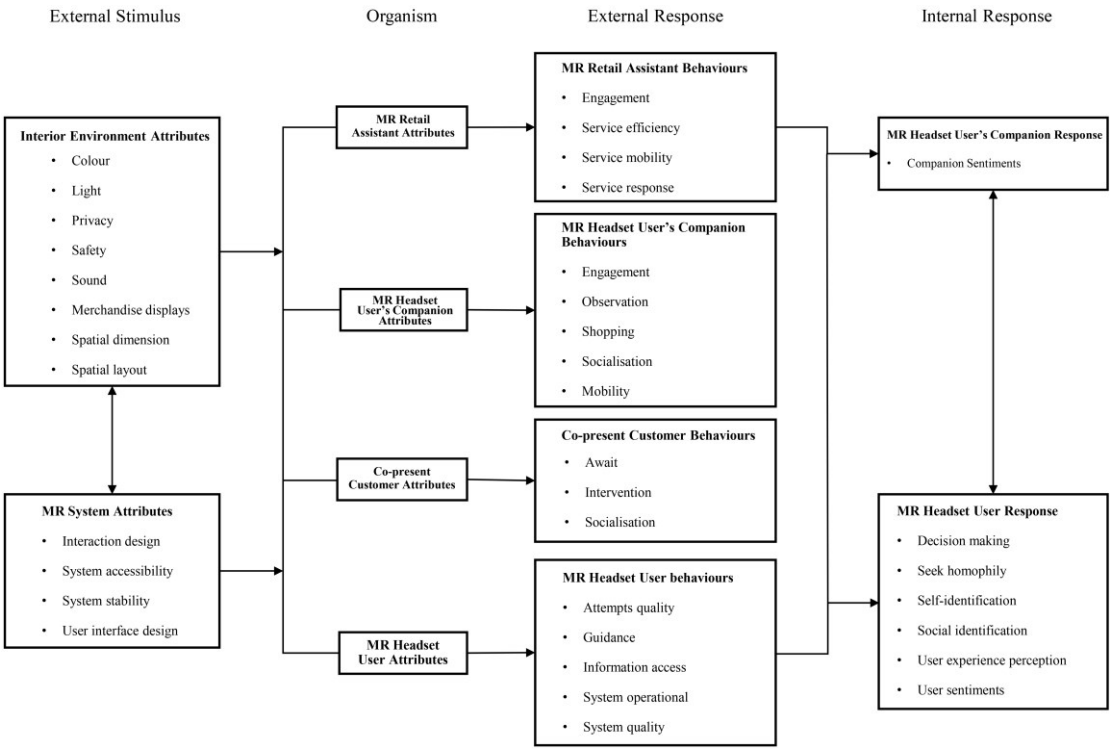


Figure 6.6 Mixed reality retail brick-and-mortar store customer experience model. Headings adapted from the S-O-R model, Mehrabian and Russell (1974)

Interior Environment Attributes

Interior environments are designed to produce an accessible and memorable brand experience (Bäckström and Johansson, 2006; Kotler, 1974). The addition of an MR retail approach increases the need for interactive accessibility and the need for interior planning. The empirical evidence extracted from verbal reports and direct behavioural descriptions of problems encountered by users when navigating through the environment encompasses eight factors.

Colour. where users encounter white fonts overlaid on white objects, making it difficult to read, and where the system objects with many physical background colours cause visual interference.

Lighting. When the user is in a position to face a direct light source or when the background is bright, leading to difficulty in readability.

Privacy. Observation from the public, companions and third-party customers creates distractions and interferes with users' behaviours. Users react to the gaze, for example, with positive affect (laughter, pleasure, excitement) to the gaze of their companions. The attention of a third-party customer brings negative affect (avoidance, suspension).

Safety. Safety considerations emerged in traditional retail environments, such as users kicking the counter while walking, users unintentionally hitting hangers while stretching, and a retail assistant (experimenter) assisting with the HMDs kicking the booths while walking. Especially where the aisles are narrow, the user's behaviour is more restricted.

Sound. In-store sound sources come from four primary sources: general dialogue, in-store acoustic, HMD acoustic and retail assistant instruction voice. Users suffer from multiple sound distractions that prevent them from focusing on the assistant's instructions and shopping tasks.

Merchandise display. User standpoint close to products or move in space, resulting in physical products with overlapping virtual objects and cluttered merchandise displays.

Spatial dimensions. Users obstruct the traffic flow of third-party customers and mismatch spatial dimensions with MR interfaces, resulting in virtual objects being displayed incompletely; a narrow path for users and customers affects movement.

Spatial layout. Mismatch layout leads to virtual contents embedded in booths and walls, as well as unplanned traffic flow obstructing the path of user movement.

MR System Attributes

MR systems are a primary component that provides a hedonic experience for customers; however, when the system design and device are inaccessible, lead to negative sentiment is outweighed by positive sentiment, and decision-making will be affected. The empirical evidence reported four factors: accessibility and stability (technical latency, accuracy, hand recognition, stability), interaction and interface design.

System accessibility and system stability, values incorporating direction incorrect, incapable targeting, incorrect gesture, miss triggers, position incorrect and uncontrollable projection. The system interfaces are unable to target virtual objects when the angle relative to the person is inappropriate (15.39%). 46.15% of users at least once failed to be aware that the position should change or are unable to move due to limited paths. P16 mentioned, "*I think the angle is wrong*". Inability to aim at objects (11.54%), including buttons not responding, hand ray point and commit[25] aiming through the background (ceiling, wall). Gesture errors (19.23%), where users create new gestures that are not recognised by the system, such as system pinch setting (from the outside in) while users (flick) spread their fingers from the inside out; unrecognised fingers caused by using the thumb and middle finger when pinching, and spreading the other fingers. Miss triggers (57.69%), such as clicking background, mis-triggers spatial recognition and moving the finger before it is recognised and released. Uncontrollable hand ray projection (23.08%), hand ray sticking to the background and unable to release, and hand ray point and commit unable to focus on near objects and projection on background. System stability, such as system errors (15.39%) and jitter (shaking) occur (3.85%). Users reported that:

> *"It's sort of going the 'fufufu' background" (system slightly jittery) (P34).*
>
> *Unintentionally flicked off the virtual product, and the ring flew away. The user was finding the ring. (P18)*

Interaction design and UI design include gamification attractiveness, system complexity, visual cues and multi-screen task interfaces. There are gamification scenes (animation creatures) in the MRPC system to augment the appeal of the application (see Section 5.6). Consumers can experience an enhanced fantasy world by having fictional pets or imaginary creatures (Rauschnabel et al., 2024). This increases the interactive session and scene experience (see Chapter 4, p. 117). 7.69% of users commented that

[25] Microsoft Learn (2022). https://learn.microsoft.com/en-us/windows/mixed-reality/design/point-and-commit (Accessed in March 2025)

the operation of the system is complex. 3.85% of users are distracted and interfered with by the physical environment, ignoring the visual aids provided by the system. Users commented that multiple screens experience is beyond reality and fun (3.85%).

Organism Attributes

In MR environments, the retail assistant, MR headset users, user's companions and co-present customers influence each other's behaviour.

MR retail assistant behaviour is shown as engagement, service effectiveness, mobility, and responsiveness. Engagement includes adjusting the device, demonstrating methods of use, assisting, and providing social communication. Retail assistant service quality, such as the ability to instruct users effectively, gesture recognition of missed triggers by retail assistants, and the retail assistant's path of movement in space and active service, positively influences the quality of the customer experience.

MR headset user behaviours include attempt quality, guidance, information access, system operation and system quality, where these behaviours lead to inner response. Attempt quality involves success, failure, unconscious attempts, repeated attempts, and invalid attempts to perform a task. Guidance-seeking users are partly inquiring about usage, while others look for tasks and next-step instructions. Information access, where users generate a dialogue with the retail assistant, includes enquiring information about the retail assistant's background, the app, designers, devices, products, the shop activity and the system's functionality. System operational behaviours consisted of users focusing on the real-world environment while using the system, describing their behaviours, finding and locating the virtual product, shifting their position in space, and trying on products. System quality consists of users reporting system errors during use. Some users stated that:

> *"Can you put it on? Can make it small enough to like" (P14).*
>
> *"How much is this headset like that?" (P5).*

The above external responses elicited the below internal responses. Users' decision-making process consists of constantly comparing product customisation effects and trying all options. Seek homophily, self-identification, and social identification consists

of the user recommending and inviting companions to participate in the experience, self-evaluating their design outcomes, and seeking evaluation and endorsement of their design outcomes from the retail assistant and their companions. User experience perceptions include comments on exercise ability, ease of purchase, innovativeness, learning to use, aligning individual interests, sound effects, and future feasibility. Some users commented that:

> *"It's rather like playing the piano. You need to learn" (P22).*

> *"It is fun like even the characters are just […] it's like if I take my glasses off, I wanna be shocked that there's not like three screens in part of me. So, it's very well done" (P24).*

MR User's companion behaviours are performed through engagement, mobility, observation, shopping, and socialisation, which generate internal response sentiments. Engagement behaviours include positive (making suggestions and interaction) and negative (urging and unconscious triggering and interfering with the HMD hand recognition). Other behaviours include movement in space, photography, queueing, shopping, and social conversations.

Co-present customer behaviours that involve waiting, intervention, and socialisation. Await, where shoppers wait in queues or stay on the sidelines to observe the user. Intervention, for instance, speaks to the user and retailer while they are using. Socialisation includes dialogue with other retail assistants and other companions next to the user.

2) The Shop Owner Interview Findings

Retailer interviews were also coded through three hierarchical structures and constant comparison, identifying 33 initial concepts, nine subcategories, and three main categories. Retailer interview feedback came from MR adoption concerns, design features, and incentive motivation.

Adoption concerns

The main concern about the indoor environment arises from the impact of user actions on other customers when in crowded times. The retailer stated:

> *"It can't interfere with customer traffic flow. Traffic flow is very important".*

MR system concerns relate to the accessibility of the system, the stability of the technology, the subsequent maintenance, and technical faults. The retailer commented on technical concern and cost concerns:

> *"Technical faults can cause irritation or dissatisfaction to customers [...] it is recommended to ensure the stability of the technology, as well as accessible, in order to give the best possible customer experience".*

> *"I think if the product can be customised then it's definitely more expensive [...] High-end or bespoke clothing is also suitable because of the product's price and shop size".*

Design features

Referring to the possibility of future adoption in this shop, the retailer suggested that apart from jewellery, they expected to include other product categories, such as apparel. Regarding functionality, the retailer suggested involving product locator service and multi-user experience.

> *"I think it's better to have two (headsets) because they come in pairs and it's an experience-based design, so it's better to have the experience together [....] maybe a bigger shop would need more helmets, but the size of my shop I think at least two (headsets) is more appropriate".*

Retailers commented that a dedicated MR area is necessary for the physical space due to the uniqueness of the customisation and the need for customers and users to be in the space without interfering with each other.

Incentive Motivation

The retailer's investment motivation involves brand benefits, consumer stimuli, and attitude towards use. After a 6-day observation from the retailer, the retailer stated that:

> *"The results I've observed may include increased sales conversions, attracting more customers".*

> *"I think the clothes themselves will have a larger footprint than jewellery whether it's a gantry or a fitting room, it's going to have a larger footprint than that, so if this is there, it could effectively solve the space problem and the time cost problem".*

The MR product configurator stimulates consumers by providing access to extensive information, interactive experiences, innovative shopping, personalisation, supported decision-making, fun and increased pleasure while waiting in a queue. In the end, the retailer reckons it is practicable to be adopted in retail brick-and-mortar shops. The retailer commented that:

> *"This technology provides customers with more detailed, personalised information to help them make more informed shopping decisions [...] making the waiting time more fun".*

Quantitative Results

The UEQ scale measures the pragmatic, hedonic and attractiveness dimensions of this MR in-store experience. The quantitative results show an effect size close to medium (Cohen's d = 0.36, $\alpha = 0.05$, power = 0.90). This demonstrates that integrating the MR experience in traditional stores has a significant positive impact and practical implications for improving the customer experience with a moderate experience improvement effect. It suggests a need for further optimisation of the experience for greater success. Additionally, participants' prior experience might influence the effect size, as the participants were mostly novice users, which might amplify sensitivity to user experience differences. For example, experienced users perceive MR shopping approaches more positively than inexperienced users (Obermeier et al., 2021). Figure 6.7 illustrates that the attractiveness and hedonic quality in UX have a high experience quality, and the pragmatic quality has a moderate experience quality. Figure 6.8 shows the relative quality of the benchmark data compared to the results of this study. The benchmark data comes from the existing values of assorted products (business software, online shops) from 468 studies provided in the UEQ toolkit. By comparing with other experience modalities, MR experience quality is categorised into three grades. First, stimulation (μ=1.91), novelty (μ=1.78) and attractiveness (μ=1.81) are significantly good to excellent quality. Second, efficiency (μ=1.10) remained above average. Third, perspicuity (μ=0.94) and dependability (μ=1.07) are lower than the average.

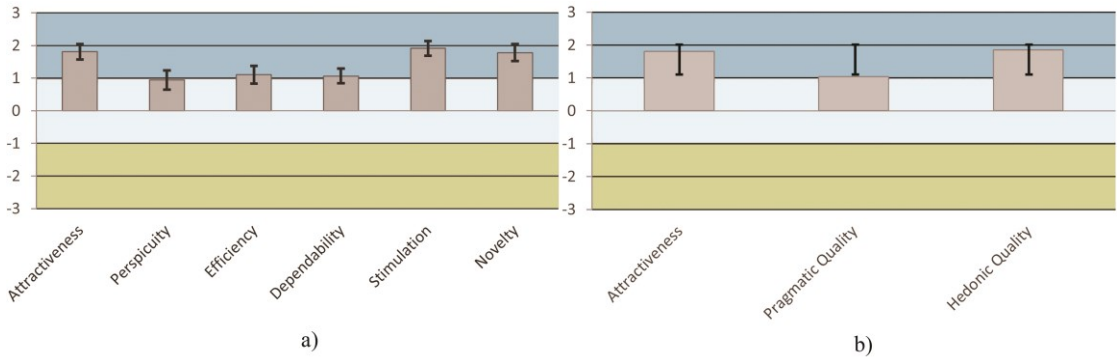


Figure 6.7 a) Mean ± S.D. of per dimension; b) Mean of user experience quality

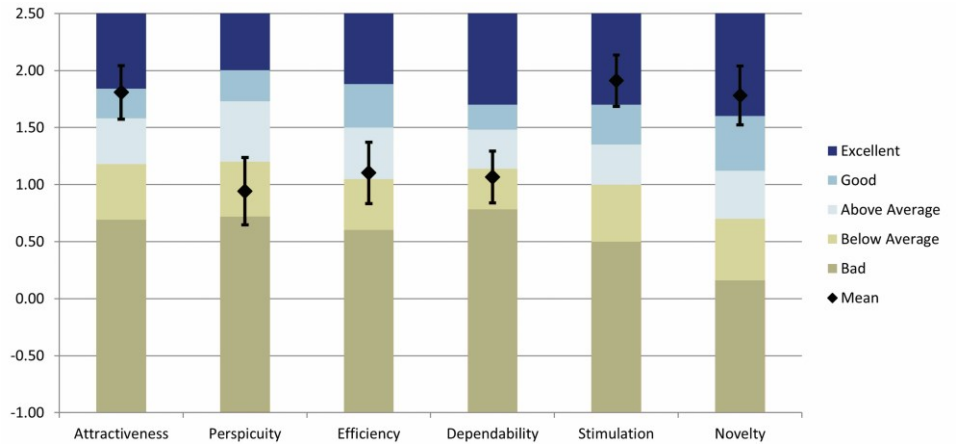


Figure 6.8 Benchmark of six dimensions (Mean±S.D.)

In terms of individual items, 23 out of 26 were positively evaluated, while three showed negative evaluations, namely predictability (dependability), speed (efficiency), and complexity (perspicuity). Combined with the qualitative results to interpret, predictability involves unfamiliarity with the operation and user interface of MR technology and the inability to predict the following steps. Additionally, inefficient intervention by retail assistants cannot effectively help users predict subsequent actions. Speed involves user onboarding speed, technical delays and failures, environmental distractions that affect the speed of use, and assistant intervention speed to resolve issues. Complexity involves onboarding learning, operating the application, and visual processing complexity. The following discussion will further interpret these findings and provide actionable recommendations.

6.6 Discussion and Implications

6.6.1 Managerial Implications for MR Store Customer Experience

The customer experience map illustrates the transformation of the traditional experience and the MR innovation experience. It includes an overview of customer and user behaviours and barriers at various process stages. Both coexisting paths of customer experience aim to increase conversion rates and achieve long-term customer loyalty. Therefore, managers need to be aware of the impact of customer experience consistency and sustainability on customer conversion. This CX map helps managers understand at which experience stages to deploy MR environments to support a seamless MR experience.

Based on variations in consumer behavioural patterns such as dwell time, positive sentiment and footprint of use, it is indicated that the benefits of the MR experience involve positive sentiment for most customers (79.17%). However, negative sentiment cannot be eliminated. Negative sentiment could be reduced by improving the usability and stability of the equipment and software, proficiency in using the technology, and the accessibility and comfort of the environment. In other words, there is a need to avoid UI jitter (slight shaking) and system lagging (slow response) caused by hardware processors. MR assistants should provide timely services, set security boundaries when the users are unfamiliar with the technology, and provide options for users and their companions to stand and sit to enhance accessibility and inclusiveness. In addition, only 2.94% of the users in the study had prior experience with MR, and 97.06% were first-time users. No participants stated that all attempts had been unsuccessful. Increasing the device's pervasive use in the public domain and customers' prior experience with MR applications can enhance their successful use, which can minimise their negative sentiments.

Further issues that should be tackled include optimising the interior environment design to minimise user interference with other customers. Whilst this study suggests a footprint, the usage space design, such as open, semi-open or enclosed situations, needs to be adapted to the business strategy. This highlights the importance of designer collaboration, who can simultaneously design both the MR system and the physical

space around the technology. These findings based on field data provide a productive case study and practices that can provide suggestions and inspiration to practitioners and restate the importance of the MR brick-and-mortar channel as a futuristic retail channel research.

In addition to the newly identified barriers in the results, certain apprehensions previously explored in the literature were also partially recognised in this study. This study did not observe privacy concerns cited in the literature, such as bystanders avoiding HMD cameras or displaying unnatural body language (Corbett et al., 2024). Aside from bystanders waiting in line, most walked by quickly or glanced briefly at the user. Queuing bystanders did not adopt a fixed waiting area, such as standing directly in front of or behind the user, but only maintained a certain distance. Additionally, customers did not raise issues of social impacts, such as feelings of isolation or preferences for virtual over reality interactions (Katins et al., 2024). However, social discomfort, categorised as a privacy factor, was confirmed in the results (Thomas and Holmquist, 2021). Physical discomfort with HMDs was also reported, with users noting device weight, arm fatigue, and neck strain after downward gazes (Thomas and Holmquist, 2021).

6.6.2 Design Implications for MR System and Shop Interior Environment

Observation results revealed that applying existing retail brick-and-mortar environments straight to MR purchases would encounter eight factors affecting user experience quality. ***Colour, lighting, privacy, safety, sound, merchandise display, space dimensions***, and ***space layout*** represent four dimensions of user experience satisfaction (accessibility, preferences, distraction, and interference). Incorporating an MR experience straight into a traditional medium-sized shop has the potential to impact the accessibility of the environment through lighting, security, space dimensions, and space layout. Merchandise display layout and colours could affect customer preferences. Distraction and interference influences come from sound, privacy, and spatial layout factors.

These eight design factors align with those in traditional shop design but take on distinct meanings, highlighting key considerations specific to MR environments. While conventional retail design focuses on factors such as aesthetics and efficient space utilisation, MR retail spaces prioritise environmental usability to address the unique challenges of MR interactions. For example, traditional retail emphasises colour schemes that stimulate purchases, lighting that enhances product attractiveness, and layouts that facilitate easy navigation.

In contrast, MR shop design needs to consider how background colours aid in system accessibility and virtual product clarity, how lighting conditions affect virtual product readability (Erickson et al., 2020), and how to provide gaze privacy when users engage with virtual elements (Corbett et al., 2024). Also, it needs to consider designing safe activity spaces to prevent customers from neglecting reality (Jung et al., 2018) to reduce risks of collisions or injuries while maintaining adequate movement flow for other shoppers. To help users distinguish retailer instructions amongst shop music, conversation noises, and MR device speakers. To minimise visual clutter and browsing comfort when displaying virtual and physical products in parallel. To define the minimum footprint of the space required and spatial layout that matches the scale of the MR and to plan the assistant's service position. Therefore, even though traditional and MR shops share environmental design factors, the design objectives differ significantly. This shows the significant contribution of this study in defining MR store experience barriers. Consequently, addressing these issues through a new experiment is necessary to provide solutions (see Chapter 7, p. 215).

As an innovative retail mode, the MR retail shop aims to facilitate decision-making by providing consumers with meaningful entertainment and efficiency. Providing consumers with an extraordinary brand experience (Gupta et al., 2024) and developing affective connections and enhanced brand memories (Dwivedi et al., 2024; Kolbl et al., 2020; Sharot et al., 2004). Retailers should provide a narrative, accessible, and inclusive retail environment to create an interactive spatial experience. Based on these design elements, it is recommended that designers undertake individual interior environmental design planning to adopt MR to create more inclusive public retail spaces.

Four factors can influence the experience quality of MR systems in both hedonic and practical aspects: ***interaction design, UI design, system accessibility,*** and ***technological stability***. Interaction and interface design play a vital role in promoting the attractiveness and uniqueness of the immersive experience. Brands should lead the creation of system content (Farah et al., 2019). Accessibility and stability are related to the UX quality utility assessment. The results report user behaviours that cause errors, and it is beneficial for retail assistants to be aware of error-prone points of use to identify the reasons for user failures to use rapidly.

The UEQ results evidence that the theoretical model of the MR retail shop customer experience has satisfactory reliability and validity. The results validate the user behaviour and the retailer model's perspective that MRPC brings a highly appealing and hedonic experience. Also, it is suggested that actions include improving factors of the pragmatism dimension, perspicuity (easy to learn and use, understandable, clear) (μ=0.94), dependability (μ=1.07), and efficiency (μ=1.10). Specifically, perspicuity should enhance ease of use (interface design and operation) and clarity (MR interface, flow of use, and retail assistant assistance). Dependability should be improved by improving predictability (interface aid design and experience flow). Efficiency should be improved by increasing speed (system responsiveness).

In summary, enterprises and retail shops who are considering establishing an MR retail shop or integrating MR technology in existing retail shops should design the interior environment, plan the software and hardware of the MR system, and train the customer service to improve the quality of the MR experience.

6.6.3 Design Managerial Implications for Consumers and Retailers

The MR retail experience creates a complex retail environment compared to traditional retail environments. MR headset users, user companions, retail assistants and co-present customers are influenced by their mutual behaviours when using a shared space. This distinctive nature provides valuable inferences to the findings that could help companies, retailers, and designers better implement MR mass customisation in the future retail market.

The MR UX model illustrates that the external behavioural responses of the user stimulate internal affective and cognitive changes. The implications of the MR retail experience for **consumers** are:

- ***Satisfactory decisions.*** Users are able to continually compare product customised outcomes during the MR experience, and this decision-making process can help consumers make more satisfactory decisions.
- ***Sentiments.*** User interactions with retailers and companions increase, positively impacting user sentiments (laughing, excitement, pleasure).
- ***Uniqueness.*** Multi-sensory retail environments immerse consumers in a brand-created place of dialogue, which increases the value of uniqueness in the physical retail shop.
- ***Products and brand image added value.*** The positive impact emerges from the distinctiveness of the immersive brick-and-mortar environment experience and the high engagement of the user, which strengthens the value potential of products and brand image.

MR users' companions are categorised into four types of customer groups that can provide different customer strategies.

- ***Hedonic motivated-oriented companions*** who generate positive sentiments and continue interacting with the user, queuing up for the experience and exchanging design outcomes. For example, *sentiments: "You look cross-site is so funny (Laughing)". Conversations: companion A talked to companion B, "He's shopping", then asked the user, "Are you shopping?" "I'm looking at a few things. That's so crazy. It looks real!"*
- ***Passive aim-oriented companions*** who are disinterested in engaging in the shopping process and urge their peers to leave to complete their purchase task. An example, *companion: "We're gonna go pay. Hurry up".*
- ***Neutral observer companions*** are less motivated and only observe the user from the sidelines.
- **Self-task-oriented companions.** Focus on individual shopping tasks and act separately from their companions. A conversation example: A user's mother (Companion) changed into new clothes and showed him. The user lifted up the glasses and walked two steps forward. Companion: *"Look, son. I might just last T-shirt with a nice bottom". User: "If this were higher, and if that would come up more [...]".*

Unlike traditional retail shops, MR retail assistants need to provide more responsive content to customers, such as adjusting equipment, assisting users, providing additional information, and co-designing. They also need to flexibly reposition themselves to avoid interfering with user movements and traffic flows of other shoppers.

The retailer experience model raises three factors: concerns (MR adoption), demands (design functions) and motivations (incentives). This helps to identify the impact of the MR retail experience holistically. Summarising the triangulation findings, the recommendations for **retailers** are as follows:

- ***MR-friendly interior design solution.*** Retail shops need an MR-friendly interior design solution to improve the accessibility of the MR system. Retail spaces need to be functionally segmented to minimise interference and accommodate a broader group of users working in the space.
- ***Inclusiveness support.*** Customers (users and companions) should be provided with seats in the MR experience area to encourage a more inclusive in-store environment for individual or group customers.
- ***Flexible and self-adaptive MR interfaces.*** MR interfaces should be flexible and self-adaptive to respond to contextual changes, such as adaptive reorientation according to sight height, spatial boundaries, and user movement.
- ***Ability to share virtual content.*** Retail assistants should be able to share the user's screen during first-time use to guide the user to learn and control the MR operation. In addition, assistants should be able to quickly navigate the user interface through additional devices to provide immediate service when the user seeks assistance halfway.
- ***Employee training.*** Retail Assistants are expected to be trained systematically on using the MR system and devices to provide efficient and effective MR in-store service.

In general, this fieldwork identified that the current market is not yet ready to implement the MR in-store experience, with the main challenges coming from customers' unfamiliarity with MR technology, resulting in inaccessibility issues. These experience obstacles could lead to the potential production of negative sentiment. To address this issue, this study provides a forecasting model of user behaviour for the in-store implementation of MR experiences in fashion-oriented retail stores with similar backgrounds and suggests solutions to facilitate a seamless MR customer experience. By addressing the problems defined in this study, brands can address inaccessibility barriers in brick-and-mortar stores, thereby enhancing customer onboarding efficiencies to enhance customer positive sentiment. This aligns with key marketing issues of how to drive AR adoption (Tan et al., 2022b).

Businesses can use two aspects to operate the optimised shops (see also Appendix F Section 07). First, product managers can use it to develop customer experience

strategies, leveraging the model's design factors to create targeted solutions when communicating requirements to the design department and software development teams. Secondly, the model is used to assist in onboarding retail assistants. For example, when users seek information (information access), the assistant has the professional knowledge to provide users with brand information related to apps, designers, and devices (service efficiency). When assistants observe through verbal and non-verbal behaviours that users are repeatedly unsuccessful (attempts quality), they should promptly ask if they need assistance (service response). Assistants should also identify the type of MR headset user's companion and adapt their service approach accordingly. For example, for hedonic-motivated and neutral observer companions, the assistant can socially engage the companion to convert to new MR users. For self-task-oriented and long-staying companions, assistants can extend MR users' duration of use and comfort by providing them with seats. For passive aim-oriented companions, assistants can assist MR users in the operation or add intelligent recommendation functions to the MR system to accelerate the customer's decision-making ability.

The service approach is closely associated with the personality of retail assistants and the strategy and scale of the brand, and a formulaic approach to service is not confidently applicable to all businesses. Therefore, the customer behaviour framework and categorisation proposed in this study intend to help brands master consumer behavioural patterns and recommend an approach to redesigning the MR customer experience in traditional stores at the current stage.

6.6.4 Implications for Public Policy and Economic Impact

At the micro level, the design and management considerations highlighted can assist stakeholders in developing productive strategies for integrating MR within physical retail spaces. On a macro level, the study encourages policymakers and retail managers to reassess and adopt MR, guiding policy development to maximise business opportunities. Government support for small- and medium-sized independent retailers could help them invest in MR shopping facilities to support their specialised and strategic growth. Large retail chains could leverage MR to drive local economic and technological advancement and enhance social impact. Public policymakers are able to

contribute to developing socially inclusive and sustainable innovative retailing through the MR means.

6.7 Limitations and Future Works

There are a few limitations to the extension of this study that need to be noted in future research. Firstly, the current study was not conducted through an external device such as a tablet or HMD to view the user interface while users were using it, which minimises the Hawthorne effect (individuals behave differently when they know they are being observed). Some studies suggested that privacy and security are user concerns about immersive technologies (Burke, 2002; Poushneh, 2018). However, the retail assistant cannot view the interfaces, which could influence the efficiency of the assistance service and impact the user's attitude towards using it. Therefore, future studies could expand the user behaviour under observed MR interface situations as a comparison.

Second, although the study has a small sample size, given the small number of visitors to the shop, the sample size is acceptable. Nevertheless, a larger sample size could make the study applicable to a broader population in future work. The study used one shop category, which might diminish the generalizability of other retail sectors, but the sampling strategy robustly increased the generalizability and reliability of the study in the fashion sector. Nevertheless, researchers are recommended to conduct their studies in different types of stores and layouts and compare various retail contexts following this methodology. Researchers are less recommended to conduct laboratory-based experiments at the stage of defining consumer behaviour and experiencing obstacles. Defining the real market problems before solving them with a precise solution of controlled experiments is vital.

Moreover, the study was conducted using a cross-sectional design, and future studies would benefit from longitudinal studies regarding the long-term effects of MR on consumer behaviour and attitudes.

The dwell and usage times of customers who did and did not use the MRPC were recorded over two six-day periods rather than through a between-groups controlled experiment with equal numbers of participants within the same timeframe. The reasons are: Although a controlled experiment would have reduced potential confounding factors, it was difficult in this store due to unpredictable daily foot traffic. Implementing group experiments under these conditions would have decreased the sample size of MRPC users and been less comprehensive across different customer types, including individual and group users. Additionally, some participants (n=2) were already familiar with AR/MR technologies and visited the store to try the MRPC and those who queued for the experience, indicating that customers' behaviours were uncontrollable. This study's recruitment method also does not work for between-subjects experiments. Finally, there was only one experimenter, leading to the inability to conduct two groups of experiments at the same time. Nonetheless, this study used certain means to reduce interruptions: the study ensured that both six days included four weekdays and one weekend while avoiding holidays and promotional events. Despite these constraints, the impact of potential confounders on dwell time is considered acceptable for the aim of this study. Nevertheless, future research would benefit from a controlled experiment conducted in large-scale retail stores with the aim of measuring dwell and usage times.

This study has practical guide implications for retail shops with similar MR interactions and for shops preparing to implement mass customisation. These usage barriers are identical, even if application functions are varied. For example, environmental factors would influence MR's accessible experience rather than limit it by app type. Similarly, MR shopping apps are less likely to affect the behaviour interpretation of the user's companion and users. However, for consumer internal responses, partial results are limited to interpreting mass customisation-related apps, which are self-identification and social identification (definitions see Appendix C). These two factors are influenced by participation in the product design process, and practitioners should be careful. Also, they should notice that the duration of use results are based on the app providing only two products, so stakeholders should note that if they amend the product amount, the duration of usage might vary.

Only one device was provided for the experience in the study, so the duration of use in the case of cluster consumers all attempting the experience may be affected by device

availability. A future direction for research would be how to convert the length of MR usage into conversion rates for shoppers who use it to wait for their companions to pass the time.

Finally, this study does not aim to measure purchase decisions or intentions of using MRPC but aims to examine experience barriers and consumer behaviour. Purchase intent is excluded because it is impacted by several factors, such as price, product style, brand awareness, and ethics. Additionally, measuring it could have interfered with the store's sales performance.

6.8 Conclusion

This study empirically provides a theoretical framework for MR customer experience in stores, which defines the challenges that need to be overcome to integrate MR technology in traditional brick-and-mortar retail shops. It also highlights the importance of improving interior design to provide a more accessible MR experience. The experience quality of MR environments can sufficiently reflect customers' willingness to engage, confidence, and increased satisfaction with brick-and-mortar shops. This chapter identified eight key design factors for interior environments, streamlining the twenty-four interior design factors derived from interviews discussed in Chapter 5. This refinement enables more targeted design recommendations and draws attention to the most pressing environment-accessible challenges. The findings find the customer satisfaction impact factors include interference and accessibility), which expands Chapter 5 interview findings (distraction and accessibility). The subsequent study will aim to quantify customer experience satisfaction by using the above design factors to measure specific interior design values.

From a practical perspective, MR in retail has the potential to impact sales, customer engagement, and brand image significantly. By creating more interactive shopping experiences, MR can attract new customers and increase sales conversions. However, it illustrates that the quality of user experience of current MR applications in brick-and-mortar shops needs to be strengthened. The study provides design recommendations for

retailers to achieve long-term success and sustainability, including designing MR-friendly stores, developing intuitive and reliable systems, and adequately training retail assistants to support customers. These design considerations aim to facilitate MR retail experiences that are inclusive of the general public by minimising distractions, improving MR experience accessibility, and enhancing user satisfaction.

On a broader societal level, the mass adoption of MR could influence public attitudes toward immersive technologies, making them more accessible and desirable. Although the finding points to potential positive impacts, such as customer ability to participate in designing products and MR-based mass customisation utility aspect, it also raises important considerations for future research on possible negative consequences, such as privacy concerns and technology usability.

6.9 Contribution Summary

This chapter has addressed three research gaps identified in Section 2.6 (p. 65):

Research gap 1: Addressing the issue of short in-store dwell time and lack of shopping enjoyment.

Research gap 6: Lack of research on MR environments integrated into brick-and-mortar retail stores.

Research gap 7: Lack of research on user experience and evaluation of MR technology integrated with brick-and-mortar retail stores.

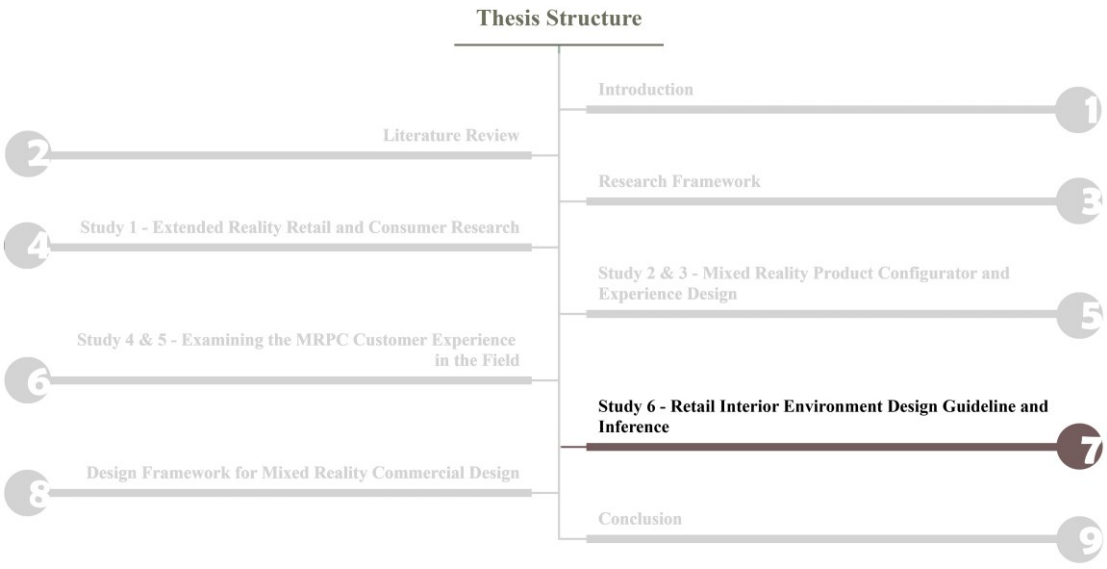
It answers research question 3:

What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops?

Review of the contributions made in this chapter:

- This chapter provides an MR customer experience map illustrating CX barriers and solutions at each stage of the experience. It demonstrates that MR can increase adequate dwell time, positive sentiments, and proposed MRRPC's footprint requirements for walking usage.
- The findings suggest that retailers should carefully design ergonomic MR environments to improve user experience accessibility and facilitate adoption. The results address eight factors for interior design (colour, lights, privacy, safety, sound, merchandise display, space dimensions and space layout) and four factors for MR system design (interaction design, UI design, system accessibility, and technological stability) for design recommendations to enhance the accessibility of the MR retail environment.
- The results highlight the critical role of interior design, UI system design, customer experience, and service design in successfully implementing MR in brick-and-mortar stores. To achieve seamless integration, designers should enhance collaboration throughout the design process.
- This outcome informs the content of the next stage of interior design experimentation and the elements that constitute the interior design guidelines (see Figure 3.12, p. 99).

7 Study 6 – Retail Interior Environment Design Guideline and Inference



7.1 Introduction

This chapter identifies interior spatial design guidelines for the implementation of MR in retail stores, including design indicators for colour, light illuminance, colour temperature, merchandise display, privacy, spatial ratio and spatial dimensions factors. It provides recommendations for designers to enable them to design inclusive MR retail spaces for general stores and designs based on user demographics. MR shops or spaces are defined as spaces that offer MR technology experiences, and shops providing MR devices as one of the purchase channels.

This study primarily used a quantitative method, along with qualitative interviews to conduct a field-built study through a within-subjects experiment (n=64). It also identifies an MR retail purchase acceptance model which suggests that users highly accept the MRPC as a future transaction and experience method. Combined with the interview results, the MRPC is evaluated and generates MR product customisation user interface principles for UI/UX designers. This empirical approach provides designers, practitioners and companies with instructions on design guidelines, investment practicability and interpretability.

7.2 Research Background

7.2.1 Influence of Store Environment on Accessibility and Inclusivity in MR Customer Experience

The affordability of digital devices such as smartphones and computers has influenced consumer habits by enabling consumers to search and compare information online anytime, anywhere, and these socio-technical factors have had a significant impact on traditional brick-and-mortar retailing (Stephen, 2016). The unique environmental ambience and in-store services of brick-and-mortar stores have a competitive advantage over online retail. Many consumers engage with the environment and retailers while making a decision at the time of purchase (Keller, 1987). Store environments directly

impact user decision-making and perceived brand image, with store atmospheres conveying informative cues to consumers regarding the quality of goods and services (Baker et al., 1994). With expensive equipment and time-consuming technology development, the strategy for mass market adoption is to maximise the benefits of in-store adoption. A well-designed in-store environment and a robust in-store experience readily enable most of the public to access MR, drive MR marketability, and contribute to bringing vitality to brick-and-mortar retail shops.

The inferences in this study relate to the accessibility and inclusion of MR technology in retail environments (see also Section 2.4.3, p.57). In traditional brick-and-mortar stores, good accessibility means good transport is available to stores (Thang and Tan, 2003). In this study, MR retail accessibility means enhancing the usability and ease of use of the technology when customers are experiencing MR shopping in stores. For example, harsh or dim lights may result in unreadable virtual interfaces and obstacles to hand capture by HMD cameras (Kruijff et al., 2010); wall colours and colour temperatures could influence the appearance of virtual products and chromatic aberration (Kruijff et al., 2010); and concerns of body extension and space boundary in relation to the stand-sit-walk position for the safety of users, other customers, and retail assistants (see also Chapter 6, p.194). Technology usability and perceived ease of use are recognised as critical components in user technology acceptance (Davis, 1989).

Inclusive MR retail in this study is defined as ensuring that MR retail design considers and benefits a wide range of customer groups to meet different user needs, regardless of their ability to be familiar with digital tools (previous MR experience), age, gender, or cultural background. This means that in addition to accessibility, design recommendations should be tailored to customer preferences and demographics.

Therefore, this study (**Part A**) aims to investigate how design factors and design values correlate to customer demographics by measuring the index of barriers to create an inclusive accessibility store design guideline.

7.2.2 Consumer Technology Acceptance in Mixed Reality Retail

All phases of the customer experience (CX) in which customers interact with branded products, systems and services produce physical and emotional responses (Laming and

Mason, 2014). It consists of customers' cognitive, emotional, affective, social, and physical responses to the retailers and brands (Verhoef et al., 2009). The technology acceptance model (TAM) is commonly used in immersive marketing to capture user cognition, affect, and behaviour responses towards new technology such as MR technology (see also Section 2.5.1, p.60). The significance of measuring these dimensions in a questionnaire is explained below.

MR experience. Consumer memory involves the input, storage, retrieval, and output of information related to a brand's products and services. It arguably means that when the retail space mobilises the consumer's emotional experience, it outputs prominent levels of results, builds a network of brand awareness associations, and the consumer's memory recalls snippets of brand information unconsciously (Conway et al., 1994; Curci and Luminet, 2009; Dolcos et al., 2005; Sharot et al., 2004). Therefore, physical experience, such as body perception, enhances the construction of memory networks to some extent. People cannot just observe but need experiences to enrich their perception of the world (Norman, 2002). The physical environment determines the subject's perception, and the unique perspective that the environment presents to the viewer makes perception meaningful (Gibson, 1950).

Cognition and perception. Neurophysiological research states that the brain is constantly generating visual perception and emotional responses in response to changes in the properties of space in virtual space (Shemesh et al., 2020). Consumers' perceptions of brands can influence consumer experiences and behaviour, and changes in the consumers' experience, such as immersive consumption, which drive consumers' memories of brands. Consumer mindsets such as perceptions, associations, attitudes, attachments and activities are key drivers of brand performance, price premium, price elasticity, market share, and expansion success (Keller and Lehmann, 2003).

Affect and attitude. When confronted with the launch of innovative technologies, shoppers are expected to embrace, learn, and master technology to engage in experiences and to create experiences. Accordingly, the degree of commitment to learning, customer dynamics, and customer engagement drives consumer behaviour and intention to adopt innovative technology in retail environments (Foroudi et al., 2018). Psychology defines positive affect as the state of internal feeling when an individual

subjectively experiences positive emotions while feeling satisfied (Miller, 2011). Positive affect is associated with better performance in incidental learning and distraction while performing the primary task. It has a distinctly positive impact on learning and problem-solving approaches (Isen and Shmidt, 2007). In light of MR retailing, positive affect promises to positively impact serendipitous learning and acquisition of innovative technologies, together with the execution of purchasing tasks.

Behaviour response. Decision-making and judgement are significant factors in consumer purchase behaviour and the innovative technology used. Some research suggests that decision-making and judgement are rational processes and are primarily concerned with making consistent choices, while the other process results from intuition or is based on rapidly occurring emotional responses (Kahneman, 2003; Slovic et al., 2005; Stanovich and West, 2000).

MR seeks to increase positive emotional responses and help customers make satisfying purchasing decisions by augmenting the experience. The TAM theory explains the design rationale of **Part B** of this study, which forecasts user acceptance for future large-scale MR brick-and-mortar retail implementation.

7.3 Research Question and Objectives

RQ4: How is it possible to design inclusive mixed reality retail interior design guidelines for diverse demographics?

RQ4 Objective in this chapter attempts to address:

- **RQ4_OBJ1**: To determine an elaborate guideline of design factors and values for planning and implementing mixed reality store interior environments. (Research gap 8)

This study adds a research objective as the experiment Part B, to evaluate MRPC design.

- **RQ4_OBJ2**: To anticipate the user acceptance of the MRPC as an innovative retail purchase approach and evaluate the MRPC design. (Research gap 9)

Study 6 (RQ4_OBJ1) utilised the experiment approach to gather data on the user experience of MR retail by designing factors extracted from the result of Study five. By statistically calculating the data, it generalised an MR interior environment guideline applicable to general stores and different user demographics.

Study 6 (RQ4_OBJ2) employed a combination of an experiment and interviews, where users experienced the MR purchase approach under a controlled environment to evaluate MR retail acceptance and predict the applicability of the MRPC for market adoption. Semi-structured interviews were also used to evaluate the MRPC design.

7.4 Methodology

This study consists of one experiment, which is divided into two parts. Part A uses questionnaires to address OBJ1, and Part B uses questionnaires and semi-structured interviews to address OBJ2. Figure 7.1 illustrates the experiment procedures.

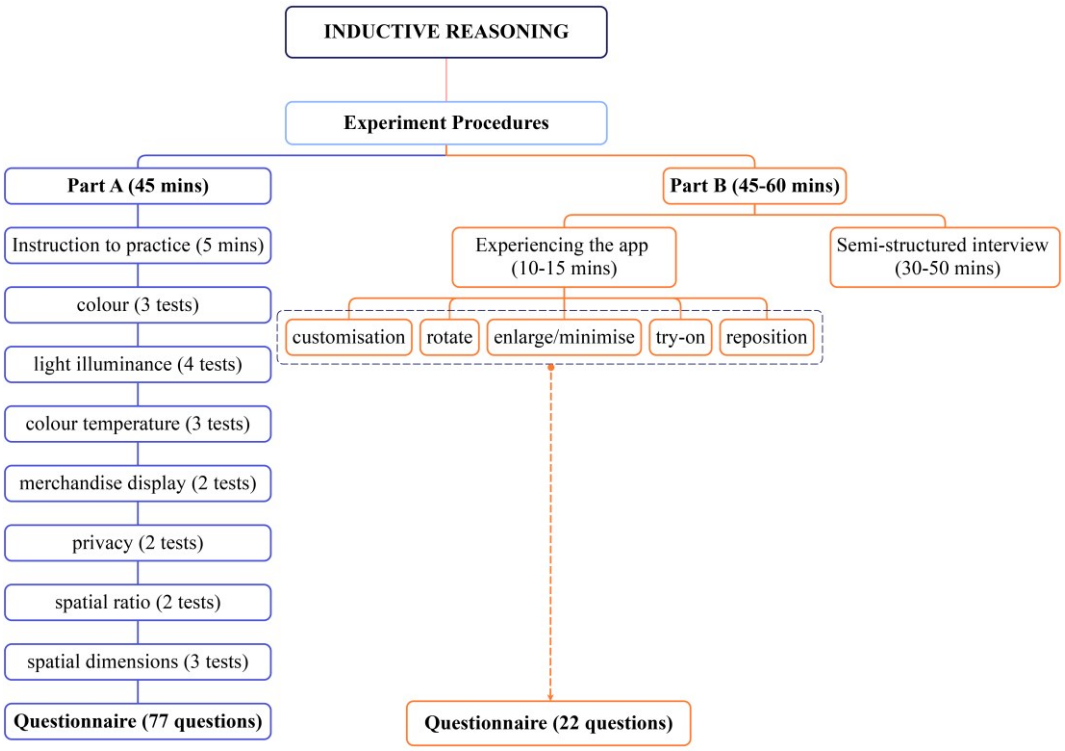


Figure 7.1 Experiment procedures

Part A

Prior fieldwork identifies eight factors for store interior environment design (see Section 6.5.2, p. 194). The factors are colour, lighting, merchandise display, privacy, sound, safety, spatial layout and spatial dimensions. Part A study extracts and quantifies five factors from the eight factors: *colour, lighting, merchandise display, spatial dimensions and privacy*. Safety is a fundamental design condition that requires designers to base their design on ergonomics. The sound and spatial layout have not been tested because the sound test needs to be conducted independently, using multiple factors experiments, which require the consideration of factors such as environmental background sound, store music acoustics, and HMDs' sound effects. Considering the limitations of the experimentation environment and measurement equipment, this factor has not been selected. The spatial layout test needs a large store area to fulfil multiple layouts, such as a grid form, free form and racetrack, which are limited by the realistic site. Regarding the selected factors, the light variable is expanded into two design factors: illuminance and colour temperature (Kruijff et al., 2010). The spatial dimensions variable is supplemented with a space ratio variable to determine suitable plan dimensions (usage posture) and space ratio (service position) (see also p. 194). As such, there are seven design factors included. The experiment design values selections will be interpreted in Section 7.4.1.

Part B

Participants experienced the MRPC app in a mock retail environment, answered a questionnaire, and evaluated the MRPC UI design through semi-structured interviews.

7.4.1 Part A: Factors Selection and Measurement

This section explains the design values selection rationale of the Part A experiment, which includes seven design factors and nineteen design values which have been used to determine the MR store interior design guidelines (Table 7.1). The following review of previous studies on traditional store design, integrated with design considerations specific to MR retail environments, explains the reasons for identifying these design values in the table.

Table 7.1 MR Design Factors, Values and Objectives from Chapter 6

Design Factors	Design Values	Interpretation	Objectives
Colour: walls	red, white, blue.	Background wall colours for virtual product overlays when consumers use MR technology.	Measuring MR in-store colour on interior walls impacts user preferences and usability.
Light: illuminance	dim light 200 lux, bright light 500 lux; 60% intensity, 90% intensity.	Physical environment lighting and device brightness of HMDs.	Measuring MR in-store combinations of the illuminance of ambient light and HMD intensity impacts user preferences and usability.
Light: colour temperature	warm (3000K), neutral (4000K), cool(5000K).	The overall effect of the light colour temperature projects on the virtual products and interfaces, as well as physical shelves and products.	Measuring MR in-store light colour temperature impacts user preferences and usability.
Merchandise display	vertical display, horizontal display.	The product placement height when the customers are viewing products with HMDs overhead.	Measuring MR in-store jewellery display height and angle variations impact user preferences and usability.
Privacy	share screen when browsing (public access screen), share screen when needed (assistant access only).	Share screen when browsing refers to MR service on screens that the public can view, such as monitors and TV screens. Share screen when needed refers to MR service on screens that the public is inaccessible to, such as tablets or HMDs.	Measuring MR in-store privacy of two states screen sharing on user preference and usability.
Spatial ratio	stand opposite, stand same side.	When assisting the MR headset user, the retail assistant stands opposite or next to the user.	Measuring MR in-store customer service position variations impact user preferences and usability.
Spatial dimensions	stand, sit, walk.	Users who adopt MR shopping stand, sit, or walk require different floor areas.	Measuring MR in-store on different postures of operation mode's user preferences and usability.

Colour: walls

Many existing studies have indicated the importance of the impact of colour in store interior environments. Colour influences consumers' evaluation-related and activation-related emotions (Crowley, 1993). Some research suggests that red and blue in shopping scenarios show a significant positive influence in stimulating consumers' shopping behaviours (Babin et al., 2003; Crowley, 1993). Colour dimensions are often associated with wavelengths (Valdez and Mehrabian, 1994). Cool colours such as blue and purple

are considered to be low arousal (short wavelength) colours that evoke calm and peaceful associations, while warm colours such as red and orange represent high arousal (high wavelength) colours that produce a sense of excitement and tension (Yildirim et al., 2007). High arousal colours are thought to distract customers and interfere with task performance (Stone, 2003; Stone and English, 1998). Blue, as a shorter wavelength colour, is more responsive, especially in high-end jewellery stores and fine dining environments where it creates an evaluatively pleasing atmosphere, and the activating effect of red can significantly stimulate purchase intention. Psychological studies have suggested that red is more stimulating than blue (Valdez and Mehrabian, 1994), and studies of fashion retailers have shown that cooler colours are preferred to warmer colours (Babin et al., 2003). Nevertheless, another study stated that the impact of colour was not significant for task-oriented shoppers (van Rompay et al., 2012).

In practical scenes, there have been occasions when brands have experimented with different interior background wall colours. The jewellery brand Pomellato uses red, which is its brand colour, in its store design[26]. Other brands, such as Chaumet, use a deep blue brand colour for their interior walls[27]. The most common and frequently occurring store wall colour in people's daily lives is white. White, as a neutral colour, has no distinct hue bias. Therefore, the colours targeted – red, white and blue – which are warm, neutral and cool – were selected for the experiments.

Lights: illuminance

Many studies have been conducted in the direction of environmental psychology to explain the importance of light and its effect on human behaviour. Some lighting studies suggest that lighting levels can stimulate an individual's abilities. For example, a bright

[26] Pomellato. https://nationaljeweler.com/articles/1789-pomellato-celebrates-10-years-in-chicago-with-new-boutique (Accessed in March 2025)

[27] Chaumet. https://stores.chaumet.com/en/macau-sar-china/macau/level-1-the-shops-at-the-boulevard-city-of-dreams--18 (Accessed in March 2025)

room is more stimulating than a dimly lit room (Mehrabian, 1976). Meanwhile, more energy is expended in completing experimental tasks when the light level is higher (Gifford, 1988). Lighting has an impact on consumers' shopping behaviours. Soft and dim light persuades the consumer to read carefully and take their experience slowly, while bright and harsh light may increase buying intentions (Birren, 1982; Gifford, 1988; Markin et al., 1976; Mehrabian, 1976). This confirms that designers can influence consumer shopping and experience time by adjusting in-store lighting levels when working on interiors. However, MR technology requirements may make it inaccessible in direct sunlight or under bright light. Therefore, this experiment intends to test the dual factor availability of physical light illumination and virtual luminous intensity.

Retail lighting encompasses general lighting, accent lighting and display lighting. The average illumination level is between 500–1000 lumen/m² (lux) for low-budget retail stores without accent and display lighting (CIBSE, 2018). For high-quality, premium retail stores where accent and display lighting are used, the average background illumination is between 50–200 lux (CIBSE, 2018). The typical background illumination for stores with some accent lighting is between 250–500 lux (CIBSE, 2018). Jewellery stores are generally equipped with accent lighting for jewellery display, depending on the profile of the store, and some jewellery stores are equipped with display lighting. Based on the above scenarios, two store lighting scenarios are simulated for HMD luminance testing. The experimental lighting environment selected 500 lux as bright illumination to mimic a shop equipped with typical backgrounds and accent lighting. For premium shops with accent and display lighting, the experimental lighting environment selected 200 lux as a dim illumination.

Erickson et al. (2020) tested contrast ratios for HoloLens 1 and HoloLens 2 of 70% and 30% at ambient lighting levels of 1000 lux and 100 lux, respectively, confirming the impact of ambient light on the contrast of the devices (Erickson et al., 2020). The HoloLens 2 supports eleven levels of brightness (HMD intensity) adjustment, with test brightness nits of 16, 38, 59, 91, 113, 140, 221, 291, 360, 414, and 538 (Guttag, 2020). A previous pilot test had two users (one female and one male) tested in the 200 lux and 500 lux position intensity readable level range. The testing method used a light meter to test the lighting at 200 lux and 500 lux from the user's eye height, considering that

user heights might be varied. The HMD brightness is adjusted from dim to bright (1-11 levels), which fits the human eye condition. Each participant was tested five times and averaged the readings. At 200 lux, user A suggested a minimum to maximum readable range from 40%–80%, while user B suggested 30%–80%. On 500 lux, user A suggested the range from 60%–90%, while user B suggested 40%–90%. To accommodate minimum user-readable demands on both 200 lux and 500 lux, as such, 60% (221 nits) and 90% (414 nits) intensity have been chosen.

Lights: colour temperature

A study exploring seventeen combinations of colour temperature and illuminance (5×4 factors) has confirmed that preference strongly depends on colour temperature and illuminance, with the combination of 200 lux and 3000 Kelvin (K) being the most preferred (Nakamura and Karasawa, 1999). Kruithof (1941) discovered experimentally that each colour temperature has a comfortable range of illuminances, low illuminances comfortably at low and high illuminances comfortably at high colour temperatures (Kruithof, 1941). Therefore, this study is guided by the table's comfort zone range of 3000K, 4000K, and 5000K selected to suit the ambient light source illuminance of 200 lux–500 lux in a jewellery retail store.

Merchandise display

Well-ordered displays assist consumers with navigation and visual aids (Claus and Garaus, 2015). For example, it assists in visualising products, improving tangibility and accessibility, providing appropriate freedom of choice and reducing information overload, together with structuring visual displays through product variety and quantity control (Bastow-Shoop et al., 1991; Bell and Ternus, 2006; Claus and Garaus, 2015). Product display research focused on the dominant colour, visual texture, and style coordination display (Wu et al., 2013). These findings align with the fieldwork research (see Chapter 6). In the fieldwork, merchandise display was defined as the influence of the visual order of the product display on the user's experience in MR environments, which encompasses product placement, product colour combinations, and display cabinets.

This experiment focuses on the merchandise display of product cabinet displays, that is, horizontal and vertical showcases. In the vertical orientation of the display, the consumers' eye level ranges from 121.9cm to 152.4cm, and the touchable area ranges from 91.4cm to 121.9cm (Ebster, 2011). In contrast, the sight observation range is lowered in the horizontal display manner. Wearable devices are significantly distinct from traditional smartphones in terms of usage posture and device specifications (weight and size). Furthermore, HMDs physiologically interplay with the user's head, and thus, the user's physiological comfort is one of the key focuses in user-centred design towards the device's accessibility and technology acceptance. A HoloLens study showed that one-third of the participants noted minor discomfort from the headset fixtures to the point of requiring optimal positioning adjustments (Cometti et al., 2018). This discomfort in shopping scenarios may lead to the following: First, the user has to consider the pressure on the neck vertebrae brought about by the excessive length of device use, which is particularly unfriendly to the cervical spine disease-affected user group. Secondly, the headset slides downwards in a state of frequent head down possible, especially when the user's improper operation or retail assistant negligence causes the equipment to slack on the head tends to cause a worse slide downwards. Therefore, it is crucial to consider the safety of equipment and users, as well as the protection of assets and how the display showcase is presented.

Privacy

Roesner and Kohno (2021) stated that AR privacy is involved in several principal domains, namely monetisation and cross-platform support, physical world integration, brain and body interfaces, and identity and disparate access (Roesner and Kohno, 2021). Privacy is essential for user acceptance of technology in commercialised contexts of use. In addition to the software's internal privacy, such as policies and laws, other external privacy issues include multiuser sharing of virtual contents and bystanders' external gaze (Corbett et al., 2024). This experiment aims to determine consumer preferences for service devices' privacy concerns in public spaces. Considering device investment and customer service differences, the study compares how monitors, tablets, and MR headsets impact customer service experiences. In the market, some VR and AR applications, such as monitors and smart mirrors, display content on public screens or

tablets, raising vital considerations for long-term customer adoption and layout planning for device placement.

Spatial ratio

The proportional design of a brick-and-mortar store typically relates to the store layout, exemplified by the placement layout of the racks (Vrechopoulos et al., 2004). There is sparse literature related to retail assistant service positioning in stores. The customer service aspects of MR store environments involve the assistive use of equipment and planning of space utilisation to enhance accessibility and safety of the surroundings when the user immerses themselves in the virtual experience. Specifically, the retail assistant stands opposite the user, with the UI overlaid on the assistant in the user's view, and the user-assistant maintaining eye contact during interactions. The assistant's service screen may present a viewpoint that is either opposite to (HMDs) or aligned with (tablets) the user's perspective. Alternatively, when the assistant stands beside the user, the UI appears overlaid upon the background environment, with both the assistant and user sharing the same viewing perspective. In both positions, the user needs to maintain a safe distance from the assistant to avoid accidental hits during hand movements. The service position of an assistant can lead to differences in floor areas and layout planning. Therefore, the spatial proportions were intended to determine user preferences for landscape and longitudinal services to define the planning ratio of the spatial area.

Spatial dimensions

VR device brands HTC Vive and Meta Quest recommend a usage area of 2m by 1.5m and 2m by 2m, respectively. However, there is a shortage of studies on MR devices. In MR retail purchases, the user's physical movement area and vision height in different postures impact the consumer's decision-making, experience, and footprint area. Therefore, the three postures of standing, sitting, and walking are used as the experimental variables.

Spatial dimensions are defined as the area of space required for standing, sitting, and walking, and the spatial scales are derived from differences in postural heights. The previous fieldwork study calculated the maximum and average required range of motion

without limiting the user's movement range. In this experiment, the intention was to measure the ease of use and preference of the user's purchasing experience at the minimum movement scale. This factor measures whether different postures generated barriers to task completion in the MR store and the preferred postures in the MR experience. This factor can provide a data basis for the brand's footprint area design and quantity of seats.

7.4.2 Experiment Design and Tasks

Part A

Experiment Design

The study primarily used a quantitative research design for experimentation. It included a within-subjects approach for comparing values for each factor. A 'within-subjects' design of an experiment refers to a procedure in which each participant is exposed to more than one factor test. A 'between-subjects' design of the experiment means that each participant will be exposed to only one factor (Charness et al., 2012). Gender and age bands were used as the between-subjects factors to identify further differentiation for the values for each factor. The data was collected using questionnaires, and unstructured interviews interspersed into the test collected further open-ended feedback. The sub-questions construct the guideline criteria to answer the RQ4_OBJ1.

- What is the perceived significance of the seven design factors (colour, illumination, colour temperature, merchandise display, privacy, spatial dimensions, and spatial ratio) on customer behaviour in a mixed reality physical retail environment?
- Among each design factor, what design values are optimal for customer experience when implemented in a mixed-reality shop environment?
- What are the differences in customer experience based on gender, age, occupation and education for the design factors of colour (three values), lighting (four values), colour temperature (two values), merchandise display (two values), privacy (two values), spatial ratio (two values), and spatial dimensions (three values)?

Metrics

For each design value (see Table 7.1 for the complete list), the user experience was probed in the context of distraction, interference, accessibility, and preference under each factor (see also Section 6.7). Consumers tend to be distracted or disturbed in shopping environments with behavioural and judgment impacts (Biswas et al., 2009; Kent and Allen, 1994; Nowlis and Shiv, 2005). Consumer behaviour theories usually suggest that distractions should be avoided during the decision-making process to avoid distractions that reduce one's ability to complete shopping tasks in-store (Sciandra et al., 2019). Some research suggests that distraction does not lead to differentiation in the evaluation of products, but rather depends on the particular mindset of the consumer (Lerouge, 2009). However, Grewal et al. (2018) found that distraction from using mobile devices (smartphones) is associated with a consumer's age, and this distraction increases the dwell time that customers stay in the store and attention to the product, leading to an increase in purchases (Grewal et al., 2018). Accessibility has been shown to be an important factor in influencing consumer preferences (Thang and Tan, 2003). Accessibility is often associated with e-commerce as a key factor influencing consumer decisions (Thang and Tan, 2003). Therefore, the study uses these four dimensions to calculate the satisfaction of the MR in-store experience. The demographics of consumers strongly influence customer behaviour (Mittal and Kamakura, 2001), and therefore, age and gender are the factors that have been considered in this study.

The questionnaire has four questions under each design value. For example, after performing the task with the red background (factor: colour, value: red), the user answered the following four questions:

1) "Did you find the red background wall colour distracting when performing the task?"
2) "Did the red background wall colour interfere with your ability to perform the task?"
3) "How accessible do you think the red background wall-colour while using the HoloLens?"
4) "How likely are you to prefer the red background wall-colour while using the HoloLens?"

All items used a five-point Likert scale: 1-Strongly Disagree, 3-Neutral, to 5-Strongly Agree. Each value was calculated as a user experience score by the average of these

four questions. The questionnaire had 76 questions (19 values×4 questions) and an additional single-choice question on device preference. The questions about distraction and interference were coded negatively, while accessibility and preference were coded positively.

Task

The task design used the MRPC with HoloLens 2 (see Chapter 5 for MRPC design). In brick-and-mortar shops, a consumer using an MR headset in a shopping environment would normally be expected to interact with products through the headset. To mimic this interaction in a generic form, it is necessary to choose a simple task involving moving virtual objects within the MR headset's virtual environment. The user wore the headset and stayed in a diamond ring configuration platform, and then was asked to move the ring to a new position to replace a new model material and scale the ring. The user needed to repeat this operation for each factor measurement.

Part B

Experiment Design and Metrics

The MRPC evaluation includes semi-structured interviews and questionnaires. Multiple data sources converged and supported each other when analysed by observing user employ recordings, interview transcripts, and questionnaires to increase confidence in the research findings (Thyer, 2009). Using multiple tools strengthens conceptual connections and reduces researcher bias in interpreting qualitative results to help develop more comprehensive findings (Berg, 2009).

The questionnaire design was derived from previous studies (Table 7.2). All items used a five-point Likert scale: 1-Strongly Disagree, 3-Neutral, to 5-Strongly Agree. The measurements consisted of user MR system technology acceptance, user interface design evaluation, user attitude, user behaviour and retail purchase. With the design of the questionnaire, the following research hypotheses were raised to answer the OBJ2.

- Perceived user interface design has a direct significant positive influence on attitude towards use.
- Perceived user interface design has a direct significant positive influence on perceived ease of use and perceived usefulness.
- Perceived usefulness and perceived ease of use have a direct significant positive influence on attitude towards use.
- Perceived usefulness and perceived ease of use have a direct significant positive influence on purchase intent.
- Attitude towards use has a significant positive influence on purchase intent, behavioural intent to use, controlling perceived user interface design.
- Perceived ease of use has a significant positive influence on perceived usefulness and behavioural intent to use, controlling for perceived user interface design.
- Perceived usefulness has a significant positive influence on behavioural intent to use, controlling perceived ease of use and attitude towards use.
- Purchase intent and behavioural intent to use have a significant positive influence on each other, controlling perceived usefulness and perceived ease of use.

The MRPC design is evaluated using semi-structured interviews, and the questions are listed below.

- Please describe three advantages and disadvantages of using this application towards its UI design, experience, functionality and comfort.
- Based on the mock-up environment, what would make you consider using this app in real retail shops (most important and least important)?
- Do you have anything else you would like to experience to improve this app?

Table 7.2 Questionnaire design of Study six

Construct	Measurement Variables	References
Perceived Usefulness (PU)	1. If I want to buy jewellery, I could accomplish just what I might need with the MR Jewellery Configurator app in a mixed reality headset. 2. Shopping with the MR Jewellery Configurator app in a mixed reality headset would make my life easier. 3. The MR Jewellery Configurator app in a mixed reality headset would make shopping more productive. 4. The MR Jewellery Configurator app with a mixed reality headset would improve my shopping decision-making ability. 5. With the MR Jewellery Configurator app, I couldn't get the product effects that I needed.	Adopted and revised based on the scales used in Davis et al., 1989; Rese et al., 2017; Venkatesh et al., 2002; Venkatesh et al., 2003
Perceived Ease of Use (PEU)	6. Using the MR Jewellery Configurator app is clear and understandable. 7. Using the MR Jewellery Configurator app does not require a lot of mental effort. 8. This MR Jewellery Configurator app is easy to use. 9. I would find it easy to get the MR Jewellery Configurator app to do what I want it to do.	Adopted and revised based on the scales used in Davis et al., 1989; Huang and Liao, 2015; Kim and Forsythe, 2008; Venkatesh et al., 2002
Perceived User Interface Design (PUID)	10. The layout of the MR Jewellery Configurator app is user-friendly. 11. The computerised instruction provided by the MR Jewellery Configurator app is clear. 12. The layout of the MR Jewellery Configurator app is in good structure. 13. Overall, the user interface design of the MR Jewellery Configurator app is satisfactory.	Adopted based on the scales used in Cho et al, 2009
Attitude Towards Using (ATU)	14. In my opinion, using the MR Jewellery Configurator app with mixed reality headset in a brick-and-mortar retail store is a good idea. 15. Altogether, I like shopping using the mixed reality headset in the MR Jewellery Configurator app in a brick-and-mortar retail store.	Adopted and revised based on the scales used in Ajzen, 1991; Recalde et al., 2024; Venkatesh et al., 2003
Behavioural Intent to Use (BIU)	16. I will use the mixed reality headset to purchase products in the future. 17. I will recommend using the mixed reality headset to purchase products. 18. Using the mixed reality headset to purchase products in the future is important to me.	Adopted and revised based on the scales used in Ajzen, 1991; Rese et al., 2017; Ahn et al., 2004
Purchase Intent (PI)	19. Based on my experience of this experiment, shopping with MR inside a real retail store would make me more likely to purchase a product. 20. Based on my experience of this experiment, shopping with MR inside a real retail store would improve my desire to store in brick-and-mortar stores in future. 21. Based on my experience of this experiment, shopping with MR inside a real retail store would make me want to return to store at a store that uses MR for purchases. 22. Based on my experience of this experiment, shopping with MR inside a real retail store would improve my enjoyment of shopping.	Adopted and revised based on the scales used in Inman and Nikolova, 2017

Task

Users are asked to use the system as they would typically purchase a product to complete an MR product customisation in the pop-up installation (Figure 7.2). The research task consisted of a series of attempts by the participant to apply the existing operation functions, such as shifting the position of the virtual product, changing the design, enlarging and shrinking the dimensions, rotating, trying on, and relocating the interfaces. Users can change product material of the virtual product, compare it to the physical product, and fit virtual and physical products at the same time (Figure 7.3).



Figure 7.2 MR jewellery configurator effect in pop-up installation. Screen capture



Figure 7.3 Participants compare products (left). Participants' perspective in HMD (right).

7.4.3 Apparatus

A Pop-up Store Installation

The pop-up store was designed based on ergonomic and application specifications, and the available utilisation of the space area is 1.8m (length) × 1.8m (width) × 2.44m (height). It was placed on the ground floor entrance of a building on campus, so the experiment was conducted during public holidays when the building was unoccupied.

Hardware and Software Equipment

The headset used Microsoft HoloLens 2. The ambient lighting was controlled using the LEDGO-600BC-600 Bi-Colour Dimmable LED light and GODOX TL30 RGB tube light to generate the required illuminance and colour temperature conditions. Using an Extech SDL400 light meter to measure lux, the experiments were recorded with a GoPro Hero10 Camera and a Canon G26 Camcorder. The sound recordings used Rode Wireless Pro and a Zoom recorder. A laptop was connected to the HMD internal screen to test privacy (Figure 7.4). The software used the MRPC app (see Section 5.6, p. 158).

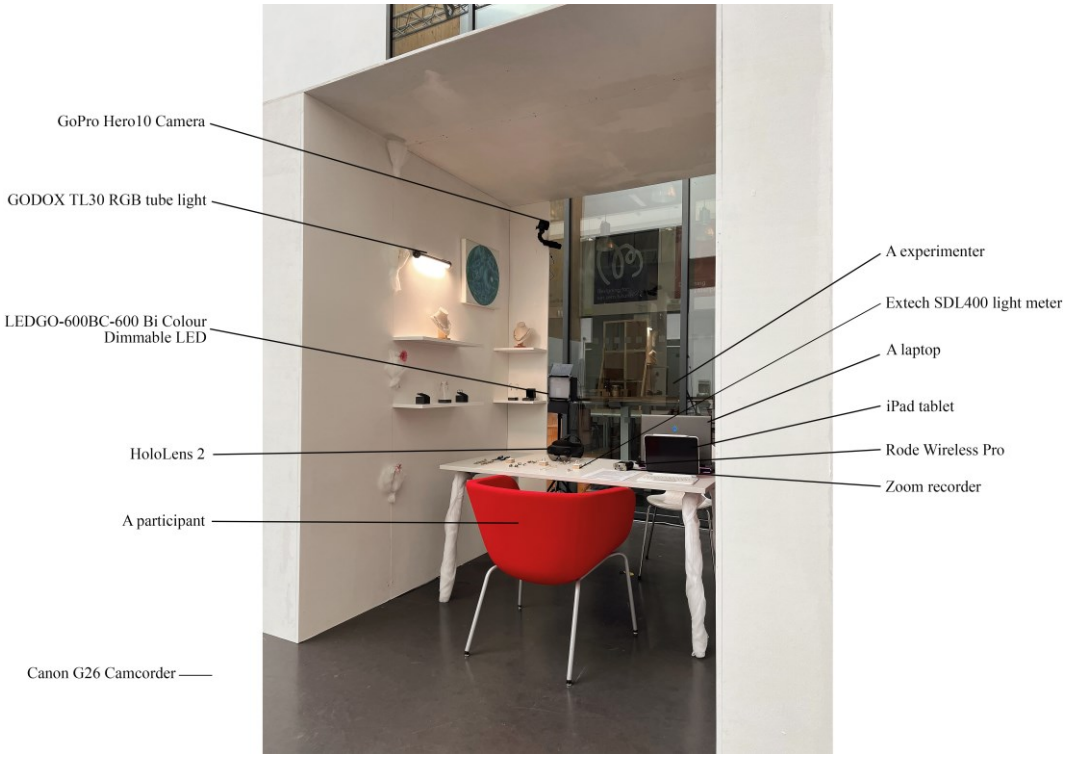


Figure 7.4 Experiment apparatus setup

Other Assets

Three power extensions are provided to ensure continuous electricity to all equipment. A table size of 1.5m by 0.6m was used to test the spatial dimensions and display products. Also provided were jewellery display stands and accessories, a light meter, a laser distance meter, hazard tape, and a magnetic stripe.

7.4.4 Pop Up Store Design and Build Scheme

Experimental Store Design and Planning

Figure 7.5 illustrates the experimental installation of timber panel dimensions and assemblies. Figure 7.6 shows the floor plan layout of the installation, and Figure 7.7 provides the elevation dimensions. The walls were made of 20-mm thick plywood, and the ceiling plywood was 15mm thick. A total of seven standard plywood panels were supplied. More details for the pop-up installation building processes are supplied in Appendix D.

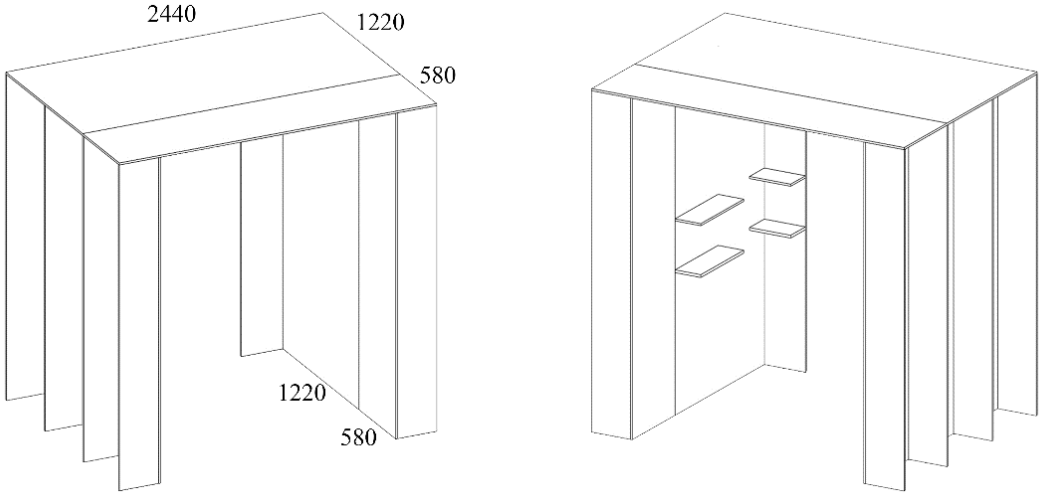


Figure 7.5 Axonometric of the pop-up store installation

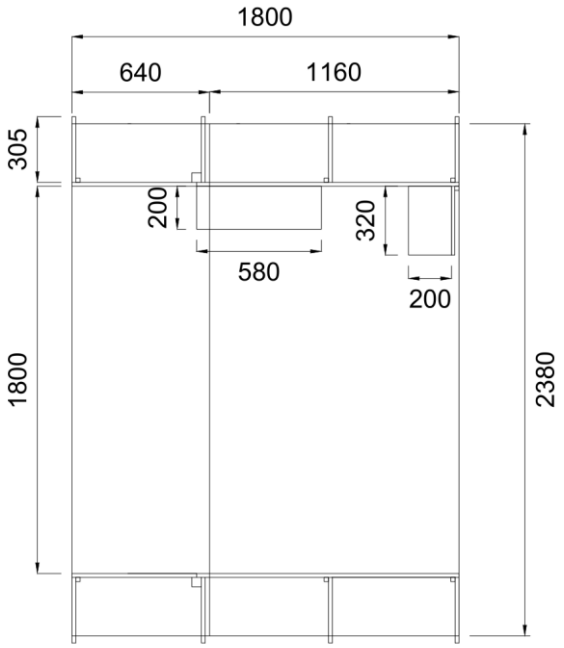


Figure 7.6 Pop-up store floor plan

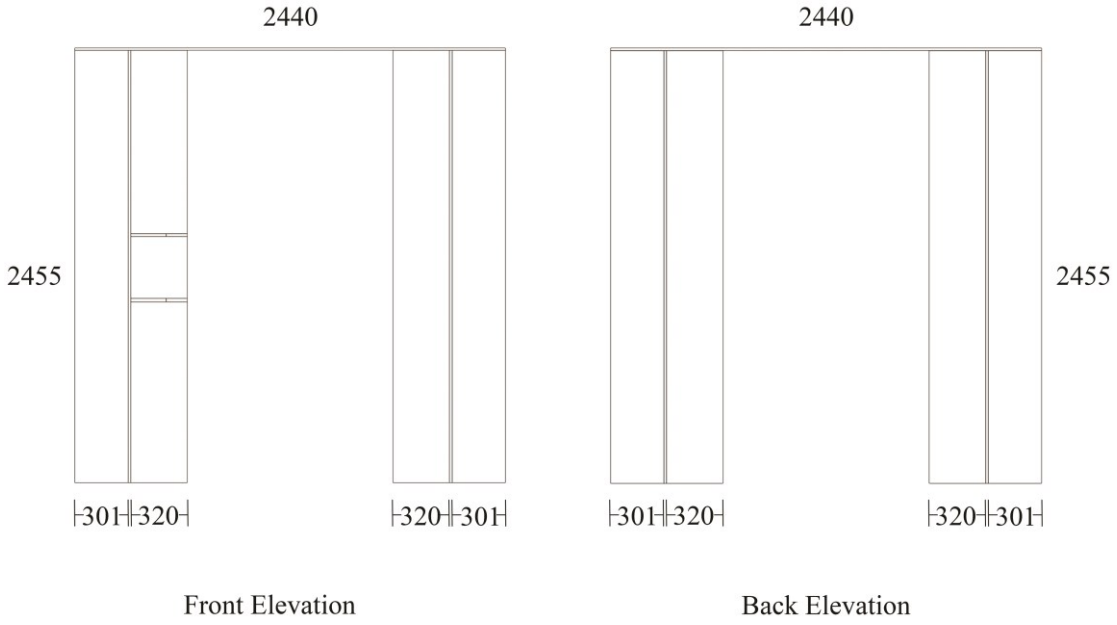


Figure 7.7 Installation elevations

Pop-up store Experiment Build Scheme

Figure 7.8 diagrams the process of building the experimental environment for the pop-up installation and presents the outcome of the experimental environment in Figure 7.9.

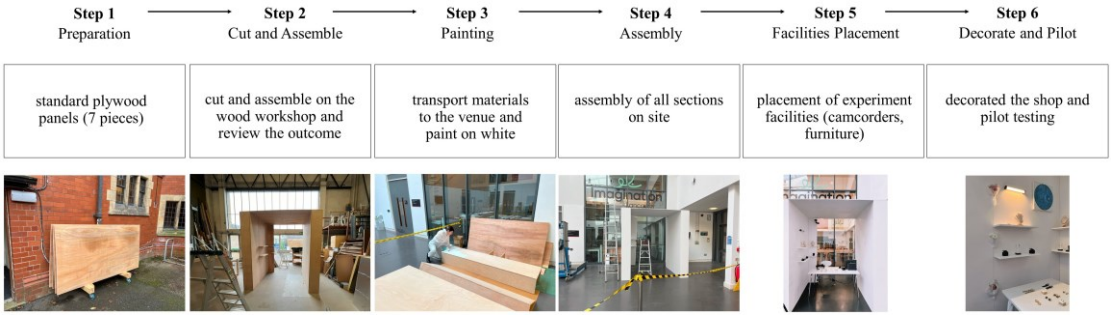


Figure 7.8 Installation build processes



Figure 7.9 Pop-up store effect, plywood, 2446×1800×2455 mm

7.4.5 Data Collection and Process

Part A

Participants were first given the information sheet and asked to sign the consent form. Next, they were given the MR headset to wear and were allowed some time to familiarise themselves with the controls of the headset. The researcher observed the participant's interactions with the MR content during this time through the connected laptop. Once the participants were comfortable with the HoloLens 2, they started the

experiment. The participants filled out questionnaires both after each block and at the end of the experiment. The learning and order effects were counterbalanced by changing the order of the conditions per participant using a Latin square design. There are 77 questions in seven groups in total. The study was conducted on Qualtrics to collect the quantitative responses from participants and the qualitative responses collected from video recordings. A pilot study was conducted to test the validity of the questionnaire and experimental procedure. The data from these five participants was discarded. 64 participants completed the actual study.

Before beginning the experiment, the experimenter measured the ambient noise levels using a sound meter to ensure the noise levels did not exceed 35 dBA. This was intended to avoid distraction and interference from ambient sound. The experiment is ordered by colour, illuminance, colour temperature, merchandise display, privacy, spatial ratio and spatial dimensions. The design values order of colour, colour temperature, merchandise display, privacy, spatial ratio and spatial dimensions were chosen based on the Latin Square method to counter learning and order effects. However, the illuminance used a constant order followed by 200 lux to 500 lux, 60% to 90% intensity. Physiologically, when people enter a dark environment from a brighter one, pupils will dilate, which needs a period for them to adapt. When entering a bright from a darker environment, the human eye quickly adapts and regains normal visual function. Hence, the illuminance test needs to be carried out from dim to bright.

Colour

Experiments were undertaken using printed A0 size papers posted on the wall that were rapidly modulated to simulate the colour variation of the walls. Based on the chosen order of the colours, the experimenter set up the ambient wall colour and asked the participant to start the task on the colour background. Participants were told to observe both virtual product visualisation and operation difficulty, whether they had been affected during the wall colour change, and whether they preferred this colour as a store atmosphere. The participant was asked to complete the task at a speed they found comfortable and as accurately as possible. Once the task was completed for a colour condition, the participant answered the questions related to the colour. Next, the experimenter changed the ambient colour to the next one, and the sequence was

repeated. Once all conditions were completed, the participant was allowed a three-minute break before continuing. Overall, each task took about 50 seconds to complete. Figure 7.10 shows the atmosphere of the store with three wall background colours. Figure 7.11 displays the effect of a set of virtual products with material alternations from the perspective of the user against a red, blue and white facade. The subjects were asked to consider the effect of product colours, including ring bases and stones. The gemstones are not visible in the images but were shown during usage.



Figure 7.10 Colour test of the MR product access background (red, blue, white)

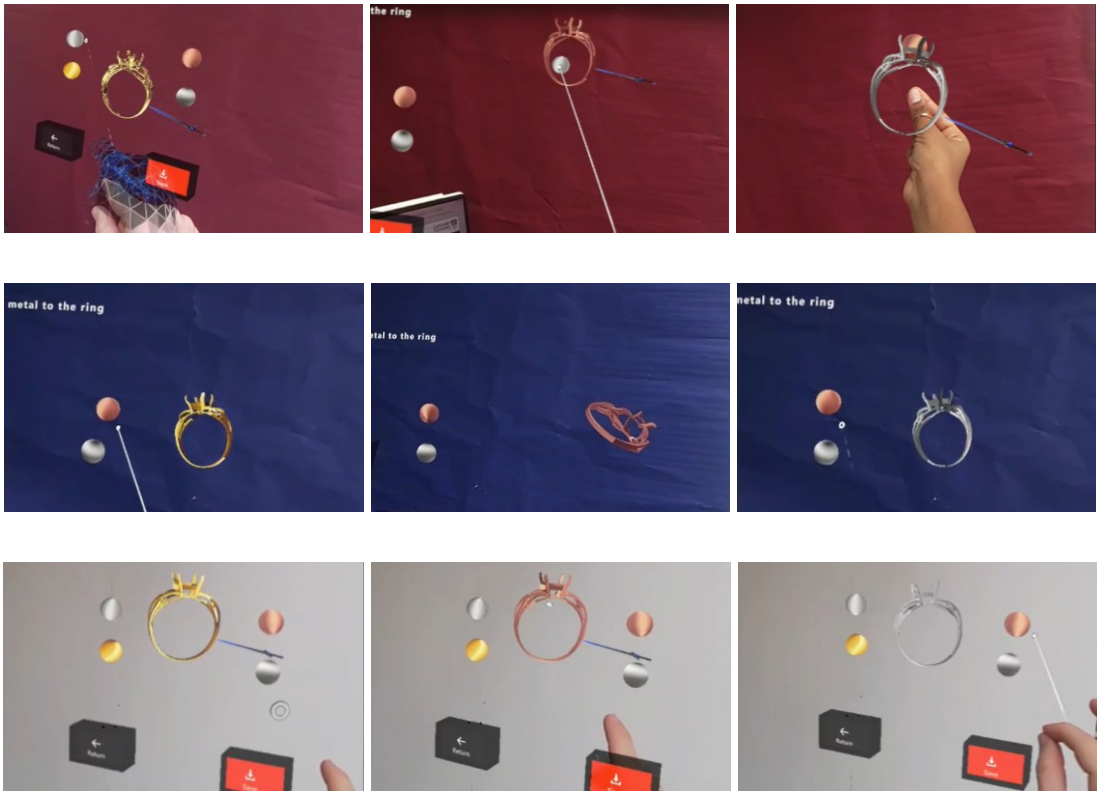


Figure 7.11 Comparison of virtual product effects on red, blue, and white walls

Illuminance

As the context is a retail environment, customers usually interact with the display cabinet products and the HMD's virtual objects. Also, height differences influence illumination. Therefore, the measurement has not been set to measure illuminance positioned parallel to the device waveguide, which is the position of the user's left eye – instead, the lux was measured based on the height of the product display cabinet. The light meter was placed horizontally at the lowest display table level of 72cm. The experimenter varied the distance between the table surface and the surface of the lights and adjusted the dimmer on the environment light to measure 200 lux and then 500 lux. The headset was adjusted brightness at 60% intensity and then 90%. The participant answered the related questions once the task for one condition was completed. Then, the experimenter adjusted the lighting combinations and the sequence was repeated. Figure 7.12 shows the ambient light in dim (200 lux) and bright (500 lux). It can be seen that the real product is affected by the ambient light source. The variation of the device intensity is not reflected in the photos recorded from the first viewpoint, while the device intensity only affects the virtual product brightness but not the brightness variation of the natural product.



Figure 7.12 Environment lights on 200 lux (left) and 500 lux (right).

Colour temperature

A LEDGO-600BC-600 Bi-Colour dimmable LED light and a GODOX TL30 RGB tube light were used in the experiments to simulate changes in the colour temperature of the ambient light source through rapid modulation. Participants began the task according to the selected temperature sequence and were asked to simultaneously observe both

virtual products and actual product variations under distinct colour temperatures. They were asked to complete the task as accurately as possible at a comfortable speed. After completing the task in a particular colour condition, participants answered questions about that colour temperature. The experimenter then changed the colour temperature and repeated the processes. Figure 7.13 shows the effect of environmental ambience at cool (5000K), medium (4000K) and warm (3000K) colour temperatures. Since the device automatically intensifies the system contrast in a pre-recorded situation, it is not adequate to visualise the changes in the virtual product as affected by the light source from a first-view image or video.

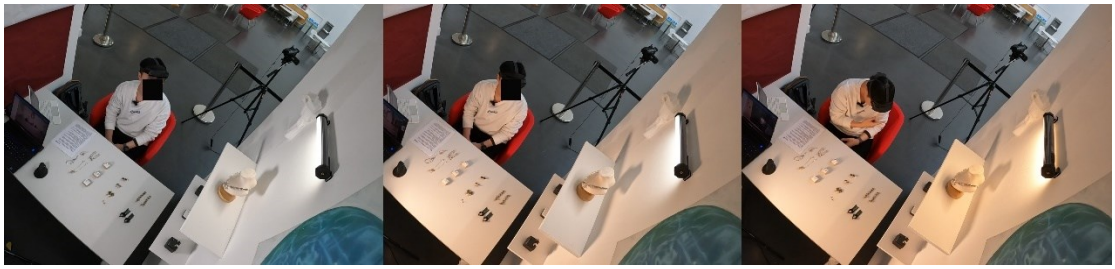


Figure 7.13 Colour temperature of 5000K (left), 4000K (middle), 3000K (right).

Merchandise display

The jewellery table stand and jewellery were displayed in the planar table condition. Users were asked to move the products above the table and complete the MR task, followed by answering questions about the manner of display. The experimenter asked participants to move the virtual product on the vertical shelf, complete the tasks, and repeat the process. Participants were told, “Please consider your overall body interaction postures, body comfort, merchandise visual display methods during the task, and complete the questions”. Figure 7.14 demonstrates the visual effect of the product in the first-person perspective, where real and virtual products are represented differently, and system interfaces are visualised distinctly. Figure 7.15 shows the variation in the way users interact with vertical and horizontal products in the third-party view. The participant stretches physically when using the vertical display, and bending and head-down movements are generated when the participant interacts with the products on the counter.

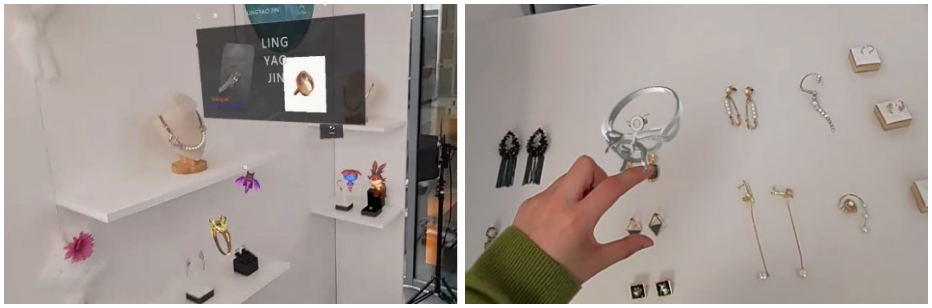


Figure 7.14 Vertical displays of first perspective (left). Horizontal display of first perspective (right).



Figure 7.15 Vertical displays of interactive poses of third perspective (left). Horizontal display of interactive poses of third perspective (right).

Privacy

After the user has completed all the previous tasks, the experimenter describes to the user, “In your previous operation, I did not read your browsing window. Please fill in some questions”. Subsequently, the experimenter informed the user, “I am now watching your browsing screen through the computer screen (show the screen to the participant)”, and asked the subject to complete an MR task. The questions were filled in after the task was completed. Finally, the experimenter put on a second HoloLens 2 and informed the subject that “There are three devices that allow the assistant to watch your browser. The first is a headset” (Figure 7.16) and showed three devices, respectively, asking the subject to complete an MR task and fill in the questions after completing the task.



Figure 7.16 The experimenter showed the subject one of the devices to assist.

Spatial ratio

The experimenter provided service to participants on opposite and beside sides. Participants were advised to consider the influence of the assistant's changed position on the perception of the app's visual effect and service delivery method, then repeated the above procedure. Figure 7.17 illustrates the perspective of the customer and the perspective of a third party when the retailer is positioned across from the customer. The experimenter is partially obscured by the system. Figure 7.18 shows the viewpoint of the customer and the third party when the retail staff stands alongside the customer.

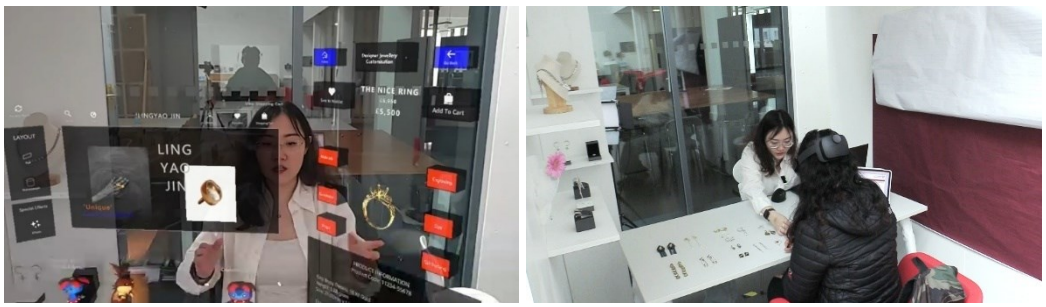


Figure 7.17 Stand opposite under the first perspective (left) and the third perspective (right).

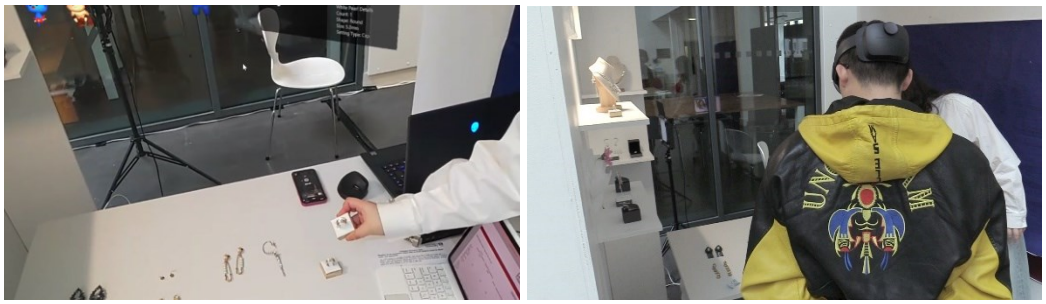


Figure 7.18 Stand beside under first perspective (left) and third perspective (right).

Spatial dimensions

In a mock store with a minimum usable space of 1.8m by 1.8m for two people, the experiment was conducted with a table spacing out the user and the retail assistant by an ergonomically sized safety distance for front-to-front access (Figure 7.19). A safety distance of 800 millimetres (mm), an average arm's length, was measured from the edge of the table in the direction of the user to the direction of the retail assistant. The distance boundary was signalled with hazard tape on the floor on the retailer's side to ensure no physical collision could occur between the two parties involved in using the device. This experiment installation was designed to serve the minimum dimension of the longitudinal space, so that it would remain face-to-face throughout, except for the spatial ratio test, where the experimenter stands alongside the participant. Figure 7.20 shows the body movement of the user sitting and standing. The experimenter later moved the table away backwards, and the user was able to walk around the store (Figure 7.21). The participant was asked to start the task based on the three postures chosen. The participant replied to the questions associated with that posture. The previous steps of the study were repeated in such a manner.

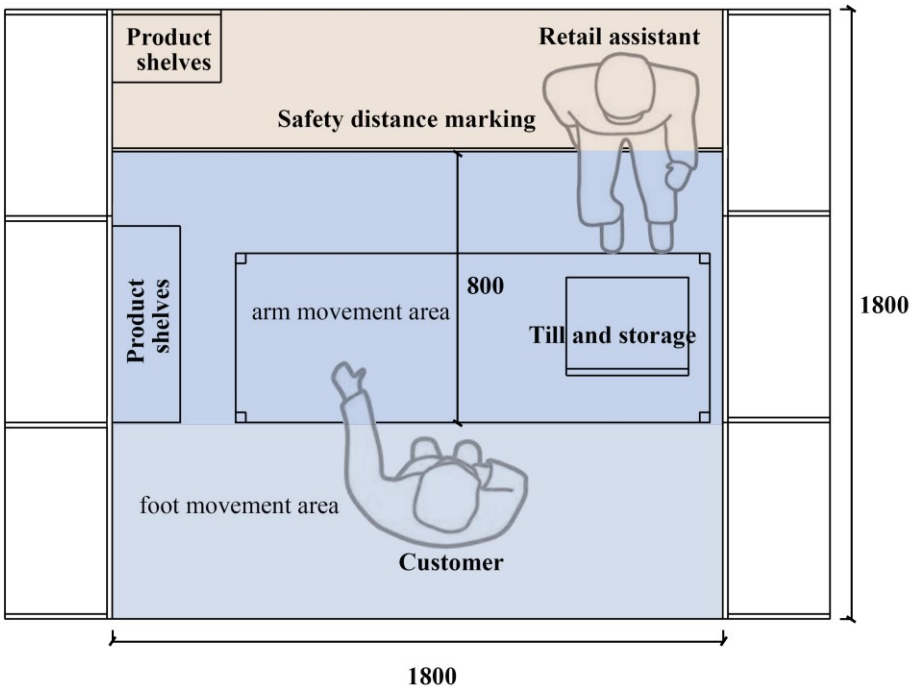


Figure 7.19 Relation of distance (mm)

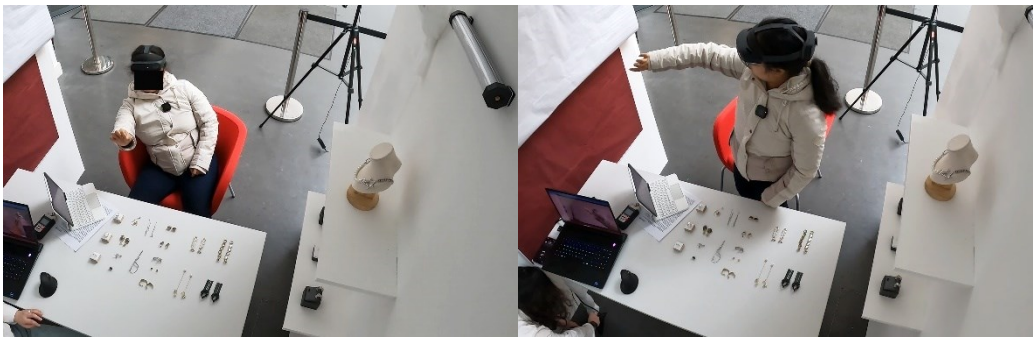


Figure 7.20 Sit and stand poses of use

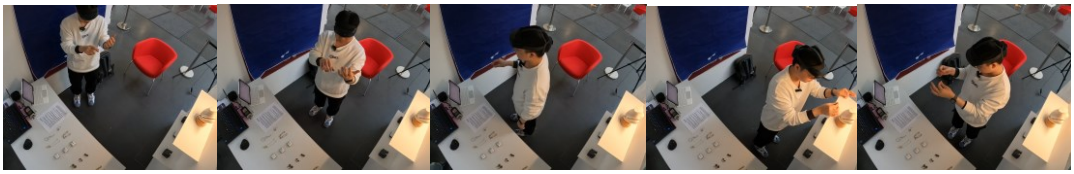


Figure 7.21 Walk poses of use

Part B

After the participants had completed the experience (approximately 15 minutes), they were invited to respond to a questionnaire, and then interview questions evaluating the MRPC and the MR purchase experience.

7.4.6 Data Analysis

Part A

The questionnaire was statistically analysed using IBM SPSS version 29 statistical software. The Analytic Hierarchy Process (AHP) weight analysis is used to identify the order of impaction of factors. It provides the weighted importance of each factor that impacts the design of MR interiors (sub-question 1). Secondly, each participant experiences all values for each dimension, so the analysis employed repeated measures. The analysis was carried out as a within-subject full factorial design with gender and age groups as the between-subjects factors, using repeated measure analysis of variance (ANOVA) (sub-questions 2 and 3). Frequency subtotal answered the only non-scale question regarding what device was used to share the screen and when it was shared for the privacy design factors. The reliability analysis of the scale questions showed a

Cronbach's α of 0.892, indicating good reliability. The qualitative data were processed on NVivo 12 for thematic analysis.

Part B

The 22 questions were standardised by making the units and directions consistent. The questionnaire included six dimensions of scale questions, which required testing the reliability of each dimension. The Cronbach's alpha values for the scale questions are PU (α = 0.80), PEU (α = 0.78), PUID (α = 0.69), ATU (α = 0.86), BIU (α = 0.86), and PI (α = 0.83), which indicate high reliability. The overall validity of the KMO value was 0.85, implying good validity. In the subsequent section, the data were analysed using least squares and hierarchical linear regressions, Pearson correlation, and descriptive analysis.

The interview data were imported into NVivo software for thematic analysis. Through random sampling, 24 subjects out of 64 were used for thematic analysis, and six samples were randomly reserved from the remaining samples for the saturation (Guest et al., 2006). The reserved samples were not found to generate new concepts, indicating that the theory is saturated. The coding procedure followed by grounded theory is structured as three hierarchies (concepts, subcategories, and themes) and is constantly compared during coding (Glaser and Strauss, 1999).

7.4.7 Participant Demographics

The research was conducted in a laboratory environment at a university in the United Kingdom for fourteen consecutive days from March to April 2024. Parts A and B were the same group of participants. Participants were recruited through posters, emails, snowballing and social media. The subject demographics consisted of 64 samples, including 26 females and 38 males, nationalities from eleven countries. The age band is 18-25 with 23 subjects, 26-35 with 36 subjects, and 36-55 with five subjects (Table 7.3). The age mean approximation is 27.5.

Table 7.3 Participant demographics of Study six

Demographics		N (n=64)	Per cent (100%)
Gender	Female	26	40.6
	Male	38	59.4
Age	18-25	23	35.9
	26-30	27	42.2
	31-35	9	14.1
	36-40	3	4.7
	41-45	1	1.6
	51-55	1	1.6
Nationality	Europe	2	3.1
	Asia	58	90.6
	Africa	3	4.7
	South America	1	1.6
Occupation	Employed	12	18.8
	Unemployed	2	3.1
	Student	53	82.8
	Self-employed	1	1.6
Education	High school	2	3.1
	Attended college/University	2	3.1
	Bachelor's degree	11	17.2
	Master's degree	24	37.8
	Doctorate degree	25	39.1

Randomly choosing the group that refused to participate and asking for reasons, including lack of time and distance issues, and there were no demographic differences between this group and the participants (gender and age). Moreover, participants were asked about their level of attention to XR or shopping, and no significant difference in responses was found between participants with high attention and with prior experience (n=2) and those with average attention. This study is grounded in a globalised consumer community. Hence, there are no remaining restrictions on participants who voluntarily registered and were aged over eighteen. The participants were compensated for their time with a £5 Amazon voucher. The experiment was carried out after approval by the University Ethics Committee.

7.5 Results

7.5.1 Part A: Mixed Reality Retail Store Interior Environment Design

Analytic Hierarchy Process Results

Table 7.4 shows the judgment matrix rated by analytic hierarchy process (AHP) analysis, which calculates the importance of the design factors. Illuminance has the highest weight. The other six factors can be grouped into two similar weighted groups via group (spatial dimension, colour temperature and colour) and group (merchandise display, spatial ratio and privacy) (Figure 7.22).

Table 7.4 Analytic hierarchy process analysis

Factors	Eigenvectors	Weight	Maximum eigenvalue
Colour	1.077	15.384%	7.000
Illuminance	1.435	20.493%	
Colour temperature	1.117	15.960%	
Merchandise display	0.747	10.674%	
Privacy	0.719	10.274%	
Spatial ratio	0.733	10.468%	
Spatial dimensions	1.172	16.747%	

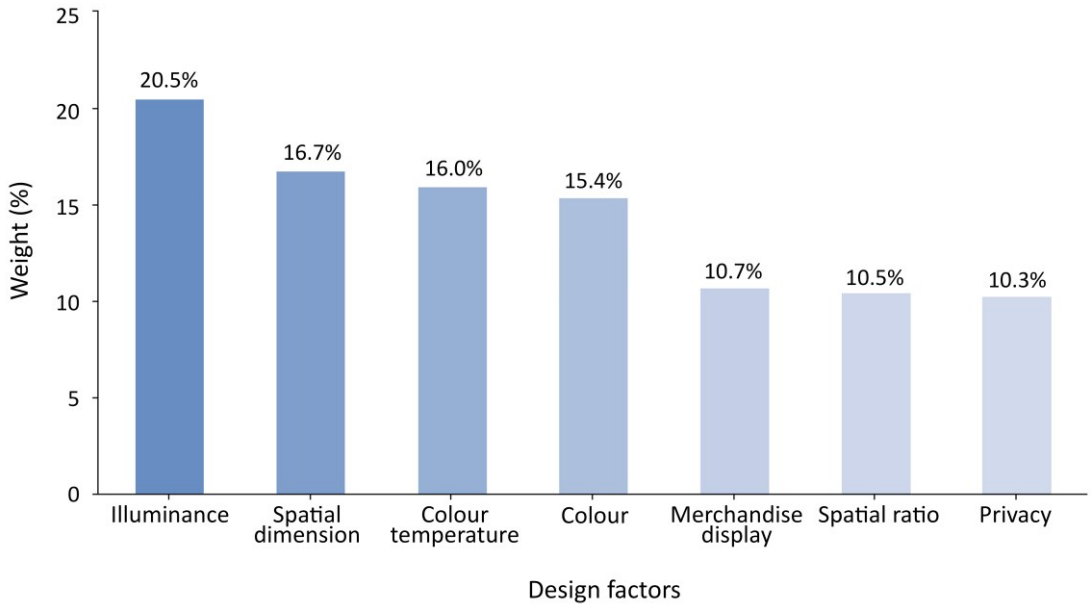


Figure 7.22 Analytic hierarchy process of the weight of design factors

Repeated-measure ANOVA Results

Table 7.5 counts the frequency of responses to the preference for device type in the privacy factor and calculates the responses to the preference for privacy frequency. 60.9% of consumers preferred a share screen when needed (public access screen), 26.6% of consumers did not have a preference, and 12.5% of consumers stated that they preferred a share screen when browsing (assistant access only). Table 7.6 provides a tabulation of repeated measure ANOVA, each value associated with design factors.

Table 7.5 Frequency of screen share devices and response rate of privacy

Factors	Values	N (%)
Screen share devices	An assistant wears a headset (*n*=39)	39 (60.9)
	An assistant uses a tablet (*n*=43)	43 (67.2)
	An assistant uses a PC screen (*n*=20)	20 (31.3)
Privacy	Share screen when needed	39 (60.9)
	Both equal	17 (26.7)
	Share screen when browsing	8 (12.5)

Table 7.6 Descriptive analysis of repeated-measures ANOVA on gender versus factors

Factors	Values	Values (Mean±S. D.) (n=64)	p	Gender (Mean± S. D.) Female (*n*=26)	Male (*n*=38)	p
Colour	Red	2.98±0.92		2.75±0.96	3.15±0.87	
	Blue	3.60±0.96	<0.05*	3.46±1.09	3.70±0.86	N.S.
	White	3.33±1.07		3.27±1.08	3.37±1.08	
Illuminance	Dim light + 60% intensity	2.93±0.86		2.89±0.93	2.95±0.81	
	Dim light + 90% intensity	3.85±0.78		3.85±0.83	3.86±0.76	
	Bright light + 60% intensity	2.93±1.02	<0.05*	2.92±1.11	2.94±0.96	N.S.
	Bright light + 90% intensity	3.49±1.04		3.39±1.05	3.56±1.04	
Colour temperature	Warm	3.37±1.11		3.27±1.16	3.44±1.08	
	Neutral	3.55±0.91	N.S.	3.53±0.97	3.57±0.88	N.S.
	Cool	3.36±1.05		3.29±1.23	3.41±0.93	
Merchandise display	Horizontal	3.35±0.92	N.S.	3.47±0.94	3.27±0.91	N.S.
	Vertical	3.53±1.08		3.64±0.95	3.45±1.17	
Privacy	Share screen when needed	3.81±0.92		3.76±1.09	3.84±0.81	
	Share screen when browsing	2.82±1.01	<0.05*	2.73±1.09	2.88±0.96	N.S.
Spatial ratio	Opposite side	3.34±1.01	N.S.	3.00±0.93	3.58±1.00	N.S.
	Same side	3.40±1.04		3.51±1.14	3.33±0.98	
Spatial dimension	Stand	3.60±0.93		3.53±1.02	3.65±0.88	
	Sit	3.81±1.05	N.S.	3.84±1.00	3.80±1.09	N.S.
	Walk	3.39±1.10		3.47±1.11	3.33±1.09	

*P<0.05 Significance difference, N.S.: p>0.05

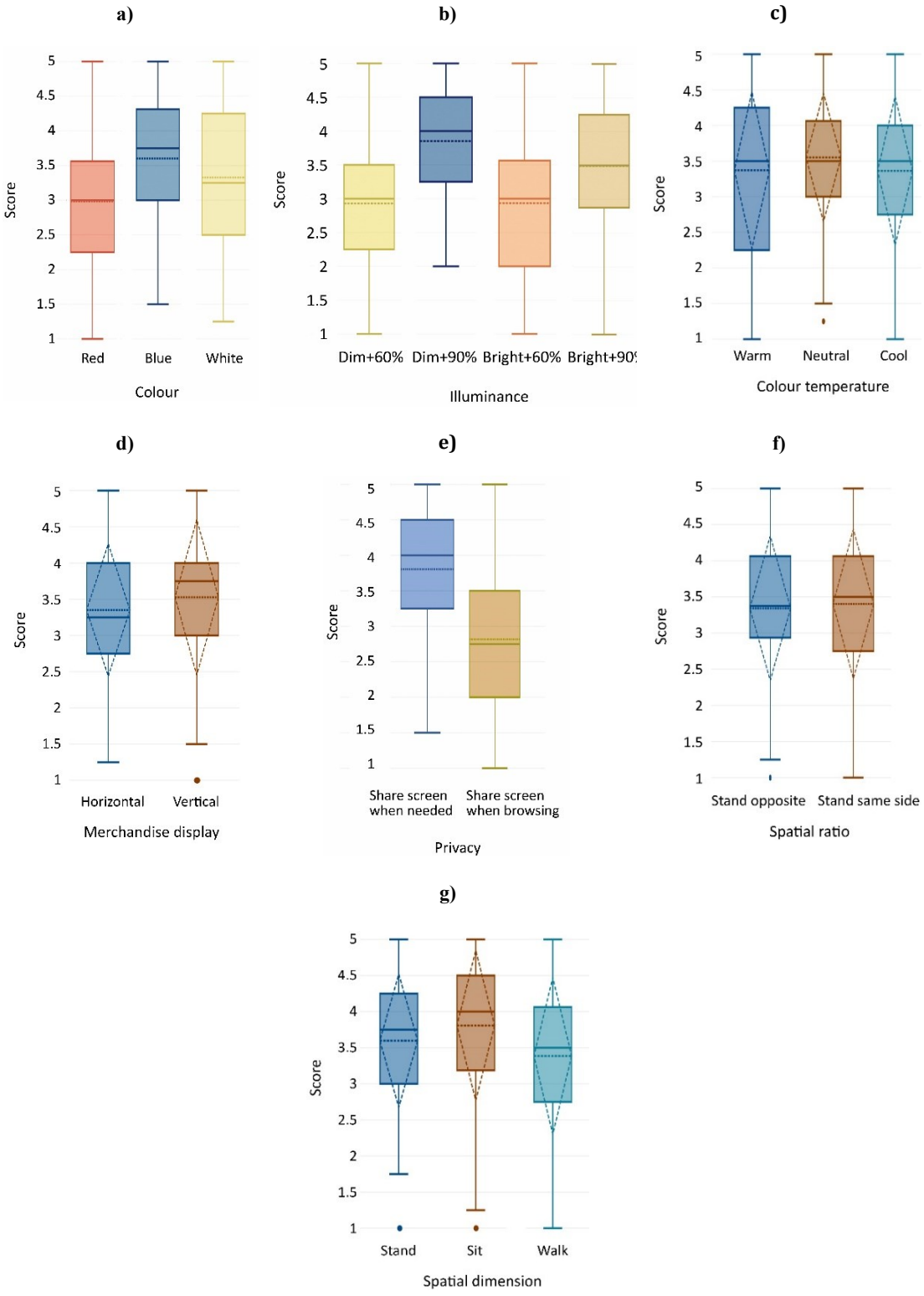


Figure 7.23 Box plot of average score a) Colour; b) Illuminance; c) Colour temperature; d) Merchandise display; e) Privacy; f) Spatial ratio; g) Spatial dimensions

Using repeated-measures ANOVA with Colour, Illuminance, Colour temperature, Merchandise display, Privacy, Spatial ratio and Spatial dimension as the repeated factor within-subjects and gender as the between-subjects factor. Mauchly's test of Sphericity was significant or not significant. Hence, Huynh-Feldt correction or Sphericity Assumed was used. Multivariate tests were significant or not significant, Wilks' Lambda was used as it is robust.

Colour versus gender. Between subjects, the main effect of colour is statistically significant (Figure 7.23a), λ (Wilks') = 0.757, $F(2,61) = 9.776$, $p<0.001$. However, the interaction of gender versus colour is not statistically significant. Within-subjects, the main effects of colour are statistically significant, Huyn-Feldt approximation for sphericity, $F(1.849, 114.645) = 6.370$, $p<0.05$. Pairwise comparisons show a significant difference between an average experience satisfaction for red ($\mu_{Red} = 2.98$) and blue ($\mu_{Blue} = 3.60$), $p<0.05$.

Illuminance versus gender. Between subjects, the main effect of illuminance is statistically significant (Figure 7.23b), λ (Wilks') = 0.507, $F(3,60) = 19.433$, $p<0.001$. However, the interaction of gender versus illuminance is not statistically significant. Within-subjects, the main effects of illuminance are statistically significant, Huyn-Feldt approximation for sphericity, $F(3, 186) = 17.052$, $p<0.001$. Pairwise comparisons show a significant difference ($p<0.001$) between average experience satisfaction for illuminance in dim + 60% intensity ($\mu_{D60} = 2.93$) versus dim + 90% intensity ($\mu_{D90} = 3.85$), dim + 60% intensity ($\mu_{D60} = 2.93$) versus bright +90% intensity ($\mu_{B90} = 3.49$), and dim + 90% intensity ($\mu_{D90} = 3.85$) versus bright + 60% intensity ($\mu_{B60} = 2.93$).

Colour temperature versus gender. Between subjects, the main effect of colour temperature is statistically not significant, λ (Wilks') = 0.963, $F(2,61) = 1.176$, $p>0.05$. The interaction of gender versus colour temperature is not statistically significant. Within-subjects, the main effects of colour temperature are statistically insignificant, Huyn-Feldt approximation for sphericity insignificant, $p>0.05$.

Merchandise display versus gender. Between subjects, the main effect of merchandise display is statistically not significant, $p>0.05$. The interaction of gender versus merchandise display is not statistically significant. Within-subjects, the main effects of

merchandise display are statistically insignificant, Sphericity Assumed approximation for sphericity insignificant, $p>0.05$.

Privacy versus gender. Between subjects, the main effect of privacy is statistically significant (Figure 7.23e), λ (Wilks') = 0.615, $F(1,62) = 38.758$, $p<0.001$. The interaction of gender versus privacy is not statistically significant. Within-subjects, the main effects of privacy are statistically significant, Sphericity Assumed approximation for sphericity, $F(1, 62) = 38.758$, $p<0.001$. Pairwise comparisons show a significant difference between average experience satisfaction for share screen when needed (μ_{SCWN}=3.81) and share screen when browsing (μ_{SCWB} = 2.82), $p<0.001$.

Spatial ratio versus gender. Between-subjects, the main effect of spatial ratio is statistically not significant, $p>0.05$. The interaction of gender versus spatial ratio is not statistically significant. Within-subjects, the main effects of spatial ratio are statistically insignificant, and Sphericity Assumed approximation for sphericity is insignificant, $p>0.05$. While there is no significant difference observed for both within-subjects and between-subjects effects, it is noted that there was a significant difference in average score for stand opposite, $\mu_{Female} = 3$, versus $\mu_{Male} = 3.57$.

Spatial dimension versus gender. Between subjects, the main effect of spatial dimension is statistically not significant, λ (Wilks') = 0.931, $F(2,61) = 2.248$, $p>0.05$. The interaction of gender versus spatial dimension is not statistically significant. Within-subjects, the main effects of spatial dimension are statistically not significant, and the Huyn-Feldt approximation for sphericity is not significant, $p>0.05$.

The analysis with repeated-measures ANOVA for the design factors versus age is shown in Table 7.7.

Table 7.7 Repeated-measures ANOVA on age and factors

Dimensions	Values	Age (Mean±Std. Deviation)			p
		18-25 (*n*=23)	26-35 (*n*=36)	36-55 (*n*=5)	
Colour	Red	2.91±1.01	2.96±0.85	3.50±1.08	N.S.
	Blue	3.64±0.93	3.58±1.04	3.60±0.38	
	White	3.46±1.04	3.24±1.12	3.35±1.08	
Illuminance	Dim light + 60% intensity	3.03±0.85	2.96±0.85	2.25±0.77	N.S.
	Dim light + 90% intensity	3.93±0.72	3.88±0.83	3.30±0.60	
	Bright light + 60% intensity	3.18±0.97	2.76±1.06	3.00±0.77	
	Bright light + 90% intensity	3.48±0.90	3.46±1.17	3.80±0.62	
Colour temperature	Warm	3.69±1.04	3.18±1.11	3.30±1.29	<0.05*
	Neutral	3.40±0.70	3.73±0.93	2.95±1.36	
	Cool	3.22±1.10	3.36±1.06	4.05±0.41	
Merchandise display	Horizontal	3.66±0.89	3.25±0.90	2.65±0.80	N.S.
	Vertical	3.43±1.23	3.51±1.03	4.10±0.58	
Privacy	Share screen when needed	3.91±0.95	3.85±0.86	3.00±1.03	N.S.
	Share screen when browsing	2.90±0.89	2.72±1.11	3.15±0.78	
Spatial ratio	Opposite side	3.37±0.97	3.36±1.08	3.10±0.74	N.S.
	Same side	3.45±0.98	3.38±1.12	3.35±0.89	
Spatial dimension	Stand	3.90±0.62	3.40±1.09	3.65±0.55	<0.05*
	Sit	3.57±1.16	4.06±0.90	3.15±1.17	
	Walk	3.53±1.11	3.16±1.07	4.35±0.49	
***P<0.05 Significance difference, N.S.: p>0.05**					

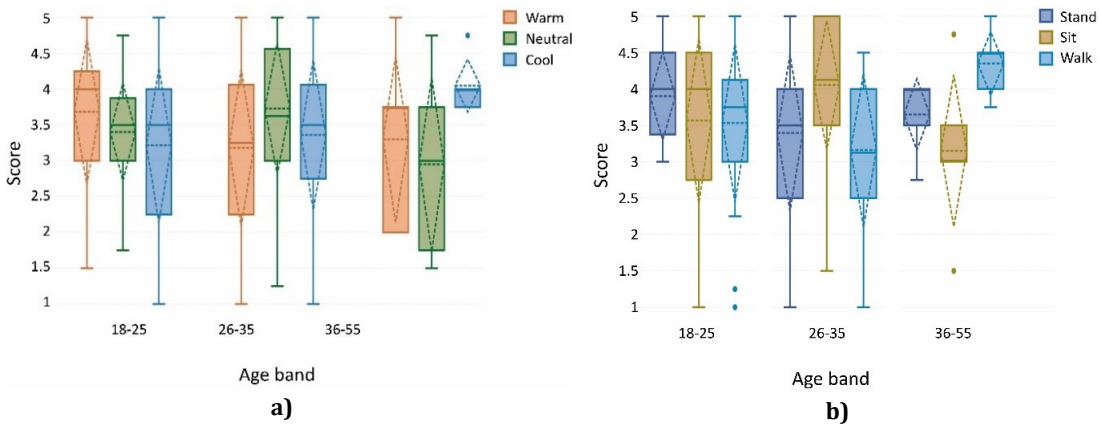


Figure 7.24 Box plot (±Std.D.) contrasts a) colour temperature versus age; b) spatial dimension versus age

Colour temperature versus age. The interaction of age versus colour temperature is statistically significant, λ (Wilks') = 0.824, F(4,120) = 3.045, $p<0.05$. The significant difference ($p<0.05$) noted for pairwise comparisons was for the age group 26-35, who showed a higher average experience satisfaction for neutral colour temperature (($\mu_{Neutral}$ = 3.73) than warm colour temperature ((μ_{Warm} = 3.18) (Figure 7.24a).

Spatial dimension versus age. Between-subjects, the interaction of age versus spatial dimension is statistically significant, λ (Wilks') = 0.795, F(4,120) = 3.657, $p<0.05$. Within-subjects, a significant difference between spatial dimension versus age interaction effect, F(4, 122) = 3.883, $p<0.05$. Pairwise comparisons show a significant difference between average experience satisfaction for spatial dimension versus age ($p<0.05$). Age 26-35 had a significant difference in standing (μ_{Stand} = 3.40) versus sitting (μ_{Sit} = 4.06), and sitting versus walking (μ_{Walk} = 3.16), while ages 18-25 and 36-55 had no significant difference in spatial dimension (Figure 7.24b).

Colour, Illuminance, Privacy, Merchandise display, and Spatial ratio Versus Age show no statistically significant interaction effect.

7.5.2 Part B: Mixed Reality Product Configurator System Design

Qualitative Results

There are 101 initial concepts, twelve subcategories, and three theme categories generated for MRPC. The three thematic categories were ***advantages***, ***improvements***, and ***new design features***. Users discussed the advantages of the current system in terms of affective value, experience optimisation, functional demands and comfort. Improvements were suggested in terms of UI design, system experience, functionality, hardware and physiological comfort. Finally, discussions were generated regarding the generation of new design features for system design needs for the overall shopping experience and additional opinions on MR shopping. The evidence from user experience will be exemplified below.

MRPC Advantages. Affective value is experienced from social escape, product satisfaction, and positive sentiment. MRPC comfort was commonly cited as not

requiring improvement, with the main complaint coming from the heavy weight of the device. Experience optimisation shows advantages such as fun, convenience and novelty. Self-sufficiency and freedom of fitting are additional advantages that MRPC delivers in comparison to other systems. Some empirical evidence is presented below:

> *"I don't have to go and talk to sales as often, even if it has a feature for this kind of advice, even I can get away with not having to ask the sales for too much advice" (P22).*

> *"And compared to you letting the sales express your ideas, talk to the sales to operate, certainly is not as good as you directly is to use this APP with this thing to customise your own[...]you don't know what he will eventually present to you if he presented you are not satisfied with, to repeatedly change, may not be very convenient" (P46).*

> *"For example, this jewellery with this dress what is the look, because I definitely want to match jewellery with the clothes, I think it's also the physical shop is very difficult to give me, because I can't change 20 sets of clothes in a row in someone's shop to try this jewellery" (P3).*

MRPC Improvement. This mainly reports on design and functional improvements to the system, presents user experience that needs to be optimised in conjunction with the physical shop experience, discusses downsides of the hardware, and parts of the physiological comfort that can be improved. This includes material – it is suggested to improve the realism of textures closer to actual products, such as features of gloss and colour differences. In terms of size, it is suggested to have a product automatic detection and adsorption to user body and offering size recommendations. Pin button – partial users report that it causes vertigo, improves the transparency of UI during movement, or eliminates this feature. Sound aids – Audio could be provided for product information. The special effect recommendation function is combined with the special effect cartoon avatar. One user mentioned that the dim ambient light caused eye fatigue, and two users reported vertigo. One of the users described their feelings after using the following mode (pin button):

> *"I get motion sickness, and I'm sensitive to that kind of stuff when it's jiggling" (P46).*

MRPC New Design Features. Users suggest that the in-store experience, the environment and the MRPC are inseparable and form a holistic experience. Moreover,

users derived extended opinions about familiarity, learning costs, and a sense of tangibility. A participant stated that:

> *"Its (MR) interaction and 2D (online) is definitely not the same. Another is visual is not the same. One is you click the mouse, and this, you are directly reaching out or this way-pinch [...]. It is a plane, and then your mouse moves because this is a habit. But if you say into VR (MR), their feeling of interaction will be stronger, but the second point is that they are not familiar with it, and for the aiming of this thing may be the technology is not there yet" (P14).*

The results are concluded in Table 7.8 summarising participant suggestions for improvement based on the existing MRPC design. Table 7.9 lists new design features based on participants' preferences.

Table 7.8 Suggestions for MRPC iteration and improvement based on existing functions

Original Design	Improvement	New Design Features
Material	Improve the realism of textures closer to actual products, such as features of gloss and colour differences.	×
Gemstone	×	×
Engraving	×	×
Size	Adapt product fitting better to the body.	Product automatic detection and adsorption to user body and offer size recommendations.
Shape	Enhance the realism of textures to closely resemble actual products.	×
Gift packaging	×	×
Comparison	×	×
Shopping cart	×	×
Position reset button	×	×
Come over button	×	×
Pin button	Partial users report that it causes vertigo, improves the transparency of UI during movement, or eliminates this feature.	×
Instruction text	×	×
Sound aids	×	Audio for product information
Video	×	×
Visual aid	×	×
Picture cursor	×	×
Special effect	Changing the unified style of special effects to match the brand's style.	Add recommendation function combined with special effect cartoon/avatar.
Natural interaction gestures	Mainly on hardware issues: improving hand recognition accuracy, resolution, crash, speed of response, frame rate, and stability.	×
UI ergonomic comfort	×	×

Table 7.9 Future suggestions for undeveloped new design features

Function Design	Design Features
Assembly parameter bar	Add parameter bars to assembly platforms to help users change parameters such as edge radius, thickness.
Automatic information recognition	Add the function of identifying physical products and providing information.
Automatic windows folding	The interface should shrink automatically or with a tap when some windows are not in use.
Drawing scan	Scanning of hand drawings, uploading, and parameter modifications to provide a fully bespoke product.
Recommendation	Provide a complete package of outfit matching and usage scenario suggestions based on the user's product choice.
Payment	There is a need for a quick and fun MR payment experience, such as app-independent payments or a combination of apps and tills.
Outfit scene	When a user tries on a product, be able to try on other products simultaneously (namely, apparel and, or footwear).

Quantitative Results

Most of the independent and dependent variables of hypotheses are correlated with each other in Pearson correlation, while H2b is not valid. Table 7.10 displays the results of the least squares regression for the direct hypotheses (H1/2/3/4). Table 7.11 shows the causal relationships of the hypotheses requiring control variables, and all control variables were turned into dummy variables and subjected to a hierarchical regression test (H5/6/7/8). Figure 7.25 summarises the regression coefficients for overall hypotheses. The calculated effect size $f^2 = 0.135$ ($\alpha = 0.05$, power = 0.9) is close to medium, which suggests a moderate influence, significant predictive power, and practical significance.

Table 7.10 Least squares linear regression of direct hypothesis

Dependent variable	Independent variable	B	Std. Error	t	β	R^2	*F* value	p
ATU	Constant	2.191	0.778	2.816	-	0.068	4.509	$p<0.01$
	PUID	0.421	0.198	2.123	0.091			$p<0.05$
PEU	Constant	1.667	0.626	2.662	-	0.121	8.574	$p<0.05$
	PUID	0.467	0.159	2.928	0.349			$p<0.01$
ATU	Constant	0.558	0.444	1.257	-	0.512	31.936	N.S.
	PEU	0.140	0.125	1.116	0.116			N.S.
	PU	0.792	0.127	6.254	0.649			$p<0.01$
PI	Constant	0.768	0.415	1.848	-	0.466	26.587	N.S.
	PEU	0.211	0.117	1.802	0.196			N.S.
	PU	0.613	0.118	5.176	0.562			$p<0.01$

N.S.: $p>0.05$

Table 7.11 Hierarchical regression of indirect hypothesis

Dependent variable	Independent variable	B	Std. Error	t	β	R^2	F value	p
PI	Constant	1.091	0.314	3.472	-	0.537	35.391	p<0.01
	PUID_dummy	0.180	0.177	1.018	0.091			N.S.
	ATU	0.632	0.080	7.896	0.707			p<0.01
BIU	Constant	0.688	0.334	2.062	-	0.566	39.766	p<0.05
	PUID_dummy	-0.040	0.188	-0.213	-0.019			N.S.
	ATU	0.742	0.085	8.727	0.756			p<0.01
PU	Constant	1.756	0.391	4.496	-	0.258	10.588	p<0.01
	PUID_dummy	0.041	0.210	0.195	0.023			N.S.
	PEU	0.494	0.115	4.308	0.500			p<0.01
BIU	Constant	1.719	0.490	3.508	-	0.184	6.874	p<0.01
	PUID_dummy	0.052	0.264	0.195	0.024			N.S.
	PEU	0.498	0.144	3.458	0.421			p<0.01
BIU	Constant	1.108	0.410	2.703	-	0.474	18.056	p<0.05
	ATU_dummy	0.612	0.230	2.660	0.299			p<0.05
	PEU_dummy	0.193	0.177	1.091	0.110			N.S.
	PU	0.509	0.138	3.695	0.426			p<0.01
BIU	Constant	0.395	0.323	1.224	-	0.634	34.707	N.S.
	PU_dummy	0.192	0.148	1.297	0.112			N.S.
	PEU_dummy	0.063	0.152	0.416	0.036			N.S.
	PI	0.806	0.096	8.428	0.735			p<0.01
PI	Constant	1.169	0.258	4.535		0.633	34.49	p<0.01
	PU_dummy	0.371	0.96	0.386				N.S.
	PEU_dummy	1.011	0.823	1.228				N.S.
	BIU	0.673	0.08	8.428				p<0.01

N.S.: p>0.05

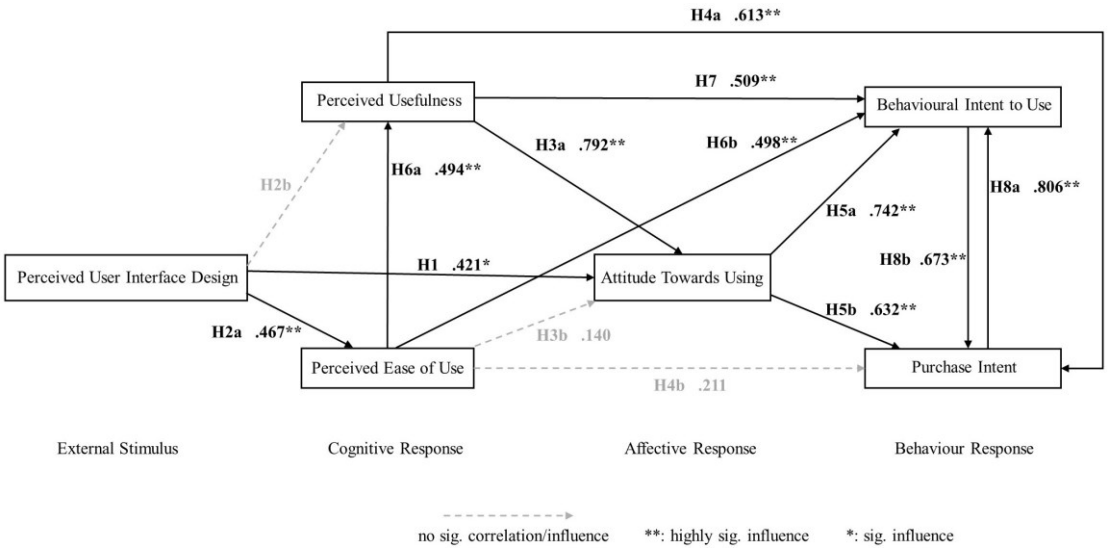


Figure 7.25 Mixed reality retail acceptance model

Perceived user interface design has a direct significant positive influence on attitude towards use, with a regression coefficient value of 0.421 (t = 2.123, p = 0.038<0.05). UI design has a direct significant positive influence on perceived ease of use (β = 0.467, t = 2.928, p<0.01), but UI design has no correlation with usefulness. UI design

influences users' judgement of the ease of use of MR technology, leading to the H3, which is whether ease of use would make users more willing to use it. H3 found that usefulness has a direct significant positive influence on attitude towards use ($p<0.01$), but ease of use does not have an influence relationship on attitude towards use ($p>0.05$). H4 proposed that perceived usefulness has a direct significant positive influence on purchase intent ($p<0.01$), and perceived ease of use does not have a direct significant positive influence on purchase intent ($p>0.05$). H5 (H0≠H1). This indicates that the more positive the perceived UI design, the more significant the positive impact of attitude towards use on purchase intent ($t = 7.896$, $p<0.01$). In H1, a relationship influence was found between UI design and attitude towards use. Consequently, UI was employed as a control variable to reduce alternative explanations and increase the validity of the results. ATU produces a significant positive influence on behavioural intent to use ($p<0.01$). H6 (H0≠H1), perceived ease of use will have a significant positive impact relationship on perceived usefulness and behavioural intent to use ($p<0.01$). H7 (H0≠H1), the more accessible the technology is perceived with a more positive attitude to use, and the more significant the positive influence of perceived usefulness on behavioural intent ($p<0.01$). H8 (H0≠H1), purchase intent and behavioural intent to use have a significant positive influence on each other ($p<0.01$).

7.6 Discussion

7.6.1 Part A: Mixed Reality Store Interior Environment Design Guideline

Discussion on the Design Factor Rank

Illuminance is the most weighted metric, followed by spatial dimensions (usage posture), colour temperature, and wall colour, which are the second weighted metrics. Product display, spatial ratio and privacy weight ratio are comparable as minor design factors. Although spatial ratio is considered less essential in user experience, designers could integrate it with spatial dimensions during design, which implies the simultaneous planning of spatial dimensions and spatial ratios.

From the perspective of user experience and physiology, technological accessibility and physiological comfort are critical factors in users making decisions to use a device. With mixed reality wearables, where the human eye is the primary organ involved in interacting with wearable equipment, designers and retailers should prioritise the physiological impact of ambient shop illumination and device light sources on the user. Equally important to physiological comfort and usability are the spatial dimensions, which are defined as the user's habitual pattern of engagement (standing, sitting, and walking). The scale of space required varies from form to form, which influences designer space layout planning, yet is also affected by retailer, brand shop sizes and financial investment.

Discussion on Impact of Design Factors

Colour. Blue is the colour with the highest average scores, followed by white. While red has been recognised in previous studies to stimulate user purchases, this has not been found to be a strength for utilising as background walls in an MR shop. Nevertheless, this does not imply that red as a decorative wall for brands affects the customer experience. Overall, it is suggested that designers and retailers could prioritise using *blue* as a background wall for the use of MR. One participant, for example, gave the following opinion about colour:

> *"If I had this gold ring, it wouldn't look very good on top of blue. Silver is clearer. I put that gold ring on top of the red to make it clearer, and it would be a lot easier to handle. If it were on top of white, it would not be as easy to handle. It feels like this is not just an effect of the colour of the wall but also what colour this thing is [...] a contrasting colour might feel easier to see" (P24).*

Illumination. In respect of both dim (200 lux) and bright (500 lux) light as an atmosphere light source in the shop, users assessed the use of device light at 60% intensity (221 nits) as inferior to 90% intensity (414 nits). The dim light paired with 90% intensity device light rated the greatest score compared to 200lux and 500lux atmosphere lights. As Microsoft suggests a limitation of device specifications, intense light leads to an unclear or unusable user interface. Users, in contrast, chose a dim ambient light paired with high-intensity device luminance for clearer optics. On the other hand, this result coincides with CIBSE (2018), which stated that high-value,

premium-quality shops typically use dim ambient light to create an upscale atmosphere (CIBSE, 2018). Therefore, an ambient light of *200 lux with 414 nits HMDs intensity* is recommended from a hardware and shop design perspective. One participant, for example, talked about the influence of environmental light illuminance:

> *"(Ambient light) I personally prefer brighter, and then you have all this detail, even though it's transparent (HMD glasses), the detail still doesn't quite check out when you look at it here (physical products)" (P22).*

Colour temperature. Neutral, cool and warm light remained consistent without considering demographics. In marketing and consumer studies, it is considered that cool light is often used in inexpensive shops, while warm light is often found in quality shops (Birren, 1982; Gifford, 1988; Markin et al., 1976; Mehrabian, 1976). In contrast, no difference was found between cool and warm light in MR shop environments for comprehensive user experience and interaction appraisal. Therefore, if retailers intend to deliver a premium shop atmosphere, a suggestion is to use *dim-lit and warm light* while users navigate and use virtual and real products with HMDs; perceptual evaluations of the virtual and authentic product experiences were optimal. For example, two participants have distinct notes for the colour temperature:

> *"In interfaces, I think warm light is best, but in this (physical product), I think neutral light is best" (P22).*

> *"I don't know why this warm light goes on. It's (virtual product) a bit unrecognisable, it'll dazzle a bit, and its natural colour isn't very visible every time" (P56).*

Merchandise Display. There is no statistical significance for vertical product displays versus horizontal displays, which suggests use of *both* merchandise display methods is valid. There are considerable differences in user interaction, body motion, field of vision height, and product display effects under horizontal and vertical display manners. It should be noted that the experiment used a 566-gram headset. The duration of wearing and the weight of headsets from different brands may affect customers' perceptions. Retailers and brands should be aware of this before acquiring devices. Considering the natural physiological curvature and comfort, if retailers intend to increase the dwell time in adoption to use HMDs, they might need to consider the group of consumers who had cervical spondylosis symptoms. As such, it is recommended that *vertical displays* be

more ergonomic for standing posture. When using vertical display after horizontal, a participant described that:

> *"I think vertical is a better way to go because vertical doesn't need to bend over or head down. A normal eye level can be seen that way, which is better for the cervical and lumbar vertebrae" (P14).*

Privacy. It is suggested that sharing a screen when needed was notably higher than sharing a screen when browsing. The use of tablets and headsets by assistants was shown to be the two most positively perceived. 67.2% of participants prefer that the assistants use tablets, 60.9% prefer that the assistants use an HMD, and 31.3% prefer that the assistants use a PC screen. Therefore, it is recommended that retail stores avoid using large screens to project the user interface. Retail assistants can use tablet devices to minimise the investment expense of HMDs. However, having at least one assist-HMD in a store is still necessary when the user needs assistance with operating apps. A participant commented on his device preferences:

> *"I wear this and can also look at his tablet just to be able to have a comparison. I think if you look at it on the screen, zooming in on this thing is a bit fake and not quite the same as the actual thing. Then, if both people are wearing this HMD, I feel like there's only one view, and there's no way to show the ring from multiple angles" (P62).*

Spatial ratio. Users perceived that the retail assistant standing on the same side of the space did not make a significant difference from the assistant standing across, which suggests *both* sides could be used. Although there is no major variation between these two service approaches in the overall evaluation of the user experience, they can be analysed and designed following the age band difference of the spatial dimension.

> *"I feel like opposite is a bit better because we can both […] You don't have to interfere from the side" (P62).*

Spatial dimensions. There is no significant difference between the three postures used. However, user age bands assessed sitting and standing as being significantly greater than walking. This suggests the necessity for retailers to establish seats for customers, and designers are encouraged to design an inclusive ergonomic space for both *sitting and standing* use. Therefore, considering the spatial ratio, there are 2 × 2 combinations that could be designed for space area. That is two people (a user and a retailer) sitting

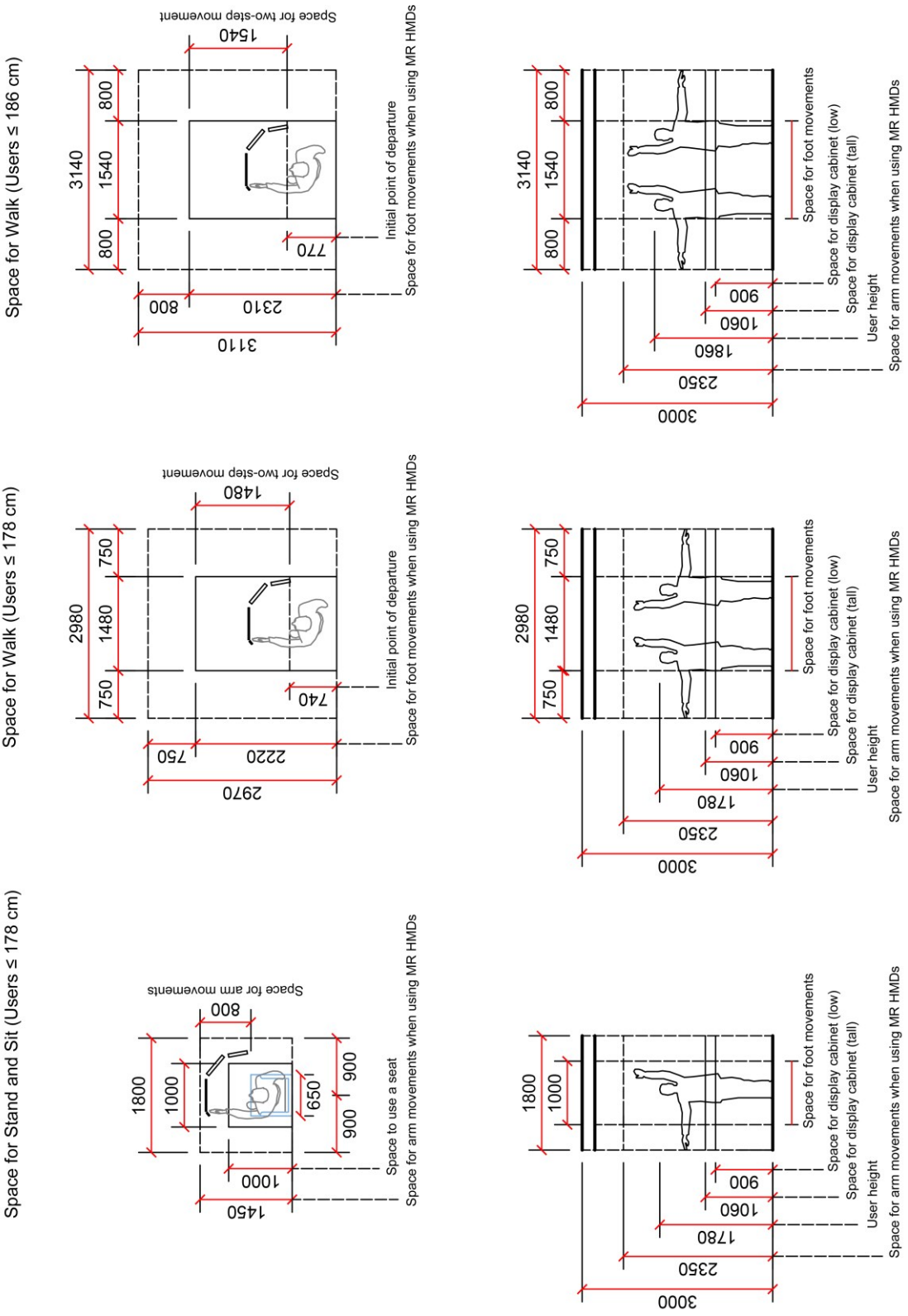
in a landscape area or longitude area, or two people (a user and a retailer) standing in a landscape area or longitude area. Participant 14 commented on the sitting posture, and Participant 29 commented on her concern about the walking posture:

> *"I think I would probably pick (products) longer. Standing would be more tiring" (P14).*
>
> *"You have a problem when you use Walk mode. It might be bumpy, right, when there are many people?" (P29).*

Discussion on Spatial Dimension in Interior Planning

The walking area for users of the MRPC was established in Chapter 6 (see also p. 187), while this chapter identified the minimum floor area required to meet the standing and seating needs of a single user and retailer. Additionally, user postures and service preferences were determined across different age groups and the general public. Based on these empirical findings, further design recommendations for spatial dimensions and ratios are provided here.

Figure 7.26 illustrates the recommended minimum dimensions for MR space design. The left column displays the minimum area required for standing and seating, while the middle and right sections show the area needed for walking. User heights are based on values of 178 cm and 186 cm. Height data indicates that 95% of women range between 150.6 cm and 178.9 cm, while 68% of men fall between 170.8 cm and 186 cm (Jelenkovic et al., 2016; Roser et al., 2013). For shops with limited space, a design accommodating a height of 178 cm is generally sufficient. However, when space allows, using dimensions suited for 186 cm is advised to meet the needs of broader customers better. Generally, a 178 cm design can be used for shops with predominantly female customers, whereas shops with mostly male customers may benefit from the 186 cm design. Although Chapter 6 results indicate a natural walking range of MRPC is typically 2:4 steps, store space limitation necessitates a reduced range of 2:3 steps (see also Section 6.5.1). This means users can take one step to the left and right, one step back, and two steps forward. Therefore, it is essential for designers to use symbols or signs to instruct or guide users to an optimal starting position.


Space for Walk (Users ≤ 186 cm)
Space for Walk (Users ≤ 178 cm)
Space for Stand and Sit (Users ≤ 178 cm)
Space for two-step movement
1540
3140
800
1540
800
770
2310
800
3110
Initial point of departure
Space for foot movements when using MR HMDs
Space for foot movements
Space for display cabinet (low)
Space for display cabinet (tall)
User height
Space for arm movements when using MR HMDs
900
1060
1860
2350
3000
Space for two-step movement
1480
2980
750
1480
750
740
2220
750
2970
Initial point of departure
Space for foot movements when using MR HMDs
Space for foot movements
Space for display cabinet (low)
Space for display cabinet (tall)
User height
Space for arm movements when using MR HMDs
900
1060
1780
2350
3000
Space for arm movements
800
1800
1000
650
900
900
1000
1450
Space to use a seat
Space for arm movements when using MR HMDs
Space for foot movements
Space for display cabinet (low)
Space for display cabinet (tall)
User height
Space for arm movements when using MR HMDs
900
1060
1780
2350
3000

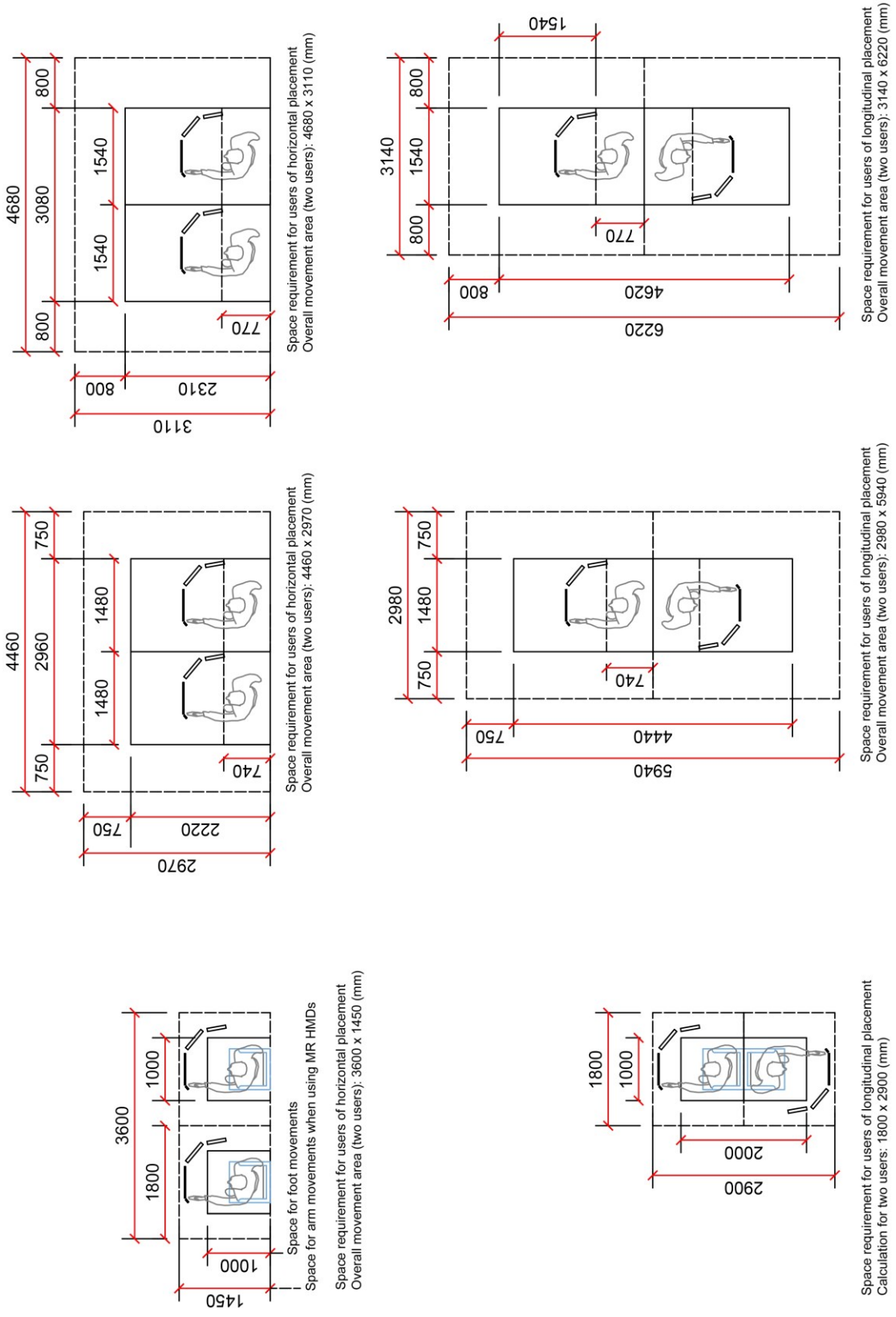


Figure 7.26 Spatial dimension requirements

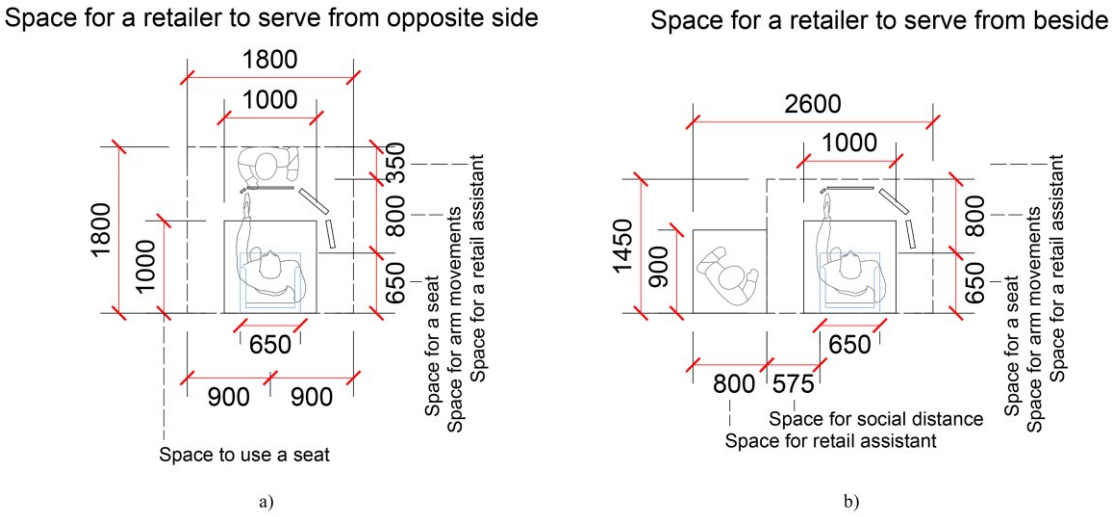


Figure 7.27 Spatial ratio requirements. a) a retailer serves on opposite. b) a retailer serves on beside

There is no significant difference between the service provided by a retail assistant who serves opposite or beside the customer. Therefore, Figure 7.27 includes designs for both situations. The space scale is 1:1, with a minimum floor area of 3.24 m², which can be used when the retail staff serves opposite. The 1:1.8 floor area is used when the retail staff serves beside customers, with an area of around 3.77 m². Designers can plan according to the topography of the store.

Figure 7.28 presents four speculative layout concepts for a medium-sized (70 m²) jewellery store to inspire interior designers. This includes dimensions for three typical jewellery display cabinets: 1500×450 mm, 950×450 mm, and 450×450 mm, with typical heights ranging from 900 to 1060 mm. Designers should ensure sufficient floor space for foot movement while minimising hand movement space waste by positioning display cabinets (under 106 cm in height) to optimise space utilisation.

It shows four scenarios for interpreting how to use spatial dimension and ratio requirements to design a layout. Layout A is designed for standing and sitting postures, and display cabinets are used to separate usage and service areas for two users. Space for retail assistants service is sited beside. Layout B employs display cabinets to create a semi-enclosed MR space where customers can see each other across height differences, allowing for a certain privacy without complete enclosure. Layout C highlights

designated areas for single and group customers, the retail assistant standing opposite, and HMD storage. Layout D can accommodate users in two separate spaces, and placing the MR area at the traffic centre increases its attractiveness to customers crossing the area. In layouts A and B, the MR space is positioned in a corner, supporting custom assistance-oriented store types. In contrast, layouts C and D place the MR space at the centre, aiming for immersive stores focused on MR customisation. Moreover, layouts A and B utilise a grid form, while layout C utilises a free form and layout D uses a racetrack layout.

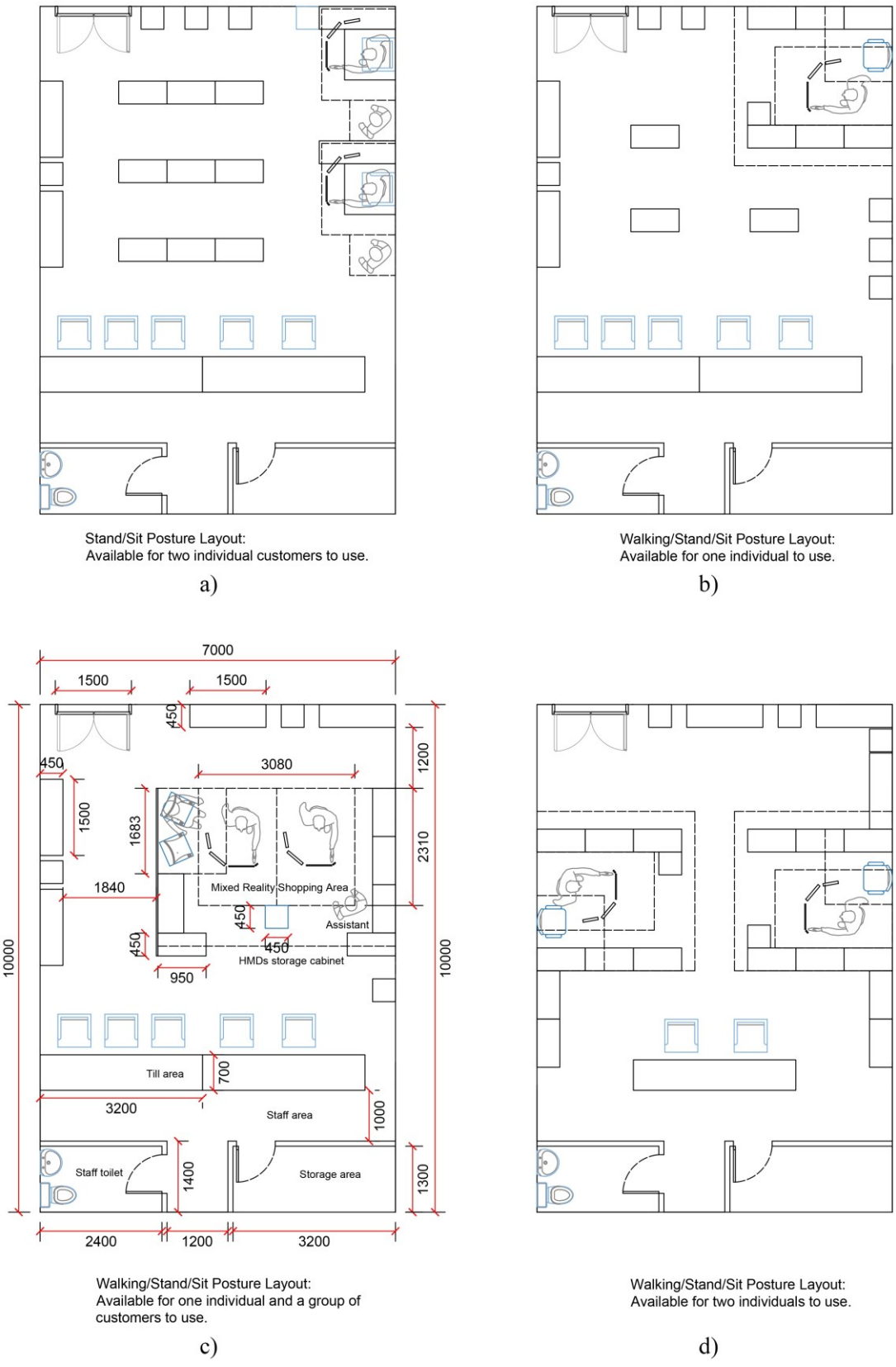


Figure 7.28 Speculative layout design: a) available for stand and sit postures; b), c), and d) available for walk, stand, and sit postures

There is no statistically significant difference between horizontal and vertical product displays. However, a more inclusive MR design may benefit from the MR area containing horizontal displays (low cabinet), which is more friendly to wheelchair and sitting users. The vertical displays (high cabinet) are more accommodating to the public with neck strains and using a standing position.

Designers should also consider spatial privacy based on retailer needs. For high privacy, fully enclosed spaces such as private rooms are ideal. For lower privacy, semi-enclosed spaces can use curtains or position users to face the wall, which limits distractions from public view. In fully open spaces, designers should create clear spatial boundaries to prevent users from unintentionally moving beyond the intended area while immersed in virtual content. While this MR environmental design guide offers detailed criteria, designers must still carefully evaluate each unique commercial setting to tailor the guidelines appropriately.

Discussion on the Demographics Consideration of MR Store Interior Design

The results outlined that gender is not a factor that influences user experience satisfaction in an MR store, but age does. For five design values (colour, illuminance, privacy, merchandise display, spatial ratio), participants showed almost consistent attitudes and satisfaction across different age bands. Nevertheless, the interaction effect of age versus colour temperature and age versus spatial dimension had significant differences ($p<0.05$). The within-subjects design factors, which are colour, illuminance, merchandise display and privacy, have significant differences ($p<0.05$). As the results stated, the age band had a significant difference in colour temperature, which suggested the use of neutral light. Therefore, a recommendation is to use *neutral light* as the accent light and *warm light* as the background light. The spatial dimension showed that the age band 26-35 has a significant difference, to be inclusivity to a wider age band, which suggested the use of *sit* and *stand* postures. This is because the sit and stand would need the same floor area, but the walk could take up more floor area.

The findings imply that the remaining design values showed universality, apart from the *colour temperature* and *spatial dimension*, which should be considered for inclusivity to age diversity. Furthermore, the repeated measure ANOVA tests for education and occupation versus design factors were addressed, but the results indicated

that this was not statistically significant for these demographics. In other words, the remaining values, which showed no significance ($p>0.05$), indicate that consumer attitude and satisfaction with in-store MR experience would be a consistent evaluation even with distinct gender, education levels and occupations (employed or unemployed). Designers could use any of these design values within the context of their MR implementation.

7.6.2 Part B: Mixed Reality Product Configurator System Design Principles

The quantitative result indicates that the more well-designed the UI on the application, the more positive the attitude towards its use (H1). UI design consists of three aspects: *visual user-friendliness of the layout (PUID1), clarity of navigation (PUID2),* and *clarity of the UI hierarchical structure (PUID3)*. Ease of use of technology correlates with user attitudes towards use but barely impacts upon attitudes towards use. Usefulness, on the other hand, affects changes in user attitudes and purchase intention (H3, H4). Using the MR configurator App to complete a customised product purchase enabled users to have a sense of usefulness, which includes the fulfilment of purchase demands (PU1), increased purchase efficiency (PU2) and decision-making ability (PU3), together with the satisfaction of expectations from the customised functionality (PU4). The more positive the attitude towards using the MR configurator app, the more it will increase consumer intention to use and increase the consumer purchase intent (H5). When users perceive using this MR configurator in the shop as being easy, it will positively influence their affective and behaviour (H6). Coupled with the results of H4, ease of use will not cause an uplift in intention to buy, but it will cause consumers to perceive in-store use of the HMD and system as useful for purchasing behaviours and will be reflected in an increase in system access behaviours. Prospective consumers who judge MR purchases as easy to use and useful tend to browse and purchase using an HMD (H7). Equally, users who intend to use the MR configurator augment the tendency to purchase products (H8).

Furthermore, the result shows that 78.1% (n=64) of users showed optimism about using MR to purchase in the future, and 60.9% are likely to commit to a practical engagement

when operating in the MR retail marketplace in the future. 71.9% of consumers intend to use MR and the MRPC app to complete purchase missions. 59.4% believe that this innovative retail approach is practical and that its usefulness directly positively contributes to boosting consumer purchase intent. Moreover, while the ease of use of technology has a positive impact on user usage behaviour (β = 0.498), usefulness has a relatively more significant impact on consumers, both in terms of attitude (β = 0.792) and behaviour (β = 0.613, 0.509). In other words, the use of technological obstacles (β = 0.211) are less critical compared to consumer cognition of the purchase task from a utilitarian viewpoint (β = 0.613) since usefulness is almost 3.4 times more influential on purchase intent than ease of use. 62.5% of users found the MRPC easy to use, and 6.3% found it challenging. Users' browsing behaviour with MR in a physical shop drives their purchase intent (β = 0.673), and purchase intent also drives users to experience the MR HMDs (β = 0.806). Therefore, increasing the frequency of users' MR adoption behaviours can be considered a means to augment consumer purchase motivation.

Therefore, increasing the frequency of users' MR adoption behaviours can be considered a means to augment consumer purchase motivation. UI design demonstrates its value in driving positive attitudes to facilitate user retention. Improving software utility can directly impact purchase behaviour. This highlights the importance of hedonic and pragmatic motivations in MRPC, aligning with existing studies (Alzayat and Lee, 2021). The following will introduce the UI design principles of MRPC for a similar direction of MR commercial application design.

Qualitative coding concepts and subcategory characteristics are inductively processed into universal characteristics to generate replicable design principles. These design principles can be used in developing similar MR configurator systems and function as a checklist for evaluation. They outline the essential design features needed for a general commercial configurator and address five attribute aspects of user requirements that must be considered during the design process. Including function demand (FD) (69.2%), experience demand (ED) (53.9%), visual demand (VD) (38.5%), affective demand (AD) (23.1%), and comfort demand (CD) (7.7%) (Table 7.12). These codings collectively derive design principles for MR product configurator design.

Table 7.12 Design principles source of initial codes and classification from Part B experiment

Design Principles	Concept Code	Attribute Code
Parametricity	Product satisfaction, parameter quantity, assembly parameter bar, parametric information	AD, FD
Informativeness	Clarity (layout, information, procedure), full-featured, holistic information presentation, instant product effect, multiperspective, audio for information, automatic information recognition, recommendation function	FD
Comfort	Interface ergonomic (height, width, distance), height of hand, HMD weight, fatigue, vertigo	CD
Comparability	Multiperspective, fitting compatibility	ED, FD
Contextual	Product close to true, brand style, connectivity to physical shops, outfit scene	ED, FD, VD
Intuitiveness	Sense of stereoscopic, less imagination required, modularity area, overall preview of interfaces, product in visual centre, colour, highlight status, visual priorities	ED, FD, VD
Beyond reality value	Social escape, affective value of special effects, fun, freedom of fitting, convenience, immersive, multisensory, novelty, self-reliance, mobility, resource-saving	AD, ED, FD
Interactivity	Operative interactivity, special effect interactiveness, playfulness	AD, ED
Predictability	Clarity (layout, information, procedure), instant product effect, logical flow, modularity area, sound aid	FD
Conciseness	No over-functional, purity and simplicity, folding interface, efficient simplification	ED, VD
Accuracy	Product texture detail, sense of real, fitting compatibility	FD, VD
Visual aesthetics	Brand style, colour, app style, interface edge radius, sense of transparency	VD
Environmental compatibility	Ray operated, resource-saving, connectivity to physical shops, assistant service, background wall, independent space, scenario matching	ED, FD

The replication of these results with the quantitative results validates the validity and reliability of the interpretation of the qualitative data. Thirteen design principles are interpreted below by summarising the qualitative and quantitative findings. This set of design principles derives a set of visualisation graphic cards as a review criteria toolkit to aid designers in their designs (see Appendix E).

1) **Parametricity.** The system offers customisation through various parameterisation options. The design should carefully consider the number of parameters available, the method of presenting these options (such as parameter bars or buttons), and the inclusion of detailed information and clear instructions for each parameter.
2) **Informativeness.** The system should be a comprehensive and informative display. The UI design should ensure a clear layout and logical structure and highlight information (such as pricing and labelling). It should provide instant, customisable design effects and detailed 3D product presentations. Important information should be available in audio aids to improve accessibility. Features

of physical product identification and personalised recommendations can help deliver a utility and responsive experience for consumers.

3) **Comfort.** The system design should integrate software and hardware comfort. Software considerations include interface height, width, and distance to users to reduce neck, arm, lumbar and eye fatigue. To minimise vertigo caused by system mobility, designers should use dynamic UIs cautiously, incorporating UI's transparency or teleportation function to minimise the interface from swaying within the user's sightline.
4) **Comparability.** The system should provide a function of comparing self-designs products to aid decision-making. Limit the quantities of comparison to reduce difficulty in decision.
5) **Contextual.** The system enhances value by contextualising usage scenarios, such as matching products with items from other categories and demonstrating product use context. Additionally, the UI style should align with brand identity and in-store interior style for consistent contextual integration. The system enhances value by contextualising usage scenarios, such as matching products with items from other categories and demonstrating product use context. Additionally, the UI style should align with brand identity and in-store interior style for consistent contextual integration.
6) **Intuitiveness.** The system should present information in a way that is easy to visualise, minimising the user's need to use their imagination. Using colour and highlighting can effectively differentiate functional areas and clarify where users are within the hierarchy. High-priority interfaces should be placed within the user's primary field of view, while less essential elements should be positioned in the periphery. Customised products should be prominently displayed in the central field of vision to ensure consumers easily notice them.
7) **Beyond reality value.** The system should offer users experiences beyond what is possible in reality by incorporating emotional value through special effects, gamification elements, and immersive multisensory experiences. Provide self-sufficiency, freedom of fitting, mobility, 3D customisation, virtual fitting, contextualised recommendation and convenience of experience options for those who avoid social interaction through configurator customisation and try-on and contextualised recommendation features. By offering a range of adjustable parameters, the system helps to reduce resource waste for retail shops, such as displaying more products in less space and minimising user returns due to dissatisfaction.
8) **Interactivity.** The system should add appropriate interactions and compensate for tactile deficits, but not over-attract attention. Increase fun by combining additional features (namely, virtual customer service, system recommendations, and video) with gamification elements.
9) **Predictability.** The UI design arrangement and progression relationships should be consistent with the regularity of general practice. It can be aided by

sound to allow the customers to anticipate upcoming actions through a real-time UI response.

10) **Conciseness.** Keep the system design and functionality pure and simple, and do not provide excessive features. Always remind yourself of the ultimate intention of the system and try to avoid adding too many features to distract users. Collapse or minimise interfaces that are not currently needed and allow users to get the maximum effect with the least effort.
11) **Accuracy.** The effect of the product should be close to the texture of physical products, reducing colour and texture differences. Designers should constantly compare the product with the actual object and test it in the environment where it is expected to be used to minimise the deviation caused by environmental factors.
12) **Visual aesthetics.** The UI design uses rounded corners to keep the user's sight focused on the centre of interfaces and buttons. It should enhance the sense of interface transparency, reduce user attention consumption, and make the key information more prominent. Add brand style characteristics to express brand images.
13) **Environmental compatibility.** UI design should address the physical environment's impact on user accessibility and virtual product display. Integrating UI design with the shop's interior design can help avoid disconnecting the virtual experience from reality, enhancing overall UX. For example, the UI size should be compatible with the space footprint. Some users may require independent spaces to avoid discomfort from bystanders.

This *Mixed Reality Product Configurator Design Principles Toolkit* is a repeatable and generic framework that attempts to aid graphic UI designers and software developers in the development of commercial MR product configurator systems. When developing and designing a commercial product configurator, designers and programmers would be advised to consistently review whether their application fulfils the thirteen design principles at different stages of the design process. This card toolkit can be used in a variety of scenarios: a) the usability testing (user testing) stage to work with users to evaluate the usability and experience value of the system. b) Used as a qualitative tool to conduct workshop activities with stakeholders (retailers, UX designers, interior designers, consumers) after completion of development to collaborate on evaluating the outcome of the application. c) As a quantitative tool – a questionnaire survey framework, it can be used to scale the system in thirteen dimensions and used repetitively throughout the design and development workflow.

The usage of thirteen principles, such as parametricity (**Principle 01**), using the jewellery configuration parameters as an example, describes the parameters' range and quantity based on ring parameters. It suggests that product managers and designers follow online product configurator parameters of their retail categories (see Sections 2.3.2 and 5.6.3). Comfort (**Principle 03**), by providing an ergonomic MR UI layout and distance design solution, coupled with environmental design (namely, the footprint for this UI size, safety, and privacy) (**Principle 13**) to enhance commercial viability (see Section 5.6.5). Comparability and beyond reality value (**Principle 04, 07**) refer to system functions and experiences development that other channels do not involve, such as virtual fitting, special effects, and recommendation (see Sections 5.5.2, 5.6.4, and 7.5.2). While Principles 02, 06, 09, 10, 11, and 12 align consistently with established online and AR UI design principles (Höllerer et al., 2001; Ko et al., 2013; Koreng and Krömker, 2021). New principles 01, 03, 04, 05, 07, 08, 10, and 13 are tailored to meet the unique requirements of commercial physical stores.

This toolkit generates a set of graphic cards that can be used alone (see Appendix E). It is also demonstrated in the thesis outcome, "*Mixed Reality Commercial Design Brochure* (see Appendix F)", which provides a coherent overview of thirteen design principles, design methods, and consumer demands.

7.7 Implications

Designing store environments is significant in facilitating the transformation of traditional shops into MR shop channels for future multichannel retail. This study analyses the relationships between consumer demographics, design factors and design values, leading to the initial MR shop interior environment design guidelines (Figure 7.29). It indicates the importance level of design factors from top to bottom, with 1 representing the most important, and 2 representing the second important.

Mixed Reality Retail Shop Interior Environment Design Recommendations					
Factor Rank	**Design Factors**	**Demographics**	**Rank & Range**	**Design Values Recommendation**	**Explanation**
1st	**Light Illuminance**	Overall	1st	200 lux + 414 nits HMDs intensity	High intensity of HMD with dim background (μ=3.85). Users chose a dim ambient light paired with a high-intensity device luminance for clearer optics.
			2nd	500 lux + 414 nits HMDs intensity	High intensity of HMD with bright background (μ=3.49) can be used for a secondary option.
			3rd	200 lux + 221 nits HMDs intensity ≈ 500 lux + 221 nits HMDs intensity	Medium intensity of HMD results in similar experience satisfaction on dim (μ=2.93) or bright (μ=2.93) backgrounds.
2nd	**Spatial Dimension (Pose)**	Overall	N/A	Sit ≈ Stand ≈ Walk	There is no statistically significant difference between the three postures used: sit (μ = 3.81), stand (μ = 3.60) and walk (μ = 3.39). However, user age bands assessed sitting and standing as being significantly greater than walking. This suggests the necessity for retailers to establish seats for customers, and designers are encouraged to design an inclusive ergonomic space for both sitting and standing use. If the store has sufficient space, consider designing MR usage areas that can accommodate three postures.
		Age	18-25	Sit ≈ Stand ≈ Walk	Sit (μ = 3.57), stand (μ = 3.90) and walk (μ = 3.53) remained statistically consistent in customer experience satisfaction. This suggests that designers can design MR spaces with multiple combinations of usage postures.
			26-35	Sit > Stand > Walk	Higher average score on sit (μ = 4.06) versus stand (μ = 3.40), sit versus walk (μ = 3.16). This suggests that retailers should establish seats for customers if the target customers are aged between 26-35.
			36-55	Sit ≈ Stand ≈ Walk	Sit (μ = 3.15), stand (μ = 3.65) and walk (μ = 4.35) remained statistically consistent in customer experience satisfaction. This suggests that designers can design MR spaces with multiple combinations of usage postures.
3rd	**Light Colour Temperature**	Overall	N/A	3000K (Warm) ≈ 4000K (Neutral) ≈ 5000K (Cool)	Neutral (μ = 3.55), cool (μ = 3.36), and warm (μ = 3.37) light remained statistically consistent in customer experience satisfaction without considering demographics.
		Age	18-25	3000K (Warm) ≈ 4000K (Neutral) ≈ 5000K (Cool)	Warm (μ=3.69), neutral (μ=3.40), and cool (μ=3.22) light remained statistically consistent in customer experience satisfaction among those aged 18-25.
			26-35	4000K (Neutral)	Customers aged 26-35 are more satisfied with experiencing neutral (μ=3.73) than warm light (μ=3.18).
			35-55	3000K (Warm) ≈ 4000K (Neutral) ≈ 5000K (Cool)	Warm (μ=3.30), neutral (μ=2.95), and cool (μ=4.05) light remained statistically consistent in customer experience satisfaction among those aged 35-55.

4th	**Colour walls**	Overall	1st	Blue	Blue (μ=3.60) has a significant difference from red (μ=2.98). Interior designers should flexibly ideate their designs according to the product's colour palette. For example, if the product's primary colour is blue, they could use a white background to contrast the colour.
			2nd	White ≈ Red	White (μ=3.33) and red (μ=2.98) remained statistically consistent in customer experience satisfaction. Designers can choose a design based on the colour contrast between the virtual product's primary colours and the background wall colour.
5th	**Merchandise Display**	Overall	N/A	Vertical display ≈ Horizontal display	It should be noted that the experiment used a 566-gram headset. The duration of wearing and the weight of headsets from different brands may affect customers' perceptions. Considering the natural physiological curvature and comfort, if retailers intend to increase the dwell time in adoption to use HMDs, they might need to consider the group of consumers who had cervical spondylosis symptoms. It is recommended that vertical displays be more ergonomic for using a standing posture
6th	**Spatial Ratio (Service mode)**	Overall	N/A	Landscape space (Retail assistant on beside) ≈ Longitudinal space (Retail assistant on opposite)	Landscape space (Retail assistant on beside) (μ=3.40) and Longitudinal space (Retail assistant on opposite) (μ=3.34) remained statistically consistent in customer experience satisfaction.
7th	**Privacy**	Overall	1st	Share screen when needed (assistant access only)	Customers are more satisfied with MR services on the public's inaccessible screens, such as tablets or HMDs (μ=3.81).
			2nd	Share screen when browsing (public access screen)	Customers are less satisfied with MR service on screens that the public can view, such as monitors and TV screens (μ=2.82).
	Screen Share Devices	Tablets and/or HMDs	Retail assistants can use either type of device or a mixture of both when providing MR customer service. 67.2% of users prefer that the assistant use tablets, 60.9% prefer that the assistant use an HMD, and 31.3% prefer that the assistant use a PC screen. Retail assistants can use tablets to replace HMDs for viewing. However, having at least one assist-HMD in a store is still necessary when the user needs assistance with operating apps.		

Notes:
1. Average score (μ) criteria: 1- strongly no prefer, 3 neutral, 5-strongly prefer.
2. Overall refers to all user preferences. Gender, education and occupation (employed or unemployed) have no statistical difference with user preferences.
3. This data is derived from experiments with jewellery products and may not be representative of all product categories.
4. Data was collected in the UK in 2024, and the sample size is 64.

Figure 7.29 Mixed reality retail shop interior environment design recommendations

This figure concludes that light illuminance is the most important design factor that impacts MR HMD users' adoption in-store. Designers should prioritise fulfilling the top factors when designing. Figure 7.29 also shows the solutions for the design factors that demographics will influence, where recommendations include overall customers and customers based on age bands. This is a flexible design guideline but not a rigorous rule. For instance, for overall customer spatial dimension preferences, three poses have no statistical differences. Therefore, designers can design a space tailored for sitting and standing, or a space can be used for three postures, depending on retailer demands. For background colour, the guideline suggests blue is the most preferable colour, considering it is less distracting and has less interference, and is more preferred and accessible. However, if most product packages are blue or the brand image colour is red, designers can adjust to an alternative option, whereas the white average score is ranked second. Designers are encouraged to reference and approach this design guideline according to the brand demands and can use it to explain their design rationale to clients.

7.7.1 Implications for MR Store Design

The MR store design framework proposed in this study provides designers with the fundamental data sources to offer insights upon which to base their designs for these benchmarks.

1) The finding of the high weighting of spatial dimensions raises the implication for establishing robust guidelines for ergonomic and embodied spatial layout planning to address user demands and optimise the user experience. For example, designers can utilise the drawings of 'Spatial dimension and ratio requirements' to design MR retail spaces (see Figure 7.26 and Figure 7.27).
2) The findings highlight the distinct weight of seven design factors. Where conflicts arise, designers can prioritise the higher important factors to design environments with greater accessibility.
3) The findings emphasise that gender will not be a significant factor in design, but age is a major factor in design differentiation. Designers are not required to design separately for users of different genders, education and employment. However, an age-friendly design for a more inclusive community could be considered for large-scale MR shop design.
4) In the section on pop-up shop design, the pop-up installation approach suggests a minimum MR space proportion of a minimum of 1.8m × 1.8m,

accommodating users below 1.83m in height and based on an arm span of the person at 1.83m. The construction method of this pop-up space aids retailers in replicating this mock-up for brand market testing. This experimentation approach could help researchers and designers replicate experiments and refine more design values in further exploration.

7.7.2 Managerial Implications for MR Stores

This design guideline facilitates retailers' better understanding of the relationship between store interior design and consumer adoption. Retailers should consider the accessibility of adopting technology by designing more inclusive spaces to enhance the potential success of mass MR shop adoption. In addition, this guideline emphasises to the brand the crucial role of retail assistants in customer service and the interchangeability between HMDs and tablets. It is recommended that retailers consider retail assistant onboarding and designers consider storage space for different devices.

7.8 Conclusion

7.8.1 Part A: Mixed Reality Store Interior Environment Design Guideline

This study discusses three aspects that provide value for the future development of MR retail stores: 1) From a research perspective, the introduction of the methodology and pop-up store design methods of this study provides an operational process for reproducible experimental research. 2) Based on the experimental results, design recommendations for MR stores are provided to offer design indicators as reference values for interior designers. 3) Provides recommendations on management implications regarding in-store service, customer preference, and equipment investment with design.

The findings reinforce the central argument of this study that retailers should consider the impact of the physical environment when implementing new technologies. This study identifies seven key design factors and emphasises that adopting design values with higher experience satisfaction can improve the accessibility of MR environments,

reducing barriers to MR adoption in commercial settings. The results suggest that if gender and age do not significantly influence design preferences, retailers can avoid additional costs for developing multiple design solutions for different demographics. An analysis of experience satisfaction by age and gender and experience accessibility considerations highlights the inclusion of this design guideline.

7.8.2 Part B: Mixed Reality Product Configurator System Design Principles

The thirteen design principles and the MRPC prototype specifications promise to provide a valuable guide for graphic UI designers and MR developers. The design principle identifies thirteen design elements: parametricity, informativeness, comfort, comparability, contextual, intuitiveness, beyond reality value, interactivity, predictability, conciseness, accuracy, visual aesthetics and environmental compatibility. These principles represent five dimensions that need to be focused on for commercial MR customisation system design: functionality, user experience, visual aesthetics, affective engagement, and user comfort. Graphic UI designers can follow these principles when designing MR UI to conceptualise their designs and iterate on prototypes using MRPaperPro (see Appendix F, Section 04).

The study highlights that MR user interface design, affective, and cognition influence consumer technology intent to use and purchase intent. MR for parametric configuration of products in brick-and-mortar retail stores can stimulate consumer purchase intent and intent to use. A robust MR UI design can enhance user attitudes toward use and deliver a better user experience beyond reality to consumers. Consumers perceive that adopting MR parametric product configurators in brick-and-mortar stores has pragmatic value. MRPC is a promising and innovative purchasing approach that can encourage consumers to return to brick-and-mortar stores for shopping.

7.9 Limitations and Future Works

One of the limitations of this study is the small sample size and the necessity to increase the sample size in future studies. Another limitation is the heterogeneous distribution of participant demographics due to the study area, duration, and site limitations. The small volume of data for ages 35-54 of the characteristic cohorts resulted in a sample that might not be typically representative. Although many previous AR studies stated that consumers below 35 are the main user cohort (Xue, 2022), increasing the sample size of 35-54 user groups can help retailers understand this cohort's usage habits.

Due to the attributes of MR, this research required offline, one-on-one data collection, making it unsuitable for online surveys. This approach is more time- and labour-intensive than traditional quantitative research, also resulting in participants being drawn from the same city. Future studies could replicate this research in different countries to consider diverse cultural backgrounds and globalised user groups.

This study uses high-value products – fine jewellery – as a pilot industry, which might limit the generalisability of its findings across other retail sectors and product categories. For example, in the case of groceries or food, variables such as background colour and colour temperature would require further evaluation. Participant feedback highlighted that colour contrast between the background and products affects readability and user preferences. Participants were instructed to consider the overall integration colours of UI and multiple colour products when selecting background colours. Although the findings show comprehensive consumer preferences, it remains challenging to eliminate the impact of wall colour contrast on all virtual products, particularly for items containing multiple colours in varying proportions. Therefore, a suggestion will be for interior designers to create their ideal design according to product colour. For example, if the majority of products are blue, designers could use the alternative option of a white background to create a colour contrast. This is a flexible guideline instead of restrictive rules where designers should design agile based on brand requirements. Future research could examine the effects of colour contrast, colour temperature, and lighting colour temperature on virtual products under controlled experimental conditions, especially for multi-coloured products to refine more colour options.

Considering return on investment, practitioners should assess the feasibility of implementing MR in low-value sectors, as factors such as floor area planning, retail assistant training, hardware costs, and lighting requirements vary significantly between high and low-value product categories. Moreover, researchers could conduct their research based on this study's methodology to explore additional design factors in MR retail environments, such as the influence of sound and temperature.

Another limitation is that it lacks a controlled test of the subjects' previous MR experience, with only two out of 64 individuals having prior knowledge of MR. These individual differences may affect MR stimulus responses. Therefore, considering the customer's previous experience, a longitudinal study could benefit the results.

Other limitations include the mock-up store not being in a real brick-and-mortar store situation. No actual purchases are made, meaning precise forecasting of purchase intention and power is less possible. However, purchase intention and power are influenced by many factors, such as shopper consumption demands, product price, product quality, and brand awareness. Brands and businesses should therefore be cautious about these results. Retailers were not invited to participate in the evaluation of the purchase intention of the customers experiencing MRPC in this study. This was because this was a mock shop environment, and a store retailer had already provided feedback through six days of observing shoppers in a real shop using the MRPC in Study 5 (see also Chapter 6). Therefore, this study did not involve input from retailers.

An intriguing future direction is whether the duration of HMD access is related to the posture to use and whether the duration of MR access impacts purchasing power. Furthermore, the proposed MRPC application intends to be deployed in omnichannel retail. However, this experiment was conducted in the jewellery industry. Given the influence of product variety, an empirical measurement encompassing a wider assortment of merchandise would be a valuable complementary study.

7.10 Contribution Summary

This chapter has addressed two research gaps in Section 2.6 (p. 65):

Research gap 8: No interior environment design guidelines exist for mixed reality integrated with brick-and-mortar retail stores.

Research gap 9: Lack of research evaluating user acceptance of mixed reality product configurators integrated into brick-and-mortar stores.

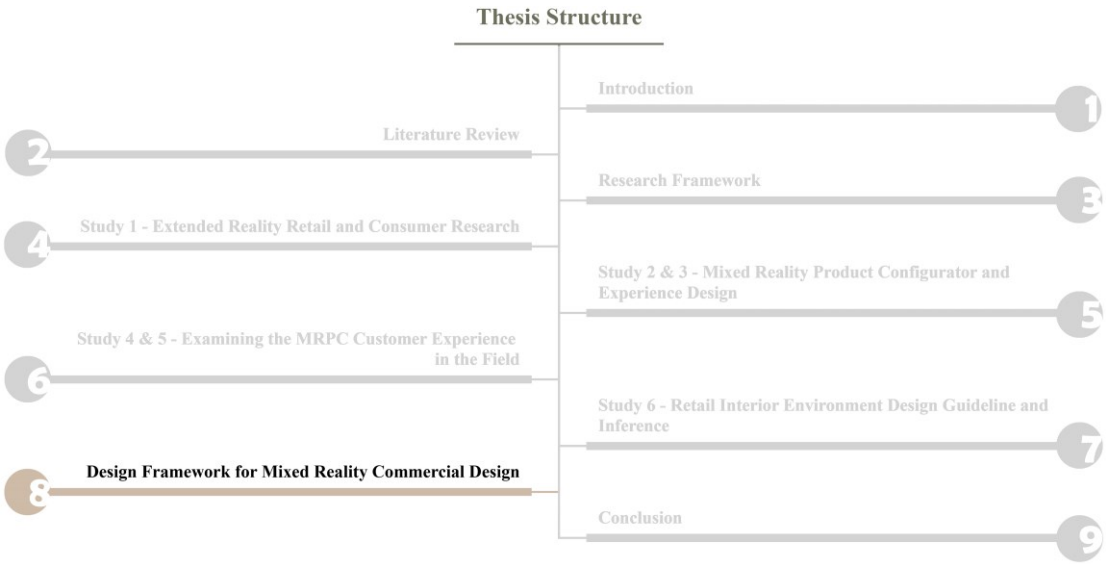
It answers research question 4:

How is it possible to design inclusive mixed reality retail interior design guidelines for diverse demographics?

Review of the contributions made in this chapter:

- This chapter offers an inclusive MR retail store interior environment design guideline for general stores and a user demographics-based implementation. It enables designers to enhance the store environment to increase accessibility to MR in stores. This helps MR retail benefit a wider range of customer groups regardless of their familiarity with MR's experience. Designers can also design stores based on age preferences to make MR adoption more inclusive for the public (Figure 7.29).
- The MR retail purchase acceptance model helps to infer the potential feasibility of large-scale retail industry adoption, indicating customers have a positive acceptance of the MRPC used in brick-and-mortar stores (Figure 7.25).
- The user evaluation of the MRPC resulted in experience-based thirteen design principles for the MR commercial configurator user interface to guide graphic UI designers in their work towards MR design (Section 7.5.2 and Appendix E).
- This finding forms the basis of the MR interior design guidelines and MRPC system design principles within the design brochure (see Figure 3.12, p. 99).

8 Design Framework for Mixed Reality Commercial Design



8.1 Introduction

The customer experience management (CEM) framework effectively coordinates the efforts of key stakeholders, including the departments of design, development, marketing, sales, and customer analytics, before delivering the customer experience (Lemon and Verhoef, 2016). However, an MR-based CEM framework remains undeveloped. This thesis adapts the traditional CEM framework to establish an MR CEM framework (see also Section 2.5.2). Following conventional CEM principles, this research has conducted customer research (Study 1), defined the MR experience and built the MRPC experience platform (Studies 2 and 3). The thesis also involves action research (Study 2), prioritising areas for development, developing and piloting the changes (pop-up store typology recommendations, see Section 2.4.2), analysing the world of customer experience (Studies 4 and 5), and promoting continuous innovation (MR system suggestions, see Section 7.5.2). Additionally, this thesis identifies two critical stages for MR CEM implementation: MR-based store interior design and onboarding services (derived from Studies 3, 5, 6). These outputs collectively form this MR CEM design framework, its derivative – ***Mixed Reality Commercial Design Brochure: Design the Space and Interface for Commerce Mixed Reality in Brick and Mortar Stores*** (see also Appendix F). This design framework addresses the meta-research question (see below) and research gap ten.

Meta question: ***How is it possible to design accessible customer experiences in mixed reality retail environments for brick-and-mortar stores?***

- **Meta question OBJ:** Determine a systematic mixed reality customer experience design management framework to improve the accessibility of brick-and-mortar store experiences, from technology matching, designing MR interfaces and store interior environment to consumer acceptance. (Research gap 10)

This chapter will introduce the *Design Brochure* – how it can be applied, and relevant stakeholders' (retail managers, interior designers, product or jewellery designers, MR software engineers, and product manufacturers) insights into and comments on the design brochure.

8.2 Mixed Reality Commercial Design Framework

The *Design Brochure* is a flexible framework, a set of generalisable principles rather than strict metrics or rules. It aims to provide value for stakeholders from a design perspective by exploring the desires of consumers and retailers and utilising mixed reality immersive technology to enhance the user and retail shopping experience, purchasing power, and market competitiveness. The brochure proposes an MR CEM framework to implement in large-scale MR brick-and-mortar stores to improve the accessibility of the MR headset customer experience and assist retailers in planning strategies.

This thesis recommends that retailers and their design teams adopt the following framework. However, given the diversity in company identities and brand positioning, each organisation should determine which retail design aspects align most closely with its strategic goals. To help retail leaders follow this guide, they should start with the first stage, as some solutions may be incompatible with some retail context or not investigated by this research.

The MR commercial design framework in Table 8.1 outlines sequential approaches, with targeted recommendations provided at each stage. This framework is structured into eight stages, each involving specific practitioners. Figure 8.1 visualises the design framework from the brochure to guide industry practitioners. This MR commercial design framework consists of one principle, namely, "**DIDPOE**": *Define, Ideate, Design, Prototype, Onboarding, and Evaluate*. It delivers a holistic design loop and aims to achieve an accessible MR customer experience in brick-and-mortar stores. Figure 8.2 illustrates the working relationships between stakeholders at different stages of the MR commercial design framework to help retail product managers arrange work and aid other practitioners in understanding which stage to be involved in. In stages two to four, ideas, designs, and prototypes should circulate through the design process in multiple iterations.

Table 8.1 Mixed reality commercial design framework and source of contents

Stage	Practitioners	Design Aim	Design Requirements	MR Design Solutions	Relevance Details
1	Retailers	Evaluate compatibility. Reduce technology acceptance barriers.	***Define*** a retail sector and consumers.	**1)** Suggested sectors: clothes, shoes, groceries and jewellery. **2)** Suggested age: 18-54 years old. **3)** Suggest experience: including well-designed scene effects, interactive flows and customisation.	See Sections 4.6 and 5.5.2 for recommendations.
2	Retailers	Enhance seamless customer experience.	***Ideate*** customer experience. Select MR equipment.	**4)** Stores should be equipped with the appropriate number of devices, depending on the store scale and the MR app function. Retailers need to identify their goals and ideate the customer experience journey.	See Section 2.2.5 – device selection, Section 6.5.1 – CX map and Section 6.5.2 – MR challenges and barriers.
3	UI/UX Designers and Program Developers	Design MR product configurator. Improve shopping ability.	***Design*** an MR commercial application with both utility function and hedonic experience.	**5)** UI design follows 13 design principles and the design recommendations of MRPC, considering its parameters, functions and ergonomic layout.	See Section 5.6, and Appendix E – MRPC design graphic card toolkit.
4	UI/UX/ Interior Designers	Enhance app usability and meet user preferences.	***Prototyping*** and iterating MR product configurator design.	**6)** Designers invite consumers to participate in UI iteration and test usability. **7)** UI and interior designers communicate shop planning solutions.	See Chapter 5, MRPaperPro toolkit.
5	Interior Designers	Design an effective MR store interior.	***Design*** and plan the store environment and MR adoption space.	**8)** Offer consumers a safe and easy-to-use environment.	See Figure 7.29 – MR store interior environment design guidelines, Figure 7.26 and Figure 7.27 – space layout requirements, and Figure 7.28 – speculative store layout.
6	Retailers, Interior Designers, UI Designers	Attract consumer engagement.	***Design*** pop-up events and marketing. (Alternative)	**9)** Build a pop-up installation or an in-store pop-up to test the environment and UI accessibility.	See Section 2.4.2 – pop-up store typology suggestions, and Section

Stage	Practitioners	Design Aim	Design Requirements	MR Design Solutions	Relevance Details
				10) Attract customers and increase awareness.	7.4.4 – small-scale pop-up build recommendations.
7	Retailers	Enhance seamless customer service.	***Onboarding training*** retail assistants to enhance the efficiency of service.	**11)** Retail assistants should provide seamless customer service by identifying user external behaviours (engagement, verbal, movement, etc.) and internal responses (facial expression, attitude, etc.).	See Section 6.6 – managerial suggestions.
8	Retailers	Evaluate customer experience satisfaction.	***Evaluate*** design solutions and marketing strategies.	**12)** Establish brand customer journey maps. This can be accomplished through observation, surveys, interviews, or A/B testing.	See Section 6.5.1 – customer experience map.

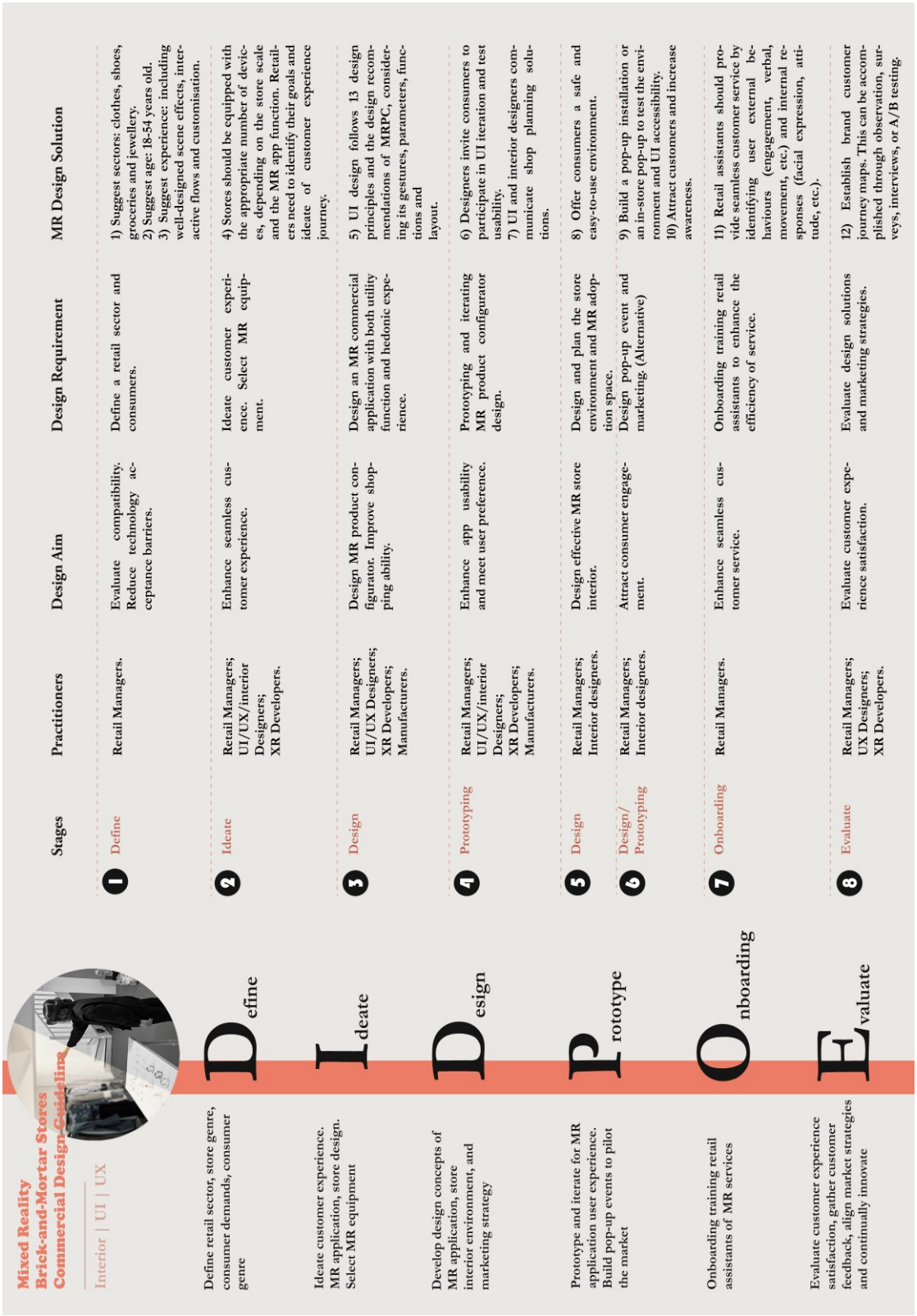


Figure 8.1 MR commercial design framework from the brochure, p.9

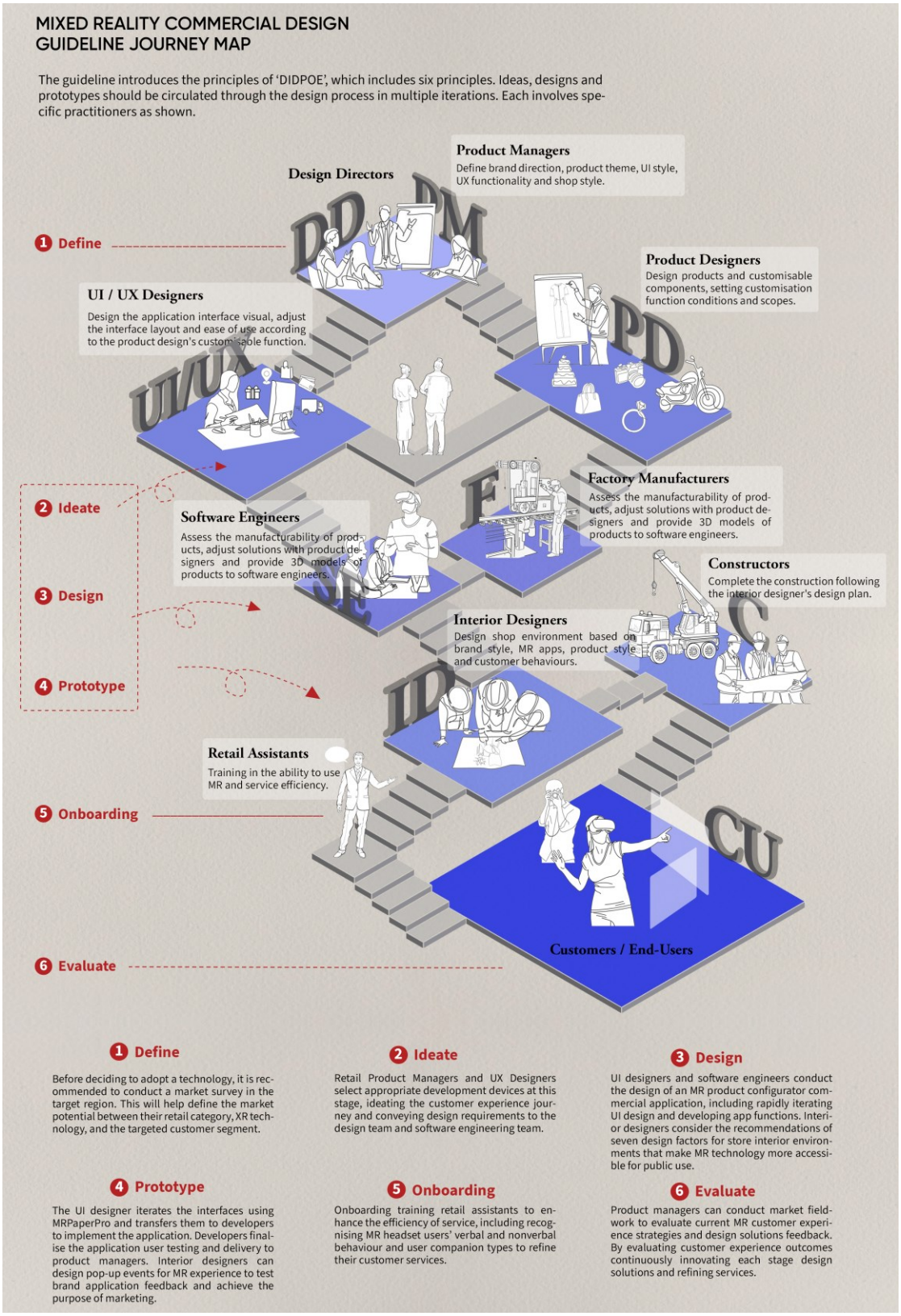


Figure 8.2 Mixed reality commercial design framework journey map from the brochure, p.8

To encourage designers and developers to further integrate the commitment to inclusivity into their design solutions during the research and development process, a supplementary checklist is provided to provoke designers to critically consider and reflect on inclusivity at each stage of the design engagement (DIDPOE) (Figure 8.3).

Mixed Reality Inclusivity Design Commercial Development Checklists

• Whether allowing users to interact through multiple modes?

☐ Gesture (left-handed / right-handed / both hands)

☐ Voice

☐ Gaze and Commit

☐ Mobility Mode (walk)

☐ Stationary Mode (stand / sit)

• Whether enabling application content to be adjusted based on user needs?

☐ Language

☐ Reading Level

☐ Agent-assisted Operation

• Whether applying visual design principles that accommodate different abilities of vision users? (e.g. Web Content Accessibility Guidelines (WCAG) / MRUI Principles)

☐ Yes ☐ No

• Whether applying interior design principles that accommodate different abilities of space users based on the region? (e.g. Building Regulations Approved Document M (UK) / Codes for accessibility design (CN) / MR Commercial Interior Design Guidelines)

☐ Yes ☐ No

• Whether testing process by involving users with a range of abilities?

☐ Age Group

☐ Gender

☐ Regions and Culture

☐ Digital Literacy Levels

Figure 8.3 MR inclusivity design commercial development checklists

8.3 Insights from Practitioners for the Design Brochure

The outputs of this thesis benefit multiple communities (see also Section 1.5), with the intended readership including interior designers, UI/UX designers, product (jewellery) designers, retailers and product managers, and MR developers. The outcomes also aim to benefit product manufacturers, policymakers, and researchers constructively.

To evaluate the design brochure and further evaluate its viability, an interior designer, jewellery designer, retail shop owner, MR program developer, UI/UX designer and jewellery manufacturer were invited to read through the study design brochure in January 2025 and to give their insights. Evaluation data was gathered in semi-structured interviews consisting of a 45-minute reading of the brochure per person, followed by a 45-minute in-depth interview. The interviewee sampling approach used purposive sampling due to the small number of participants, so it was required that the participant sample had relevant retail work experience to be representative of the relevant industry in order for valid feedback to be obtained. The semi-structured questions include:

- Which departments (both superiors and subordinates) do you usually collaborate with?
- What do you think are the strengths of this design framework?
- What do you think is missing from this design framework?
- Do you think this design framework includes practical recommendations that are transferable between design and technical realisation?
- Do you think the design framework provides understandable language and, or illustrations, and is the structure clear?
- Do you think there is anything in the framework that can be added to or modified?

The transcriptions were imported into NVivo 12 to conduct theme analysis. Based on the interview purpose, the analysis included three themes: advantages, improvements, and future usage suggestions. The participant profiles are shown in Table 8.2 below. The following sections will interpret the perspectives of each group by examining these themes.

Table 8.2 Profiles of practitioner interviewees

Practitioners (n=6)	Gender	Education	Occupation	Work Experience
Interior designer (ID)	Female	Masters degree	Interior designer.	Worked as an interior designer for 6 years, which included interior design of residential and commercial buildings. Usually negotiated projects with clients, constructors, architectural firm directors and project managers.
Product (Jewellery) Designer (PD)	Female	Masters degree	Lead designer.	Worked as a high-end bespoke jewellery designer and as a designer in an international export branding company for around 6 years. Usually approaches work with jewellery manufacturers and customers.
User Interface Designer (UID)	Female	Masters degree	User Interface Designer.	As a graphic UI designer in a mobile phone company, designing commercial UI and UX for smartphone applications, and with around 5 years of work experience. Usually approaches work with product managers, design directors and programmers.
Product Manager/Retailer (PM)	Female	Masters degree	Owner of a fashion store, founder of a jewellery brand, jewellery designer.	Operated a brick-and-mortar business for about 4 years and owned an individual jewellery brand for 6 years. Worked in bespoke jewellery and high-end jewellery.
Software Engineer/MR Developer (SE)	Male	Bachelors degree	Leader of a game developer team.	Worked as a programmer for 13 years, and 3 years working in MR development. Usually approaches programs with product managers.
Factory Manufacturer of Jewellery (F)	Male	Pre-Bachelor degree	Head of a jewellery factory.	Worked and owned the factory for around 10 years. The factory undertakes high-end customisation and works as the brand supplier. Usually approaches work with jewellery designers and distributors.

Advantages of the *Design Brochure*

The advantages include the brochure being: articulate and well-organised, chronologically arranged, comprehensive, convenient, heuristic, instructive having significance, readable, realisable, recommendable, possibility in reducing costs of developing apps, MRPC system reusable, time-saving, and acting as an aid to a better understanding of design language. Some qualitative evidence is provided below:

- **Better understanding of design language**. It can assist parties to better interpret their design language and undertake design.
  "It has to be explained, from start to finish, why did I design it this way? Why this colour? Why is this style, why is there one more thing here, one less thing here, to be sure to explain clearly, for example, why this background is white? Well, because we have done research, white is the most clear [...]. That's a very important part of the design, your design comes from that, and it doesn't just come out of nowhere. That is, all of your designs are there for a reason, there is no one line, and a wall painting is there in that place without a reason" (Interior designer).
  "This way the retailer may understand your design language and why the designer is asking for my shop to be designed this way, right? My placement should be here, my distance should be how much? He can understand it and doesn't find the designer designing many odd things" (Software engineer).
- **Comprehensive.** The contents of this brochure are comprehensive and elaborated.
  "If you're looking to integrate this with modern technology, you'd definitely need to collaborate with other industries or explore it further together, which I think is a better approach. Nowadays, it's all about collaboration rather than just specialising in one thing. Even interior designers need to have a broad understanding of various fields. They don't necessarily have to master everything, but at the very least, they should be familiar with different aspects" (Interior designer).
  "I think the whole process is great, and the explanation is really detailed" (Retailer).
  "If I'm going to get involved in your approach, I need to know exactly what I can do [...] That way, I can save time and energy [...] So, there absolutely needs to be a thorough guide telling me exactly what I need to do" (Jewellery designer).
- **Heuristic.** It brings heuristic open-ended discussions.
  "It doesn't have to be a closed loop. It can be a starting point, and then it's just going to inspire some ideas from the shopkeeper who reads this handbook [...] I think, for example, a handbook like yours is an open-source handbook, and then it might be placed in a library or a public place, and it might be placed for several years, [...]. Because prices are different for each period, in this case, I don't think it's really necessary to describe some of the cost control or some of the reference prices when you write it. You can, for example, describe some of your reference equipment, and then they can go to search by themselves and estimate the cost of this on their own. I think the cost of budgeting above (brochure) may have to be the shopkeepers themselves to go to do an estimate. This is the part that I think it's probably not necessary to write out because it's going to keep changing over time, and then it's going to change […] it's kinda nice it's an open-ended discussion" (Retailer).
- **Instructive significance.** The brochure is instructive for designers and developers.
  "Definitely all of these factors are useful, and I think all of them are well worth looking at, and without them, you wouldn't know how to show the client

how to install this software, how to explain it to the client, or how to discuss this stuff together" (Interior designer).
"They may not have had at the beginning of this no such experience, and then you give this guidance, this idea, these are technical selection, we call technical guidance. There is actually a guiding significance as they directly know can be based on this, and then towards some of the basic content of this to develop on the line [...]. For those who have no experience, so, the document states that the technical conditions have been enough for programmers to study the need to develop their work. Then the actual development process, they may need to communicate with the product manager and designers about the functionality because not every function developed is necessarily reusable. So need to go into discussion. There should be such a process, but this document has provided the basic support. It can start up and can go to do this thing, and then based on specific development needs, the next steps involve implementing the corresponding functions." (Software engineer).
"This one is more of a comfort issue, and 2D designs and graphics are not going to take this into account [...]. You're pretty meticulous in your writing" (UI designer).

- **Realisable.** Manufacturers, designers and developers consider this to be an achievable retail solution.
  "If there is a need for this in the market, it should be considered by the software suppliers. Programmers should consider what format the mainstream software in the market uses. If they can be converted to each other, there is not really a big and extra supply and demand problem" (Factory manufacturer).
  "This programme I think is fairly well-rounded, and I believe it's achievable" (UI designer).
  "It should be transferable since it's already well-explained, for instance, there are ready-made development tools available, and cases proving its feasibility. The remaining technical challenges are addressable" (Software engineer).
- **Recommendable.** Stakeholders considered it recommendable for those who work in a related work content.
  "If doing a relevant piece of this, it can be recommended because it provides a basic guide and at least has some cases, because I'm in the development process I can refer to a thing that can avoid some pitfalls" (Software engineer).
- **Possibility of reducing costs of developing apps.** Software developers assume that this prototype as an open resource to some extent could help reduce software development expenditures in terms of investment.
  "I can do it at extremely low cost, say you've done it right, even if you have to charge for it right? I might have had to spend a couple of hundred thousand on development, so now I might spend a rent right? A few hundred or a few thousand (CNY) that's extremely low cost, I can trial and error. This aspect can be, is a good customised platform for the merchant, they can trial, they can customise to transform [sic]" (Software engineer).
- **System reusability.** The software developer believes that the design of this MR system has a degree of replicability for retail brands with similar requirements.

"I would say that reusability might probably be 60% [...]. Your document is not likely to fully meet all the user needs, but you can act as a basic guide, no problem if according to your approach to developing [...]. The reusability of the basic is possible, but if too many customisation requirements (by retailers) may not be able to do, because we can't predict that [sic]" (Software engineer).

- **Convenience.** The brochure facilitates the communication between various departments, as it connects multiple organisations.
  "If no (the brochure), then the product managers need to describe this thing clearly in the form of graphics, and then with the developers to communicate clearly then the developers assess the information whether can be achieved. The market has it (the brochure) then can deepen the understanding and easier for understanding. We directly observe how others do, to refer to our own works" (Software engineer).

Improvements to the *Design Brochure*

Two amendments have been made to the *Design Brochure* based on stakeholders raising two points for improvements: 1) add a diagram of the practitioners' journey to display more explicitly the content of each stage of work and the stages at which they should engage (UID, PD) (see Figure 8.2). 2) Provide a more targeted scope for business projects and business planning at the beginning of the brochure (PM) (see p. 2 in the brochure in Appendix F). The other stakeholders (ID, SE, F) did not suggest additional modifications.

Suggestions for the Future Usage of the *Design Brochure*

Suggestions for future use of this brochure focused on six points: a brief project overview (PM), challenges for product designers (PM), cost estimates (SE), more elaborate visual design advice and targets (UID), application lags (ID), and technological extensions (SE). Some descriptions are given below.

- **Providing brief project overviews and cost estimates used for project collaboration.** The party intending to use this brochure as a reference guideline for their project proposal should refine the business plan according to the collaboration brand's tone and the business project. They can adapt from the brochure and provide a brief, targeted overview of the business project to attract investors' attention. Based on their business size, provide a project brief, potential clients, and a description of the project costs, project duration, and return on investment. If a partnership is established, an implementation framework can be provided using the recommendations in this brochure as a basis.

"Let's say you're already making software to go to them, do you rent it out to them, or with what kind of plan, or is it completely customised by the shop? [...] It takes a UI design (employee), then a modelling (employee), and a scenario design (employee) right? Then the programmers would probably need two [...] and then probably take around three months for development. The development of a software system requires an estimated timeframe, followed by testing" (SE).
"For example, you have this project [...]. Then you sell the project to a shop owner [...]. I think there are several steps to attract me, such as a concise introduction to the project to attract attention and potential customers, the cost of the project, the duration of the project, and the return on investment. Finally, confirm the intention to cooperate and provide product implementation instructions, which is the implementation framework" (PM).

- **Challenges for work scope of product designers.** The product designers' workload may increase accordingly, including designing the number of parameters and customisable components, and collaboration and communication with product modellers, UI designers, and software developers will be required.
"(If required to develop a new product category or new applications) the software developer provides techniques, and then the main content of how to partition, and how to list the specific data columns, are decisions that designers need to make, which means that this software is very much in need of (product) designers and engineers, and UI designers to complete a thing together […] I am going to get involved in this software [...] oh, so I have such a heavy workload" (UID).
- **Providing more elaborate visual design advice and targets.** The MR UI design framework can be expanded and refined in future research on the visual aspects, including detailed recommendations based on subgroups of specific design elements such as UI styles, colour palettes, and text placement.
"The principle is very clear, but I think if it is given to the designer as guidance, it may need to talk a little bit more about this product [...]. So for example, if you say I want rounded corners on every part, how do I place that text? And what's the overall colour palette?" (UID)
- **Challenges for hardware performance and application lags.** Application latency and slow reactions are important technical challenges that need to be addressed in future hardware development.
"I was involved in a project […]. It's kind of like what you're doing here, where you put the glasses on and the customer can literally step into the house that we're drawing. The app is huge, really laggy, yeah, extremely laggy" (ID).
- **Possibilities of technological extensions**. Based on the customer demands outlined in the brochure, it is possible to create a better customer experience in the future by integrating multiple computer technologies to realise these demands.
"I think it can be combined with AI to achieve some functions. For example, your ring can be adapted to the finger, right? Then with the help of AI, you can accurately identify some of the dimensions and boundaries of the finger, and then at the same time, the ring can be adaptively scaled to fit it on the hand. I think it was mentioned in there that it might be better to have it on in real-time,

> *right? Because it's hard for a program to analyse how thick your fingers are, right? That can use AI to do image recognition, right? Depending on demands, actually, you can approach this area, and make this experience better"* (SE).

This design brochure presents a research-driven design framework and practical recommendations developed through a series of sub-studies. Relevant readers and stakeholders have reviewed the brochure, evaluated its applicability in the marketplace, and provided insights for future improvements. Their feedback provides confidence in the guide's feasibility and practical value, indicating that practitioners can reference this thesis to advance their work effectively.

8.4 Contribution Summary

This chapter has addressed a research gap identified in Section 2.6 (p. 65):

Research gap 10: Lack of a holistic mixed reality customer experience management framework in integrating the MR commercial design.

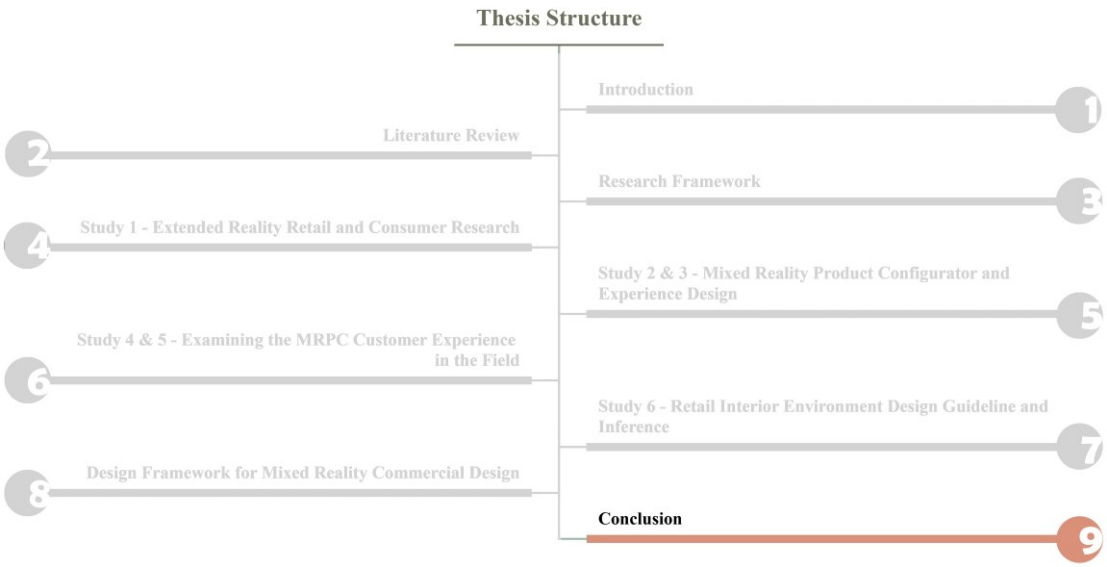
It answers meta research question:

How is it possible to design accessible customer experiences in mixed reality retail environments for brick-and-mortar stores?

Review of the contributions made in this chapter:

- This chapter presents the outcome of this thesis – an MR commercial design framework. This framework consists of one principle, "DIDPOE", which generalises all prior studies into and considerations regarding MR commercial design. From MR UI design and store interior design to customer experience services, the CX design management framework should be considered a unity. Product managers can use this design framework as a basis for conceiving the brand's MR experience, which can enhance the possibility of facilitating the fulfilment of an accessible brick-and-mortar customer experience (see Design Brochure in Appendix F).

9 Conclusion



9.1 Overview of the Research Aim and Findings

This thesis explores how to provide an accessible MR customer experience in brick-and-mortar retail stores through research and design. It aims to enhance consumer accessibility to MR, dwell time, decision-making and experience satisfaction, thereby increasing offline retail conversion rates. Relying on ephemeral sensations of pleasure and temporary experiences is insufficient for the MR channel to develop sustainably and lastingly in the market. Therefore, through a series of studies, this research provides an MR commercial design framework. It consists of recommendations for MR store environment design, UI design, and customer experience management to assist retailers in planning strategies for the MR experience. Specifically, this thesis answers four research questions and addresses ten research gaps:

RQ1: What is the feasibility of, and user preference for, mixed reality adoption in the retail industry?

Research gaps addressed:

Lack of research on XR technologies (VR, MR, AR) in retail with user acceptance and consumer demographics. (Research gap 2)

Lack of comparison between MR and AR retailing, including consumer intent to use, experience, and purchase. (Research gap 3)

Study One investigated RQ1 (see Chapter 4). Study One proposes an XR development consumer model, preferences, and retail typology recommendations for matching technology between consumer and retail. It was found that between VR, AR, and MR, MR is more desirable for shopping purposes. Consumers aged 18-64 prefer MR, while those aged 18-54 are most motivated by it. Females (52.7%) show more preference for MR than males (43.6%). Clothes, shoes, groceries, and jewellery customisation positively correlate with MR preferences. Customers intend to experience MR scenes, sound effects and workshop activities. Users with prior experience perceived MR shopping as more positive than those without experience. Only 5.3% of users (n=807) who experience XR become disinterested.

RQ2: How is it possible to design mixed reality product customisation user interfaces for use in brick-and-mortar retail environments?

Research gaps addressed:

Absence of design recommendations and practices for mixed reality parameterised configurators for mass customisations in retail. (Research gap 4)

Lack of a participatory rapid prototyping approach to aid rapid iterative testing of early-mid MR commercial systems. (Research gap 5)

Studies Two and Three investigated RQ 2 (see Chapter 5). Study Two results provide an MR commercial rapid prototyping tool for designers and consumers to help reduce research and development costs and provide user-participatory design solutions (n=15). Study Three suggests that utility is vital to sustainable consumer use. MR in-store purchasing, as an innovative retail channel, can address some of the customer experience pain points in both online and offline retailing. However, the stakeholders (designers, retailers, XR experts, MR software engineers) identified that the challenges that obstruct the commercial implementation of MR also include technical challenges, retail environment accessibility, the availability of MR software in the marketplace, and investment and awareness degree of MR among retailers (n=26).

Based on these two studies, this chapter proposes a design approach for an MR product configurator for mass customisation in retail stores. Practitioners can use this design solution as a foundation for the development of generalised MR product customisation apps. It also suggests retail shop genres and customer genres suitable for MR mass customisation retail to assist retail managers in situating business.

RQ3: What are the barriers to, and challenges of, mixed reality configurators in traditional brick-and-mortar shops?

Research gaps addressed:

Addressing the issue of short in-store dwell time and lack of shopping enjoyment. (Research gap 1)

Lack of research on MR environments integrated into brick-and-mortar retail stores. (Research gap 6)

Lack of research on user experience and evaluation of MR technology integrated with brick-and-mortar retail stores. (Research gap 7)

Studies Four and Five investigated RQ3 (see Chapter 6). Study Four compares traditional CX and MR CX, suggesting that the adoption of MRPC in retail brick-and-mortar shops can increase customer experience enjoyment and dwell time. However, spacing barriers challenge customer experience satisfaction (Study Five). These barriers mainly arise from usability issues related to MR in-store adoption. Through the study of customers experiencing the MRPC in a store (n=68), the retail environment design factors raised from Study Three are narrowed to eight crucial factors and four factors of MR UI design.

This chapter creates the MR retail customer experience behaviours model, identifies the customer companion genre, and maps MR CX. It helps train retail assistants to understand customer behaviour when adopting MR. These two studies suggest that addressing the issues of environment accessibility, retail assistant training, and MR UI system usability can increase customer experience quality and create a more inclusive MR in-store experience.

RQ4: How is it possible to design inclusive mixed reality retail interior design guidelines for diverse demographics?

Research gaps addressed:

No interior environment design guidelines exist for mixed reality integrated with brick-and-mortar retail stores. (Research gap 8)

Lack of research evaluating user acceptance of mixed reality product configurators integrated into brick-and-mortar stores. (Research gap 9)

Study Six investigated RQ4 and evaluated the design results of RQ2 (see Chapter 7). Study Six extracted and transitioned to seven design factors from the eight interior design factors suggested in Study Five to design the experiment. The study proposed the development of MR store environment design guidelines to provide background colour, illuminance, colour temperature, merchandise display, privacy, spatial dimensions and ratio design values for interior design to improve accessibility to use MR technology in the store environment. It also provides ergonomic recommendations

for space requirements, aiding designers in ideating MR store layout design. It also offers design recommendations regarding differences in customer age groups, height, and preferred usage postures to encourage a wider range of customers to use MR. Therefore, these guidelines thereby help with the accessibility of MR, customer preferences, and demographics to make the MR customer experience more inclusive in brick-and-mortar stores, regardless of their ability to use digital technology.

Evaluating the MRPC design and experience using questionnaires and interviews shows that customers have a positive attitude toward adopting MRPC for future purchases in brick-and-mortar stores. The evaluation data generated the thirteen design principles of the MRPC. It considers both the physical environment and UI design for use in MR retail, which aims to aid graphic UI designers in designing works from 2D to MR.

Meta question: ***How is it possible to design accessible customer experiences in mixed reality retail environments for brick-and-mortar stores?***

Research gaps addressed:

Lack of a holistic mixed reality customer experience management framework in integrating the MR commercial design. (Research gap 10)

The meta-question integrates the findings of RQ1 to RQ4 to create the design framework (Chapter 8). It maps the thesis output by producing the brochure: *Mixed Reality Commercial Design Brochure: Design the Space and Interface for Commerce Mixed Reality in Brick and Mortar Stores* (see Appendix F). The design framework comprehensively delineates how to use these design solutions in reality. The output synthesises the findings of the six studies with conventional CEM frameworks, generating an MR CEM commercial design framework. This framework proposes the design principle, “DIDPOE”: define, ideate, design, prototype, onboard, and evaluate. The framework comprises eight stages, offering design recommendations for MR product configurator applications, store interior environments, and customer services. These insights would help retail product managers develop effective MR experience management strategies. The primary goal is to address the inefficiencies of in-store MR experiences through design. The *Design Brochure* is a practical tool for managers to

create retail strategies that facilitate accessibility and inclusivity in the customer experience. By enhancing the seamless integration of MR in physical stores, this framework supports broader public adoption, possibly accelerating MR's mass-market implementation in brick-and-mortar retail.

Although the thesis proposes physical pop-up stores as the experimental space for pilot studies, it is worth noting that the fieldwork was conducted in a standalone pop-up store (Chapter 6). This shop's interior environment format is the same as that of long-term stores, but with a short-term contract rental. It minimises the environmental experience differences with long-term stores; observations of flow, dwell time, and consumer behaviour are authentic. Furthermore, testing interior design guidelines (Chapter 7) does not necessitate conducting tests in actual venues and experiencing live shopping scenarios, as an uncontrollable actual shop environment would compromise the validity of the testing results. In this context, the pop-up stores as a research context have not minimised the adaptability and applicability of the research findings. Through this path of research from the small to the large, it can distil the core universal design principles and apply them to brick-and-mortar retail (including temporary or permanent physical stores).

On the other hand, regarding the Design Brochure's recommendation to utilise pop-up events for brand strategy development and testing, enterprises should understand the advantages and disadvantages of setting up pop-up stores before investing. Advantages include pop-ups, which have short life cycles and relatively low inputs, allowing for the rapid testing and deployment of concepts, layouts, and CX without incurring the high costs associated with trial and error, as in a permanent shop. Enterprises can collect real-world customer feedback and provide immediate reactions to design interventions. By validating the effectiveness of brand strategies in the small-unit pop-up space, they can be rolled out into permanent shops with greater confidence. Nevertheless, the limitations include lower reliability in assessing the long-term operational, sales, timeless, traffic footfall, and purchasing behavioural patterns of a permanent brick-and-mortar store. Given the different purposes for research and investment, stakeholders must be aware of the distinctions and impacts between them and make decisions with due care and consideration.

This doctoral thesis aims to provide user-centred designs by engaging consumers in each design stage. Doing so minimises the risk of designers and retailers relying on personal preferences. It provides practical design solutions by integrating well-designed MR into a more accessible and inclusivity retail environment. While this research offers significant practical contributions, I hope it also inspires innovators, designers, and researchers in related fields. As quoted in the literature review at the beginning, *"Imagination augments the values of reality"* (Bachelard, 1994). Technology is a by-product of life, yet a purely technological utopia cannot substitute for social behaviour. This work, therefore, seeks to deepen the connection between technology and social interaction by conceiving, creating, and exploring new ways to harmonise them.

9.2 Social Implications

The social implications of the mass adoption of MR technology in commerce are significant and can be examined from several perspectives.

Firstly, there is a need to point out the issues of ethics, policy, and information technology. Privacy and digital inclusion are crucial for guiding public policy and management strategies (Kernaghan, 2014). While only a brief overview is provided here about privacy concerns and the broader impact of MR technology, it is clear that ethical issues are at the forefront of global discussions. For companies considering operations in the metaverse, legal and regulatory compliance is a key factor. As noted in the literature, privacy can be compromised in multiple ways, including potential camera surveillance, bystander sights, data matching, and sharing (Kour, 2024). The thesis states that interior designers should build a spatial boundary and consider using multiple or semi-transparent materials to weaken the influence of bystanders' sight. Yet, the privacy of big data collection in retail is often used to understand customer preferences and offer personalised services. While retailers rely on big data to enhance service delivery, users may be concerned about the transparency and exposure of their personal information.

This has led to initiatives in information sharing and data matching across organisations and even across jurisdictional or national borders, raising issues of consent, data reliability, and the security of linked data (Kernaghan, 2014). As in Study 3, the XR experts also noted that data privacy regulations are closely linked to public policy. While these laws universally aim to protect personal data from unauthorised access, different regions enforce distinct regulatory standards. For instance, China implements the *Personal Information Protection Law of the People's Republic of China* (PIPL)[28], while the UK follows the European Union (EU)'s *General Data Protection Regulation* (GDPR)[29]. Consequently, companies must consider the regulatory requirements of both frameworks when handling personal data involving individuals from China and the EU.

Furthermore, whether MR advertising falls under traditional *Advertising Law*[30] or *Copyright Law*[31], protecting intellectual property within MR environments remains uncertain. Companies must also ensure secure and stable payment methods, as variations in payment options influence applicable regulations. For instance, the European Commission's *Markets in Crypto-Assets Regulation* (MiCA)[32], effective from June 2023, establishes guidelines on asset-reference tokens and e-money tokens (European Union, 2023). These considerations are essential for businesses planning to transition to MR integration. Other implications include potential changes in employment, such as whether MR will create demand for new MR service roles or changes in the labour needs for retail assistants. Additionally, user education and international regulatory cooperation are also critical in implementing MR retail (Kour,

[28] Personal Information Protection Law of the People's Republic of China. https://personalinformationprotectionlaw.com/ (Accessed in March 2025)

[29] General Data Protection Regulation. https://gdpr-info.eu/ (Accessed in March 2025)

[30] Advertising Law of the People's Republic of China. https://www.chinalawtranslate.com/en/advertising-law-2021/ (Accessed in March 2025)

[31] Copyright Law of the People's Republic of China. https://www.wipo.int/wipolex/en/text/466268 (Accessed in March 2025)

[32] Markets in Crypto-Assets Regulation. https://www.esma.europa.eu/esmas-activities/digital-finance-and-innovation/markets-crypto-assets-regulation-mica (Accessed in March 2025)

2024). Especially when it concerns vulnerable groups (such as children or people with disabilities), it is currently unknown to what extent this should be regulated (Chylinski et al., 2020). These are all effects of the consequential social changes of technology, whereas new ethical guidelines and policy advice will need to be established to accommodate the changes.

These technologies have been on the market for several years, while real-world adoption in the public domain remains non-ubiquitous. High upfront investment, commercial feasibility, and undefined ROI remain key challenges in discussion. Therefore, the heavy focus on adoption is on high-investment areas, such as healthcare, the military, or industrial manufacturing. In commerce, adoption is slow but remains of high interest and has been adopted in small pilot tests. High hardware and software costs, limited software resources, lack of inclusivity in user experience, technical maturity, and the absence of an established MR commercial ecosystem are the primary factors hindering the commercialisation and ubiquity of MR technology. From experimentation, move forward to create real-world value, prompting this thesis into adoption patterns, barriers to uptake, sustained use, and user-centred development to refine the MR commercial ecosystem and increase commercial feasibility. This output also contributes to lower upfront development costs and trial-and-error costs by addressing these pain points.

While considering the current market's technological immaturity, which leads to high commitment, MR may remain a value-added service used for strengthening market differentiation. As hardware and software become more affordable, the technology's maturity and commercial ecosystem are also more mature, positioning MR as a compelling investment option. As Chapter 4 identified MR as the most preferred XR experience among consumers (Jin et al., 2023), a study also supports this finding (Pfeifer et al., 2023). This thesis's social implication not only examines what MR technology can achieve and how it can be implemented, but also how it can generate commercial value, with a vision for its long-term integration into public domains. It contributes to building actionable business models, replicable market strategies and the creation of a sustainable MR commercial ecosystem.

9.3 Limitations

Limitations are unavoidable in any research. While the individual limitations of each study have been discussed in their respective chapters, this chapter will outline the overarching limitations of the research as a whole.

First, this interior environment design guide is ideally intended to be used with the MR UI design. Certain environmental design criteria may not be applicable if designing the UI dimensions beyond the proposal range in this study. Specifically, spatial dimensions and proportions are tailored for applications within the MRPC scale. However, design factors such as lighting, colour temperatures, background colours, merchandise display forms, service approaches, and privacy considerations are broadly applicable across various settings.

Second, this study tested the MR system and retail environment only within the context of medium-sized markets and fine jewellery, leaving its effects on smaller markets, such as costume jewellery or luxury jewellery, unexplored. Additionally, in the survey conducted in Study 1, only six retail categories were included (clothing, shoes, groceries, furniture, skincare products, and jewellery), so the relationship between MR interest and other retail categories remains uncertain. Future research should expand testing across a broader range of retail sectors.

Another limitation, as noted in Chapter 5, is that the MRPC system design addresses only the partial functional demands of customers. Due to individual technical constraints, this application did not address several identified functionality needs. However, these requirements are documented in the chapter to guide future development by programmers.

Finally, the acceptance of the technology of the MRPC was not tested in a live retail store. Considering many factors, such as customer demands, product price, brand selection, economic area, and ethics approval, the study did not test live purchase intent, and no means for purchase was provided. Therefore, it was not possible to test whether or not the MRPC improved the desire to purchase a product in reality.

9.4 Future Works

This research employed a cross-sectional methodology. A longitudinal study in the future could provide valuable insights into the long-term behavioural impact of MRPC use on consumers, which would benefit managers and businesses aiming to develop more sustainable MR business strategies. This would be especially helpful in encouraging long-term consumer behaviour in habitual use (Hsiao et al., 2016).

From a design approach perspective, this study tested only seven key MR interior design factors, while other interior design factors have not yet been tested (see also Chapters 5 and 6). Conducting laboratory experiments to test these untested factors would contribute to a more comprehensive interior environment guideline. For instance, I proposed a speculative layout design in Section 7.6.1, which could be investigated further by examining the impact of different layouts on customer behaviour. Additionally, colour is an extensive topic, and this study only focuses on three colours. A promising future research direction would be developing an MR usability colour wheel, allowing retailers to select colours that better align with their brand identity. And, the MR commercial design framework could be further tested in firms and retail markets.

The DIDPOE framework could evolve in several directions. First, its design content can be expanded to provide more comprehensive guidance. Second, further research could also explore MR service management to enrich the design brochure and develop a set of industry standards. Third, its application can be extended to a wider range of commercial scenarios beyond the current scope. Fourth, integrating MR with adaptive or intelligent technologies could enhance system responsiveness and performance. Finally, this work can establish structured feedback and evaluation mechanisms and build an MR commercial development community, encouraging enterprises and users to share how they use the framework to solve complex problems, share suggestions, and report issues. It could also include the development of efficiency indicators and error rates, conducting in-depth interviews with key stakeholders (namely, designers, managers, developers), and implementing regular updates to optimise performance based on usage feedback, making the framework a platform for sustainability goals.

Beyond the design research approach used in the thesis, some emerging research directions of MR retail themes are also intriguing. For example, the role of AI in content generation, AI in computer vision and 3D scanning integration with retail ecosystems (Ameen et al., 2021; Cao, 2021; Oosthuizen et al., 2021; Subramaniam, 2025). These integrations potentially aid in capturing and accurately measuring the customer's body size data and help optimise decisions and increase efficiency. Furthermore, some biometric data, such as eye tracking, EEG, customer flow heat map for assessing browsing paths, decision-making complexity, fatigue, and customer engagement (De Keyser et al., 2021; Kalantari et al., 2023; Modi and Singh, 2023). These emerging technologies and biometric tools can also be incorporated into future updates to the DIDPOE framework to tailor more personalised design recommendations for diverse user groups, including people with disabilities and the broader community.

Although the thesis focuses on inclusivity for public access to MR technology and experiences, accessibility for individuals with disabilities is an intriguing area for further work. For instance, although the ergonomic interior design floor plan (see Section 7.6.1), has not been explicitly drawn and designed for people with disabilities, the ergonomic floor area recommended for sitting posture can be flexibly adjusted to meet the demands of individuals with disabilities by accommodating the wheelchair's space requirements. Future work can further research the various needs of people with disabilities in adopting MR in the public domain to achieve a comprehensive and inclusivity principle in the MR commercial design brochure.

From speculative design thinking (Dunne and Raby, 2013), future possibilities may envision the evolution of MR from static applications to dynamic, integrated ecosystems. Near-future scenarios could involve a symbiotic relationship between digital and physical elements, enabling a dual input and output. For example, product packaging with responsive surfaces might allow users to trigger MR experiences, such as revealing extended product information, through gestures like double-tapping. MR could also integrate with biometric technologies, where unique biometric codes applied to a user's skin enable interactions. When touching a product, the system could automatically display content and log it in the user's browsing history. Users might exchange product lists by physically touching one another. Looking further ahead, fully immersive retail environments may combine MR with facial expression recognition,

AI-driven recommendations, and robotic service systems. These hyper-futuristic retail scenarios envision a phenomenon of hyper-commodification may emerge, where products, services, experiences, and emotions could be incorporated into the consumption ecosystem. These social imaginations or future envisioned landscapes may represent highly speculative commercial designs and the future direction of the experiential economy.

9.5 Contribution Summary

This research has contributed to the fields of design, marketing, management, and human-computer interactions in multiple aspects and has implications of societal and economic significance. The thesis has contributed in two ways: *firstly*, by offering a theoretical contribution that enriches the understanding of theories of mixed reality commercial user-interface design, shop interiors, and retail management; and *secondly*, by providing a practical contribution to the implementation of MR commercial design practices, particularly in China and the UK.

9.5.1 Theoretical Contributions

The field of MR research is highly fragmented, with most studies examining niche topics from a single disciplinary perspective (Rauschnabel et al., 2024). The thesis outcomes integrate and enrich commercial MR design approach and theories from an interdisciplinary perspective. The research will also help to build a managerial knowledge framework for marketing and consumerism in omnichannel retail. Furthermore, the consumer XR technology acceptance model (see Section 4.6), MR participatory prototyping techniques (see Sections 5.4 and 5.5.1), MR customer experience model (see Section 6.5), MRPC user interface design principles (see Section 7.6.2) and store interior environment design guidelines (see Section 7.6.1) provide researchers with a comprehensive range of theoretical, empirical, and methodological contributions to interdisciplinary design research. The methodology of this research provides replicable and actionable guidance for relevant practitioners.

This thesis involves a comprehensive demographic analysis of consumers, designers, developers, and retailers across six studies, enhancing the generalisability of the theoretical contributions. Although participants' demographics continue to highlight consumers aged 18-34 and retailers as primary parties of MR, this study also involved consumers aged 34-54 who show an interest in MR and have a certain purchasing power and consumption ability. These insights theoretically contribute to user diversity in guiding market development strategies.

Finally, design engagement as a methodological concept proposed in the thesis also creates a broader opportunity and possibility to situate the constructive design research or design anthropology. It explains a systematic commercial design research mode exploring MR-based service, space, experience, interface, and interaction design. It also provides a series of design engagement methods that involve multiple stakeholders to collectively engage in creating a design strategy and contribute to reflecting their roles during the decision-making.

9.5.2 Practical Contributions

The results of this research can be used to help implement large-scale MR retail stores. Although the research was conducted in the UK and China, it is oriented toward worldwide consumers and could be used to help implement business practices in other countries with similar contexts.

From a business perspective, this study provides actionable solutions to guide the implementation of MR retail in the market. Companies and organisations might follow the framework when considering investing in this area to understand the benefits and challenges associated with such investment, from selecting technology to hardware procurement, application development, store design, ongoing maintenance, customer acceptance, customer demand and the customer experience journey. This will enable them to develop professional marketing and management strategies to increase their business competitiveness and profitability.

From a design perspective, this research could support interior designers with emerging MR spatial planning. It could facilitate their design work by providing evidence-based best practice guidance on the design values and layout of MR activity spaces for use in

retail settings. This guideline provides a scalable methodology suitable for MR store purposes based on one or more ergonomic drawings for UI and UX designers, including design frameworks, principles and methods. It could support designers to build collaborations and develop more effective user testing and experience journey planning.

From the human-computer interaction perspective, this study could benefit MR developers and engineers working on commercial software development. It provides developers with insights into MR user development requirements and should support them in achieving the development of software features that have not yet been realised but have been identified in this study. On the other hand, engineers might profitably learn how to enhance device functionality by addressing the hardware-level technical challenges highlighted in the study.

From the broader social, economic and public policy levels, the results of this project could help influence public attitudes towards MR technology in society, making it more accessible and desirable. It could increase customer experience satisfaction by fulfilling customer demands in both hedonic and utilitarian aspects. Regarding retail employees, it could change the requirements for their professional skills and potentially lead to the emergence of related new roles.

Finally, at an economic level, adopting the results of this study could help companies increase their market competitiveness and develop innovative business channels, driving local economic benefits and technological investment to future-proof retail offerings in local and national brick-and-mortar stores.

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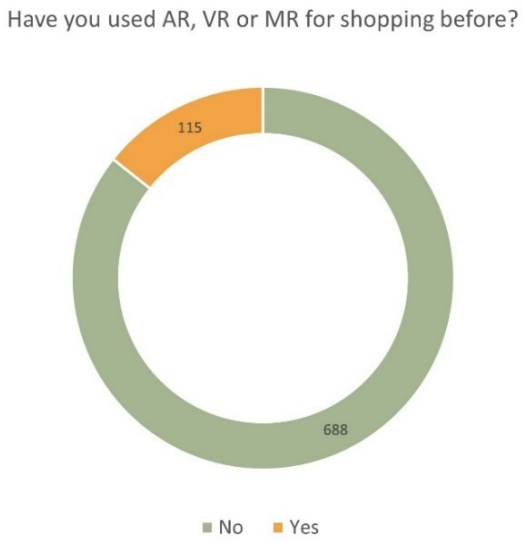
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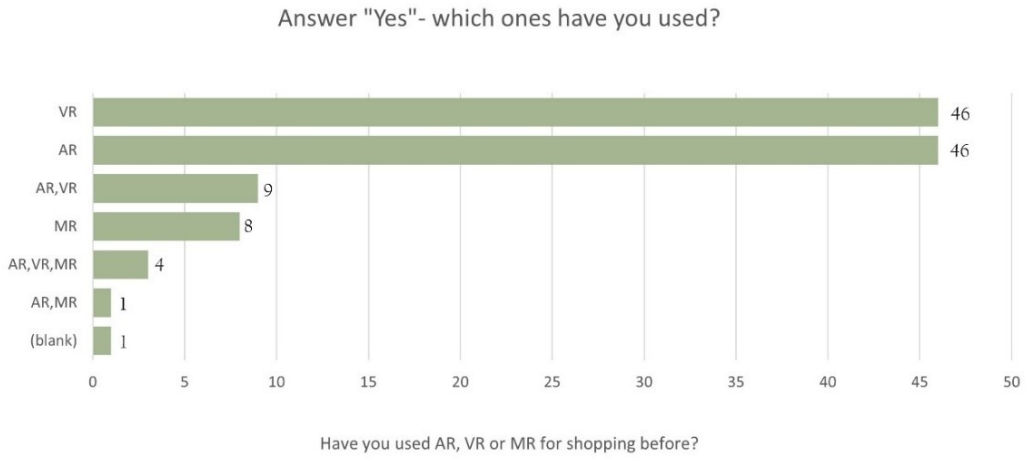
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Appendix A. Study 1: Questionnaire Survey Report

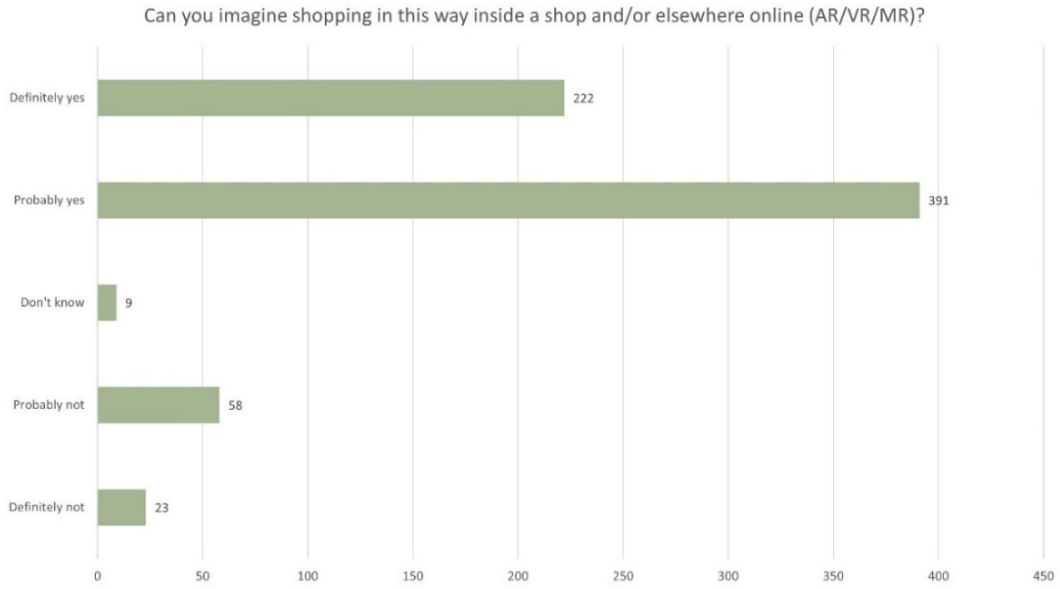
Have you used AR, VR or MR for shopping before?



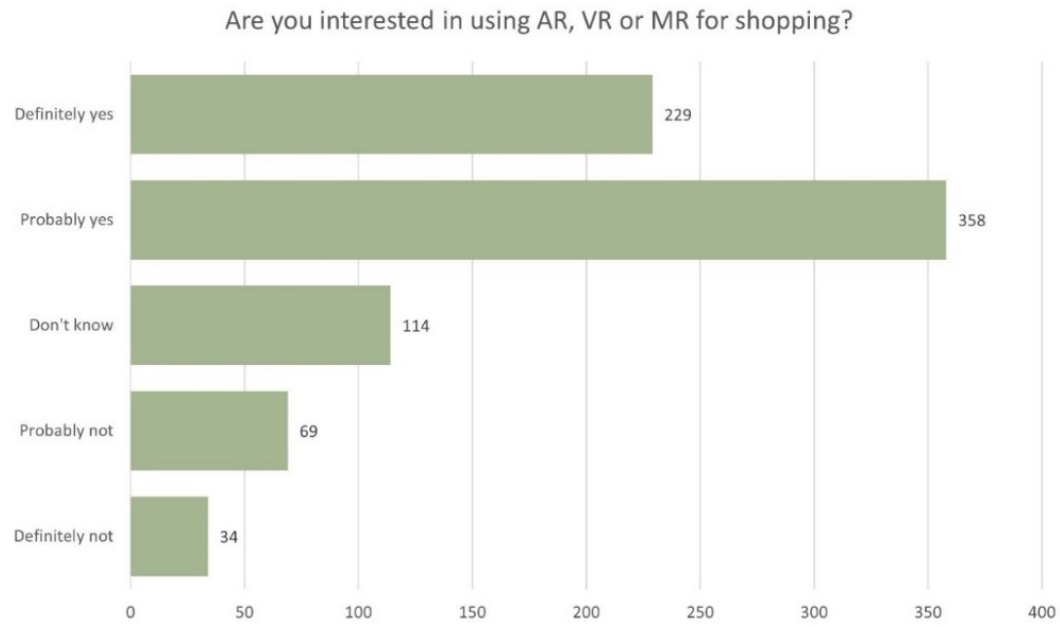
If so, which ones have you used?



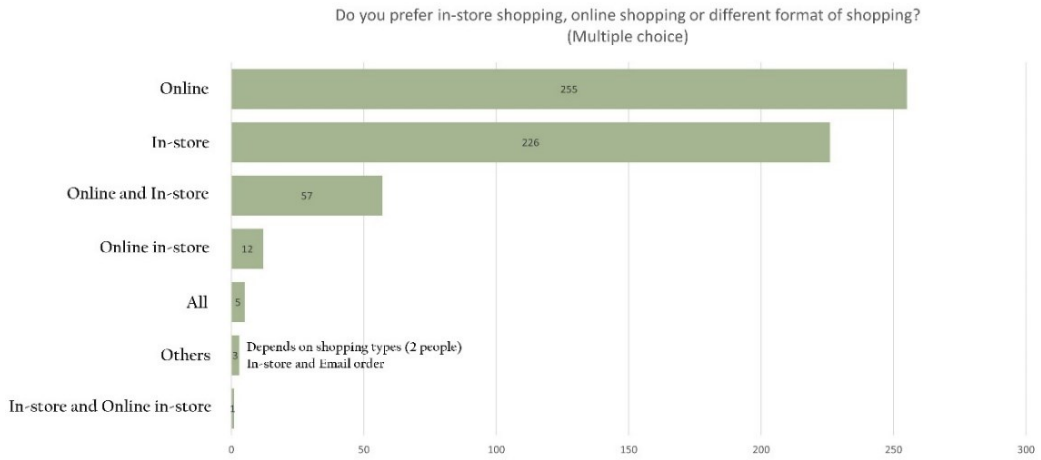
Can you imagine shopping in this way inside a store and/or elsewhere online (AR/VR/MR)?



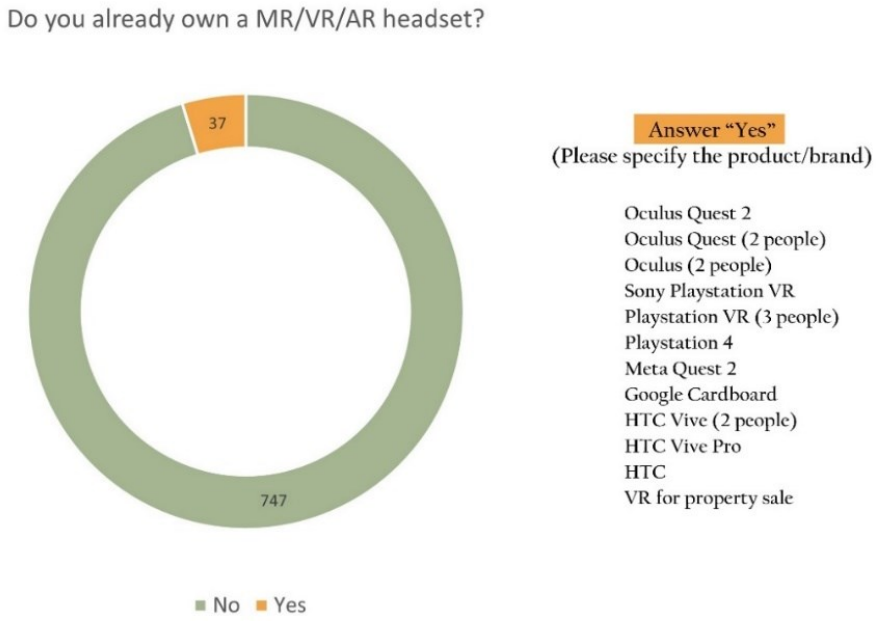
Are you interested in using AR, VR or MR for shopping?



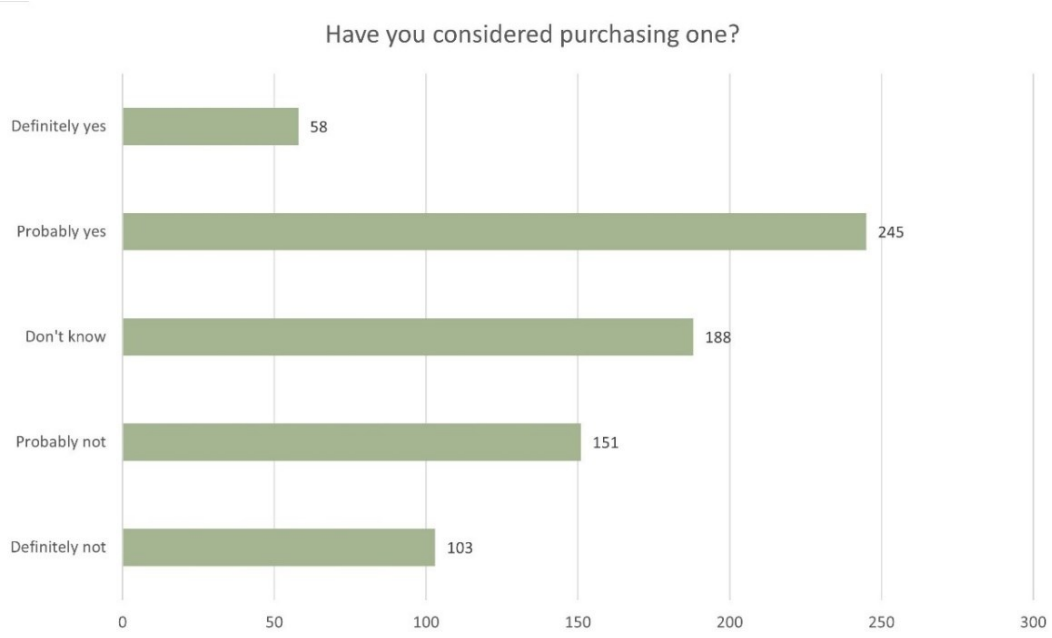
Do you prefer in-store shopping, online shopping or a different format of shopping? (Multiple choice)



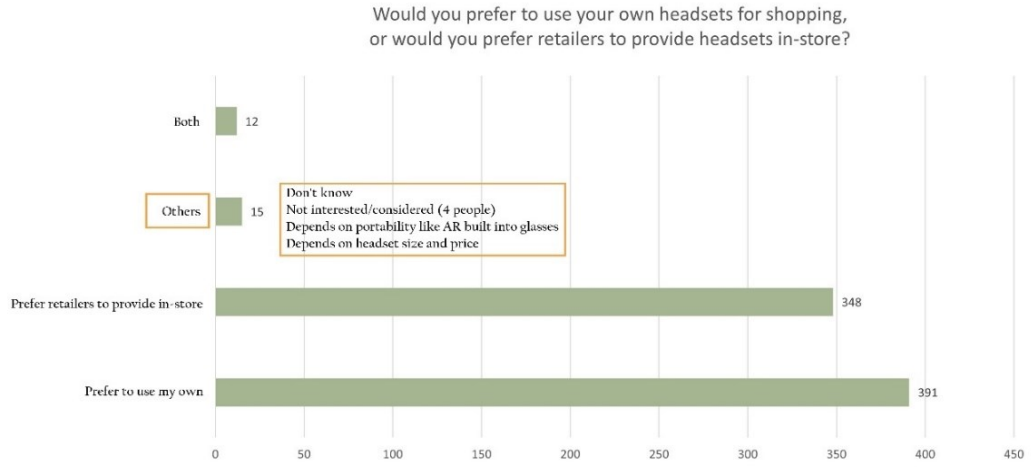
Do you already own an MR/VR/AR headset?



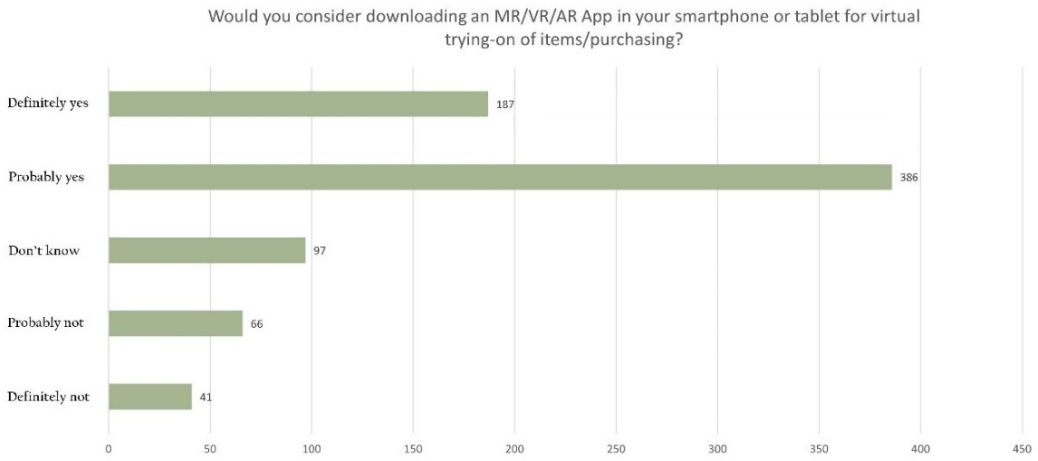
Have you considered purchasing one?



Would you prefer to use your own MR/VR headsets for shopping, or would you prefer retailers to provide MR/VR headsets in-store?



Would you consider downloading an MR/VR/AR App on your smartphone or tablet for virtual trying-on of items/purchasing?



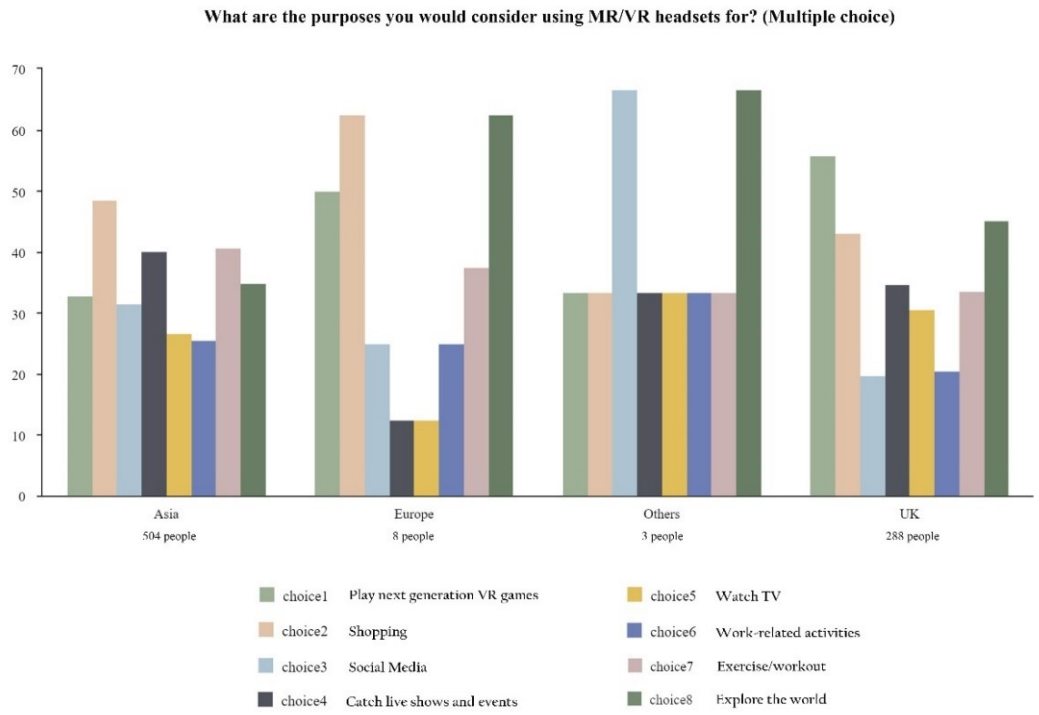
What are the purposes you would consider using MR/VR headsets for? (Multiple choice)

Alternative text responses included:

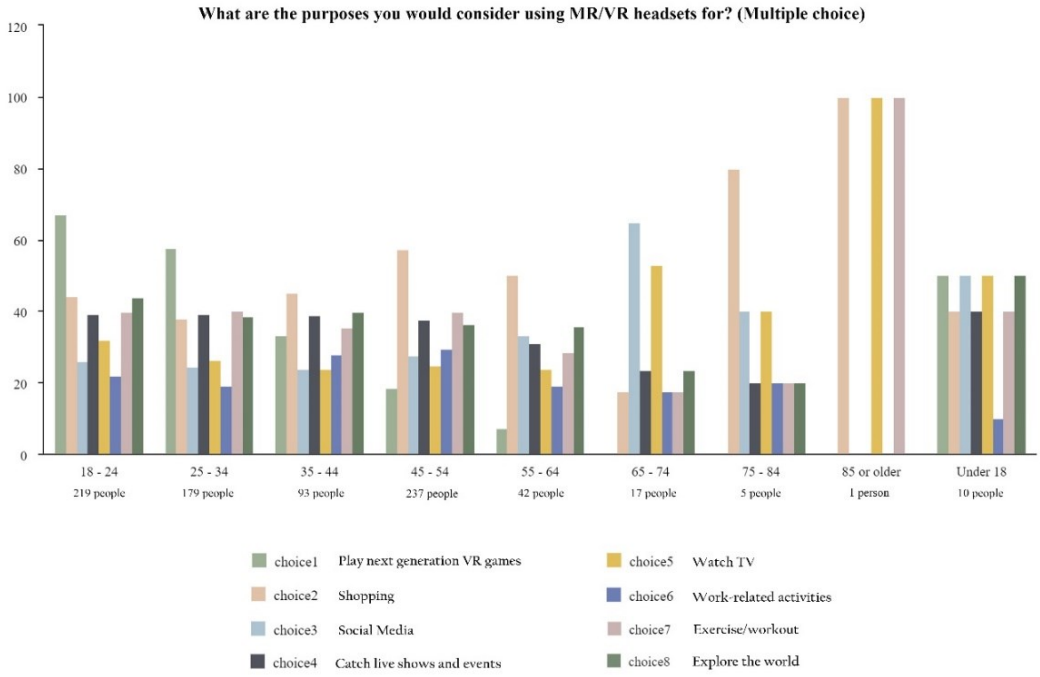
Additional suggestions: Navigation, Watching/making theatre and art, Immersion in nature or similar, Relaxation (block out real world).

Similar (more details) suggestions: Movie, Visual clothes fitting, Visual furniture in a room, Change the colour of walls to preview, Research, Training, Promote conservation.

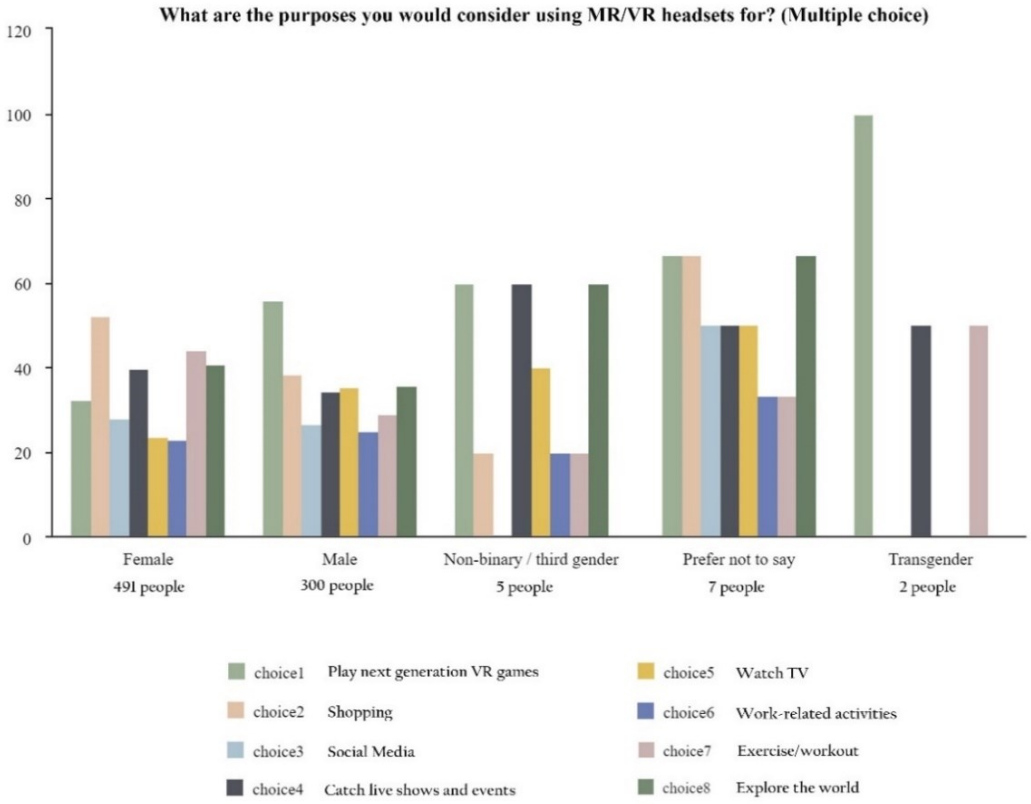
Geography / What are the purposes you would consider using MR/VR headsets for?



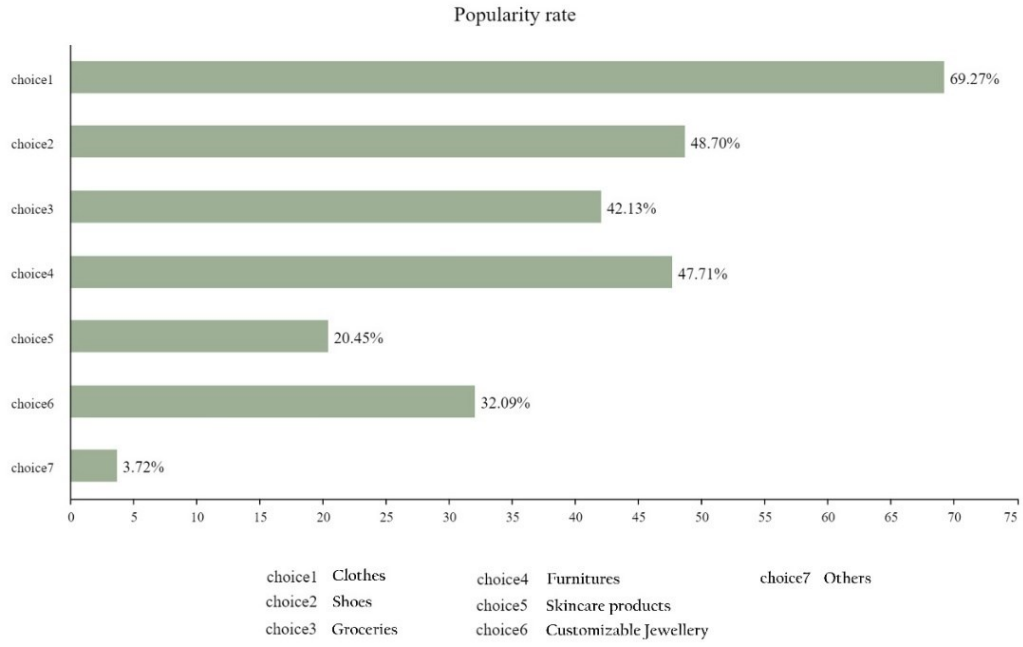
Age Band / What are the purposes you would consider using MR/VR headsets for?



Gender / What are the purposes you would consider using MR/VR headsets for?



What kind of products can you imagine buying through an MR/VR headset? (Multiple choice)



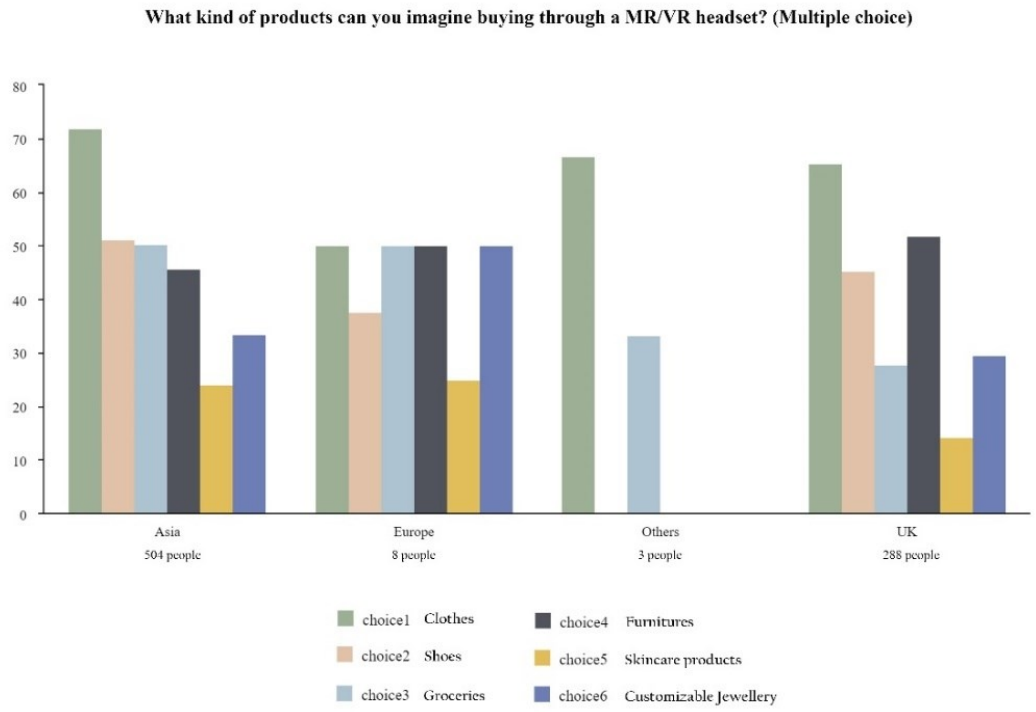
Alternative text responses included:

Expensive products: Car, Motor, Real estate

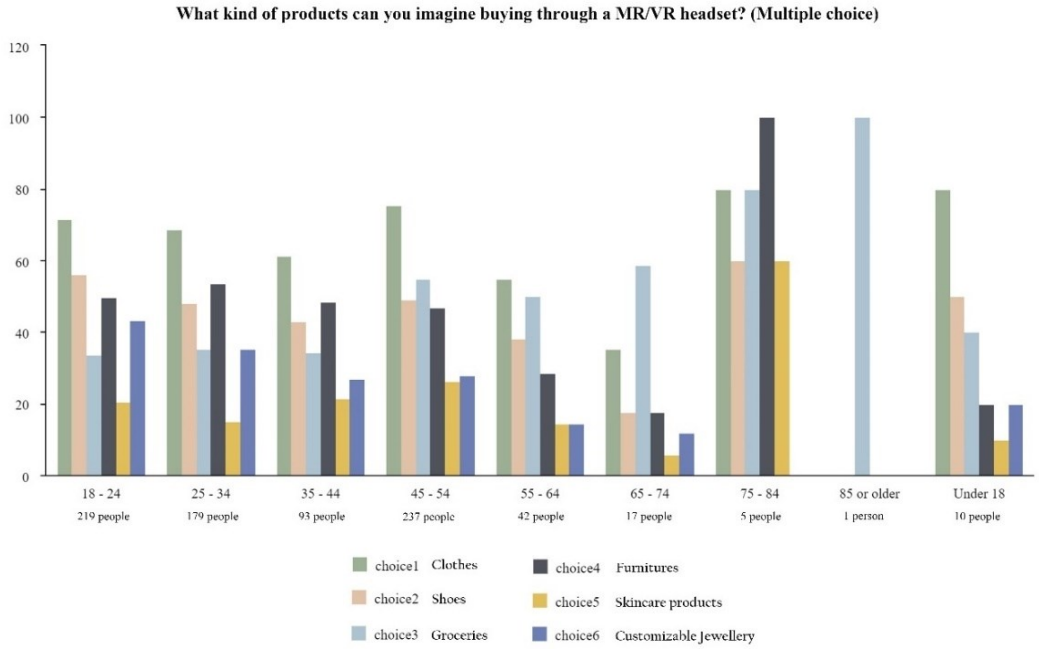
Other categories: Glasses, (home) Decorating supplies, Pet items

Visual products: Football matches, Tattoos, Hairdo, Virtual social platform appearance and other paid items, High involvement purchase

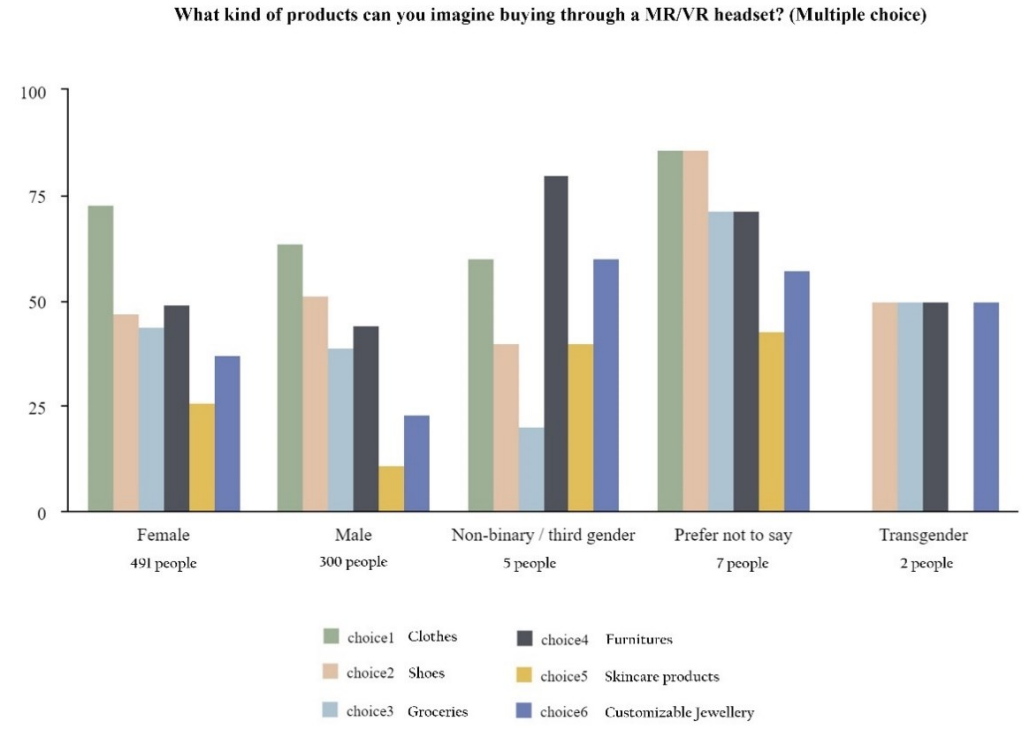
Geography / What kind of products can you imagine buying through an MR/VR headset?



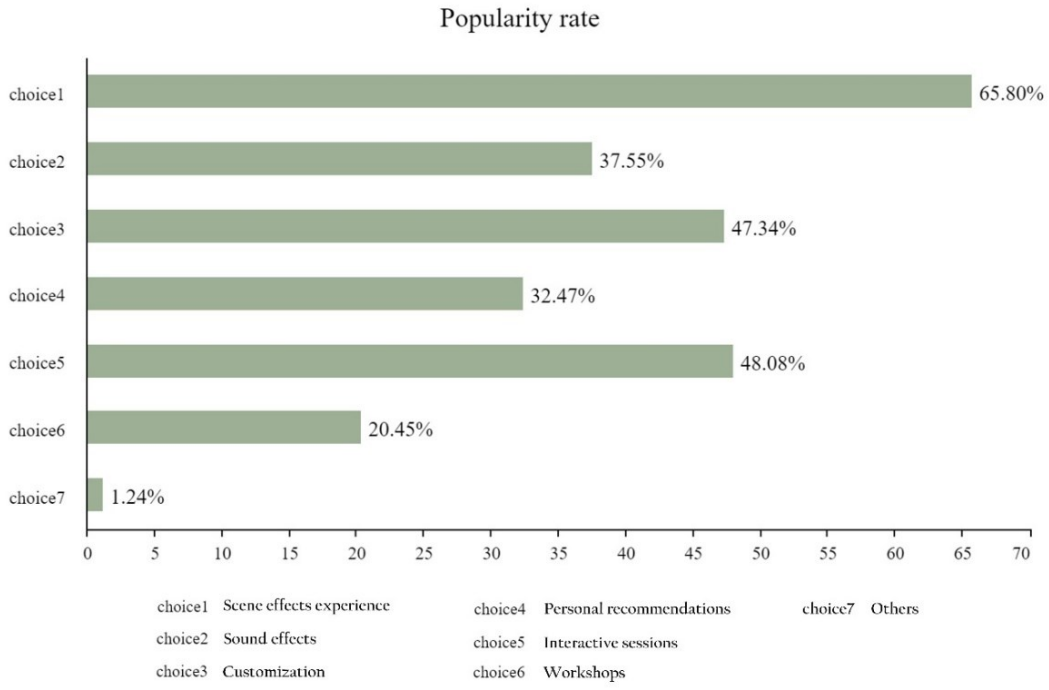
Age Band / What kind of products can you imagine buying through an MR/VR headset?



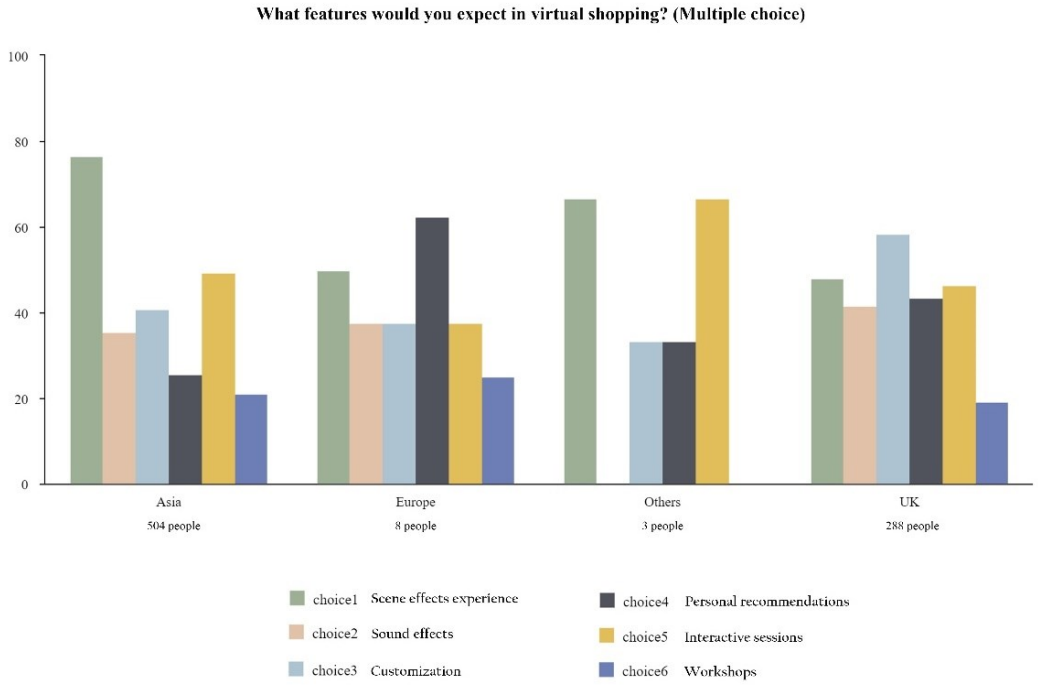
Gender / What kind of products can you imagine buying through an MR/VR headset?



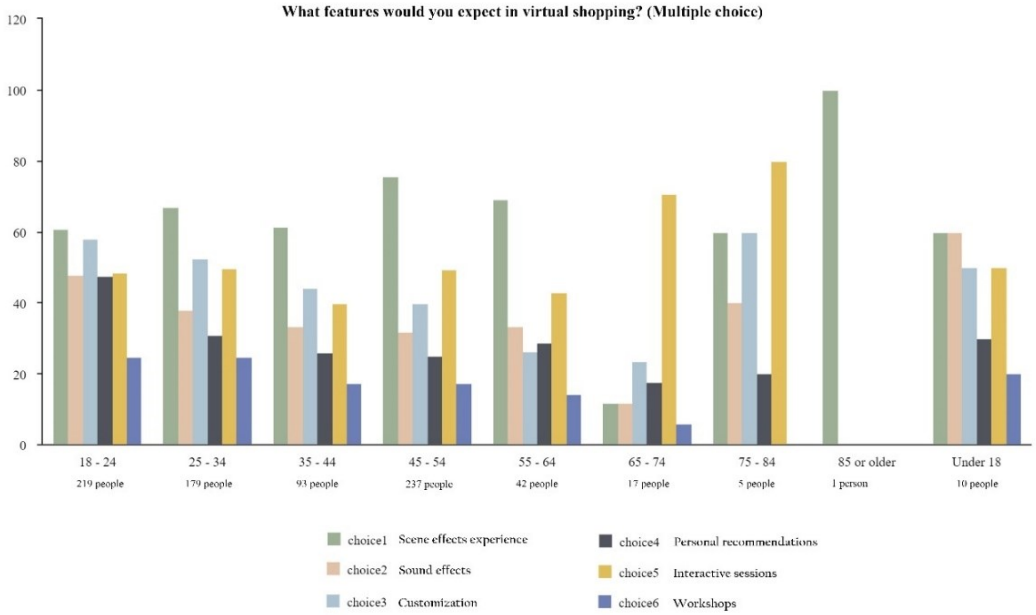
What features would you expect in virtual shopping? (Multiple choice)



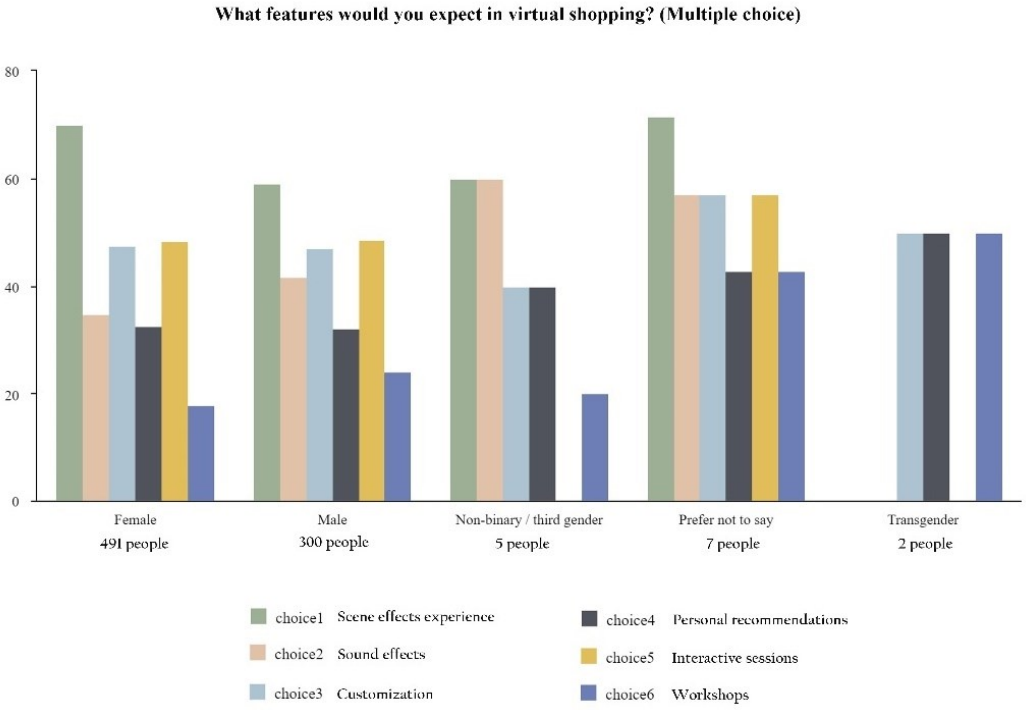
Geography / What features would you expect in virtual shopping?



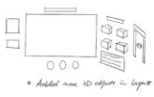
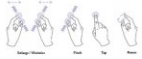
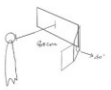
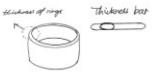
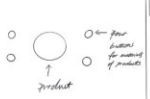
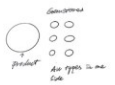
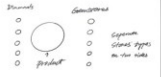
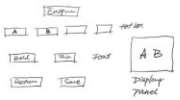
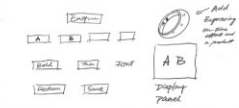
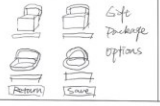
Age Band / What features would you expect in virtual shopping?

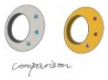
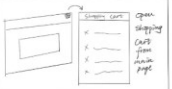
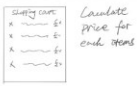
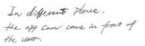
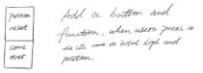
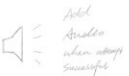
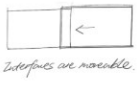
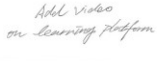
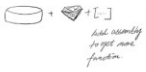
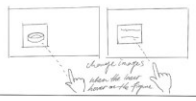
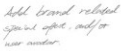


Gender / What features would you expect in virtual shopping?



Appendix B. Study 2: MRPC Iteration Processes

Design Features	Paper Prototyping Cycle A	Paper Prototyping Cycle B	Paper Prototyping Cycle C	Interview	MRPC Prototyping
Layout style				—	—
Interaction gestures			—	—	
Distance and Field of view			—	—	
UI colour			—	—	
Thickness			×	×	×
Interface quantity			—	—	—
Virtual agent (no function)	×		—	—	—
Material		—	—	—	—
Gemstone			—	—	
Engraving	×			—	
Size		—	—	—	—
Shape (texture/ extra diamond)	×			—	
Gift packaging	×		—	—	Add 3D views and interaction.

Design Features	Paper Prototyping Cycle A	Paper Prototyping Cycle B	Paper Prototyping Cycle C	Interview	MRPC Prototyping
Comparison (dual products)	×	×	×		
Shopping cart		—	—		—
Position reset button	×	×	×	×	
Come over button	×	×	×		
Pin button	×	×	×		—
Instruction text	×	×		—	—
Sound aids	×	×	×		—
Interface mobility		—	—	—	—
Video	×	×	×		
Assembly (workshop)	×		—	—	
Visual aid	—	—	—		
Picture cursor hover	×	×	×	×	
Special effect	×				—

Source of MRPC iteration design

Design Features	**Paper Prototyping** Cycle A	**Paper Prototyping** Cycle B	**Paper Prototyping** Cycle C	**Interview**	**MRPC Prototyping**
Layout style	×	✓	○	-	-
Interaction gestures	✓	○	-	-	○
Distance and Field of view	×	✓	-	-	○
UI colour	✓	○	-	-	○
Thickness	✓	×	×	×	×
Interface quantity	✓	○	-	-	-
Virtual agent (no function)	×	✓	-	-	-
Material	✓	-	-	-	-
Gemstone	✓	○	-	-	○
Engraving	×	✓	○	-	○
Size	✓	-	-	-	-
Shape (texture/extra diamond)	×	✓	○	-	○
Gift packaging	×	✓	-	-	○
Comparison (dual products)	×	×	×	✓	○
Shopping cart	✓	-	-	○	-
Position reset button	×	×	×	×	✓
Come over button	×	×	×	✓	○
Pin button	×	×	×	✓	-
Instruction text	×	×	✓	-	-
Sound aids	×	×	×	✓	-
Interface mobility	✓	-	-	-	-
Video	×	×	×	✓	○
Assembly (workshop)	×	✓	-	-	○
Visual aid	-	-	-	✓	○
Picture cursor hover	×	×	×	×	✓
Special effect	×	✓	○	○	-

×: without feature, ✓: new feature, -: remains unchanged, ○: modification of the original feature

Appendix C. Study 5: Definition of MR Retail Brick-and-mortar Stores Customer Experience Model

Main Category (Selective coding)	Subcategory (Axial coding)	Interpretation
C1 MR retail assistant attributes	B1 agent engagement	The retail assistant serves, facilitates, demonstrates and communicates with the user when they access the equipment.
	B2 service efficiency	Accuracy of the retail assistant instruction, accuracy of understanding user requests and disruptive behaviour when users access the MR system
	B3 service mobility	Movement of retail assistants in space while assisting users to use MR systems and make purchases.
	B4 service responsiveness	Proactive advice and instructions for users when the retail assistant identifies potential barriers to use or unattainable needs.
C2 MR headset user's companion attributes	B5 companion engagement	The involvement of the user's companions during user access to the device, including interactive behaviours such as chatting, making suggestions, questioning, and interrupting.
	B6 companion sentiment	Affective states of companions include positive affect, negative affect and neutral affect.
	B7 companion observation	User companions to observe users photographing, waiting and queuing behaviour while accessing the device.
	B8 companion shopping	User companions concentrate on individual shopping, dressing and browsing while the user navigates the system.
	B9 companion socialisation	Conversation between companions, companions and agents, enquiry, and other social activity.
	B10 companion mobility	Movements and trajectories of companions in space
C3 Interior environment attributes	B11 colour	The colour profile of the shop, including the colour of products, interior decoration and lights.
	B12 lighting	It includes lighting illuminance and the quantity and variety of lights that affect the performance of the MR system.
	B13 merchandise displays	The display of assortment, range, quantity, colour contrast, and order of the products hindered visual order and task processing when employing the MR system.

	B14 privacy	The motions of the users attract the gaze of outsiders, and outsiders' gaze constrains user behaviours.
	B15 safety	With access to the MR device, the user and agent's movement trajectories and motor performance intersect with the environment, and the spatial boundaries need to be manifested.
	B16 sound	Obstruction to the performance of the MR system by various sound pressure levels indoors.
	B17 spatial dimension	The dimensions of the physical space limit the dimensions, functionality and full display of the virtual interface and virtual effects.
	B18 spatial layout	Including the layout of display cabinets, lamps, furniture, and MR equipment counters. Users encounter issues, including UI embedded in objects and obstruction paths.
C4 MR system attributes	B19 interaction design	Provide users with animated elements for interaction, consider the system's interactive complexity, and use visual cues to guide interaction.
	B20 system accessibility	Users incapable of aiming at the target, uncontrolled rays, incorrect interaction gestures, and miss-triggering unintentional virtual contents are the main problems.
	B21 system stability	The system occasionally shows unstable, such as bugs, and minor interface jitters may occur during use.
	B22 user interface design	Users have responded positively to the multi-screen taskbar, noting that it offers a unique experience unattainable in a physical environment.
C5 Co-present customer attributes	B23 public await	Co-present customers have queuing behaviour while the current MR headset user is occupied.
	B24 public intervention	Co-present customers interrupt MR retail assistant serve user operation behaviours, such as asking retail assistant general and MR experience questions.
	B25 public socialisation	Co-present customers have conversations with companions and have customer service conversations with other agents.
C6 MR headset user attributes	B26 attempts quality	Users have various attempts to manipulate the system to make shopping attempts, including invalid, repeat, successful, unconscious, and unsuccessful attempts.
	B27 decision making	Users try to compare products, both virtual and physical. Some users try all customisation options and virtual effects in the app.
	B28 guidance	Users repeatedly ask for manipulation instructions and whether customised style recommendations are available.
	B29 information access	Users ask the MR retail assistant for information about agents, MR applications, designers of products and apps, devices, products, store activity, and system function.

	B30 seek homophily	Users recommend the experience to their companions and invite companions to join.
	B31 self-identification	Users evaluate their design outcome and express self-identify.
	B32 social identification	Users share design outcomes with companions, their perceptions of experiences and products, and seek companion identification.
	B33 system quality	Part of the users report system errors during use.
	B34 system operational behaviour	Users' operating MR system behaviours include describing their behaviour to the assistant, accidentally opening the device system menu, speaking out product information, reviewing designer outcomes, seeking companion perspectives, seeking product location, switching hands to manipulate, being unaware of operation success, walking in space, viewing product description, virtual fitting products, and attention to reality activity.
	B35 user experience perception	Users perceive the MR experience in various ways, including its ability to encourage physical exercises, facilitate easy purchasing and learning, offer novelty, align with personal interests, and serve as a potential future purchasing method.
	B36 user sentiment	Users express various emotions, including confusion, negative, neutral, and positive sentiments.

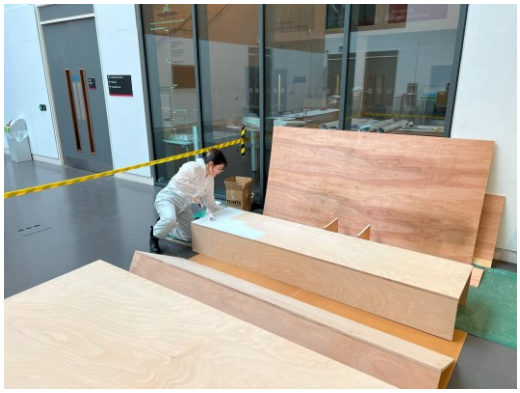
Appendix D. Study 6: Pop-up Installation Build Processes

AR modelling effect



Actual effect



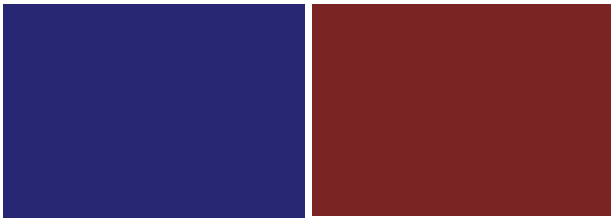







#282774 Blue: R40, G39, B116. C100%, M100%, Y23%, K10%.

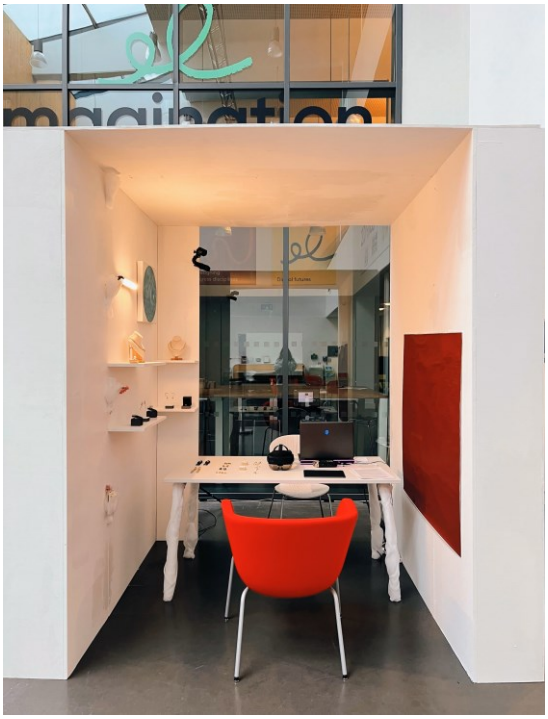
#7b2524 Red: R123, G37, B36. C31%, M92%, Y85%, K38%.

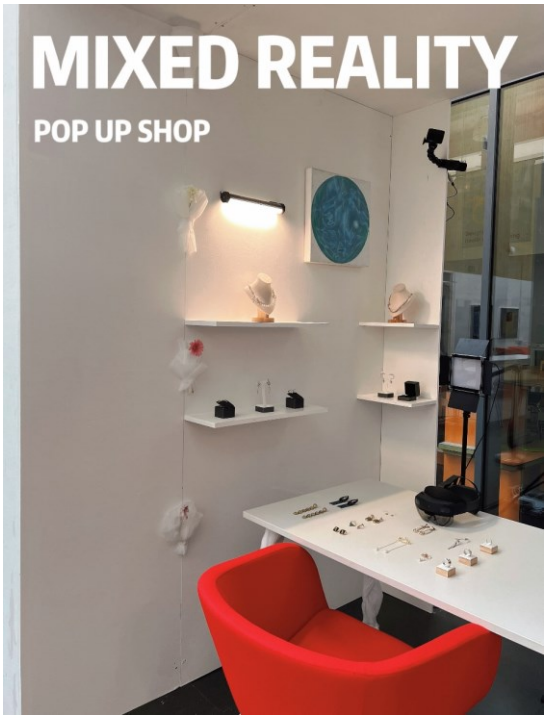




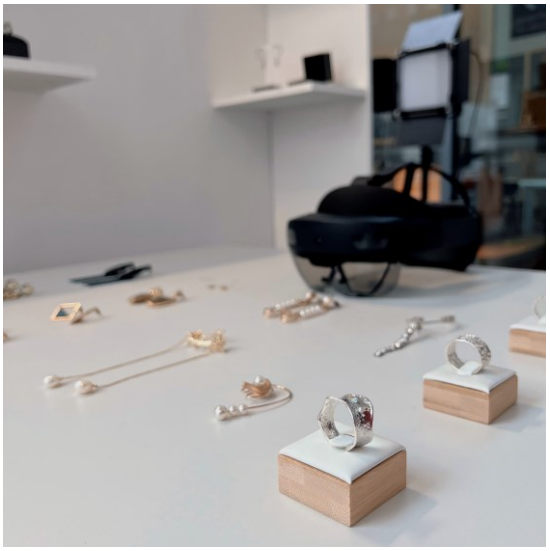







MIXED REALITY
POP UP SHOP

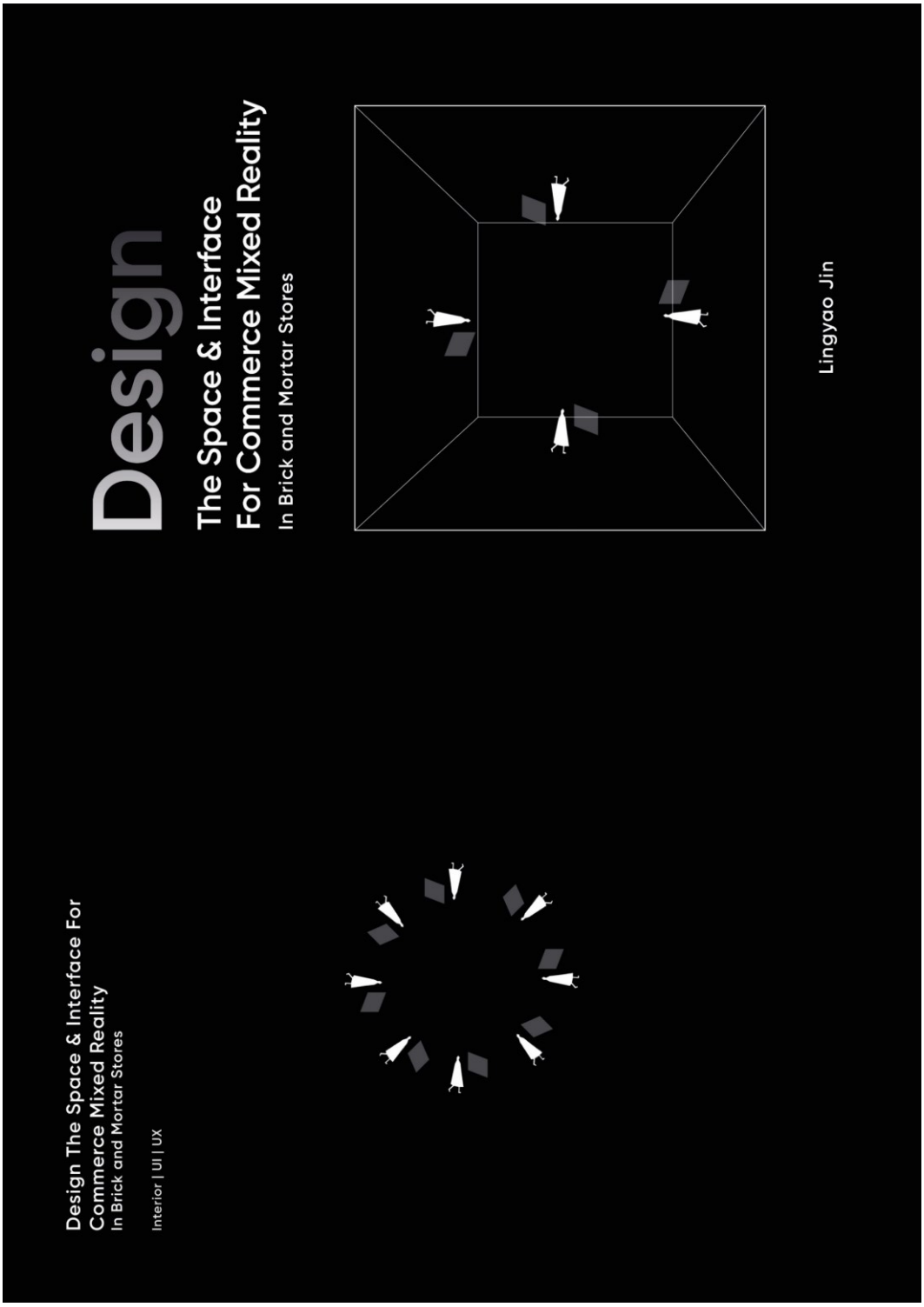




Appendix E. MR Configurator Design Principle Graphic Card Toolkit



Appendix F. MR Commercial Design Brochure



What is this brochure about?

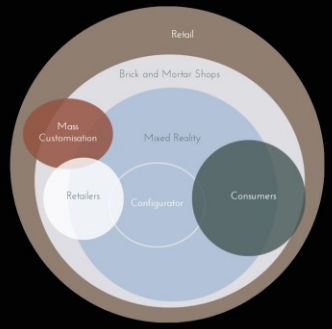


Figure 1. Scope of the brochure

The trend of omnichannel retail implies the growing integration of online and offline retail. Brick-and-mortar retail, as one of these retail channels, needs to adopt immersive technology such as Mixed Reality (MR) to enhance in-store experiential stimuli to activate the vitality of brick-and-mortar store purchasing. Therefore, it is necessary to explore the future role of MR retail channels and to recommend integrated MR retail design frameworks. Current research on MR and retail lacks data on user markets, mass customisation applications, physical environment design and MR commercial strategy. These are all significant reasons for the lack of large-scale adoption in the market.

This brochure aims to provide value for stakeholders from a design perspective by exploring the desires of consumers and retailers. By utilising mixed reality immersive technology to enhance the user and retailer shopping experience, purchasing power, and market competitiveness. The brochure proposes an MR customer experience management (CEM) framework to implement large-scale MR brick-and-mortar stores to improve MR headset customer experience accessibility and assist retailers in planning strategies(**Figure 1**). **It provides recommendations for the design of shop interior environments and product mass customisation application, and managerial suggestions using medium and large scale enterprises - fashion (fine jewellery) retail brick-and-mortar stores as a pilot test.**

This brochure is the output of a doctoral thesis - ***Mixed Reality Commercial Design: Designing The Space and Interfaces Between Digital and Physical Environments of Purchase,*** and the contents derive from excerpts from the doctoral thesis.

Who is this brochure for?

A better understanding of the needs of consumers and stakeholders will help guide the design direction of Mixed Reality channel retail purchasing. This brochure primarily provides design frameworks for designers, as well as retailers, to optimise their design approach, guide brand planning and effectiveness, and enhance consumer and user purchase confidence for their in-store experience. The design framework encompasses contextual scenarios and methods that can benefit individuals, regardless of their background and experience. ***The design guideline will benefit the following groups of the community and abbreviations will guide relative readership in each section cover, for example, D indicates designers.***

- **DESIGN (D): Interior/User Interface/Experience/Product Designers.** By giving insight into consumer behaviours, decision-making, and the relationship between mixed reality and retail. UI/UX designers will be able to understand MR user behaviours to better design customer journeys. Product designers will be able to co-design and invite customers to participate in the design process by employing the proposed MR paper prototype tool. Interior designers will be able to design accessible and inclusive MR interior spaces based on the design recommendations.

- **RETAIL MANAGEMENT (RM): Retailers, Companies, Customer Experience Managers and Product Managers.** Market research guidelines will enable retailers to determine the types of retail suitable for implementing mixed reality technology to achieve maximum profits and brand requirements. Additionally, they will be able to plan marketing strategies in advance based on user feedback of product development and technology acceptance predictions. Suggested signposts will allow them to evaluate and plan their brand strategy, identifying weaknesses and strengths.

- **SOFTWARE DEVELOPMENT (SD): Mixed Reality Developers and Software Engineers.** The Product Configurator Design Recommendations provide developers with insights into current consumer market demands, foundational development documentation, and case studies for reference. This resource equips developers with a systematic approach to accessing and utilising relevant tools and information effectively.

- **FACTORY (F): Manufacturers and Producers.** Through product configurators, brands will achieve higher product satisfaction, potentially reducing return and exchange rates. This will help manufacturers and producers increase material usage efficiency and carry out robust product manufacturing and assembly business planning.

- **POLICY AND ACADEMIA (PA): Policy Planners and Researchers.** Through comprehensive research reports, policymakers and urban planners will be able to use these contexts as reference rules and guidance for planning city business centres and economic development areas. Researchers will be able to use these research directions and experimental procedures to construct and replicate relevant study experiments.

How can I benefit from this brochure?

Significance of this *Design Brochure*

From a **business** perspective, this study provides actionable solutions to guide the implementation of MR retail in the market. Companies and organisations might follow the framework when considering investing in this area so they can understand the benefits and challenges associated with such investment, from selecting technology to hardware procurement, application development, store design, ongoing maintenance, customer acceptance, customer demand and the customer experience journey. This will enable them to develop professional marketing and management strategies to increase their business competitiveness and profitability.

From a **design** perspective, this research could support interior designers with emerging MR spatial planning. It could facilitate their design work by providing evidence-based best practice guidance on the design values and layout of MR activity spaces for use in retail settings. This guideline provides a scaleable methodology suitable for MR store purposes based on one or more ergonomic drawings for UI, UX and CX designers, including design frameworks, principles and methods. This could support designers to build collaborations and develop more effective user testing and experience journey planning.

From the **human-computer interaction** perspective, this study could benefit MR developers and engineers working on commercial software development. It provides developers with insights into MR user development requirements and should support them to achieve the development of software features that have not yet been realised, but have been identified in this study. On the other hand, engineers might profitably learn how to enhance device functionality by addressing the hardware-level technical challenges highlighted in the study.

From **broader social, economic and public policy** levels, the results of this project could help influence public attitudes towards MR technology in society, making it more accessible and desirable. It could increase customer experience satisfaction by fulfilling customer demands in both hedonic and utilitarian aspects. Regarding retail employees, it could change the requirements for their professional skills and potentially lead to the emergence of related new roles.

From an **economic** level, adopting the results of this study could help companies increase their market competitiveness and develop innovative business channels, driving local economic benefits and technological investment to future-proof retail offerings in local and national brick-and-mortar stores.

Social Implications

The social implications of the mass adoption of MR technology in commerce are significant and can be examined from several perspectives.

Firstly, there is a need to point out the issues of ethics, policy, and information technology. Privacy and digital inclusion are crucial for guiding public policy and management strategies (Kernaghan, 2014). While only a brief overview is provided here about privacy concerns and the broader impact of MR technology, it is clear that ethical issues are at the forefront of global discussions. For companies considering operations in the metaverse, legal and regulatory compliance is a key factor. As noted in the literature, privacy can be compromised in multiple ways, including potential camera surveillance, data matching, and sharing. The big data system in retail is often used to understand customer preferences and offer personalised services. While retailers rely on big data to enhance service delivery, users may be concerned about the transparency and exposure of their personal information.

This has led to initiatives in information sharing and data matching across organisations and even across jurisdictional or national borders, raising issues of consent, data reliability, and the security of linked data (Kernaghan, 2014). Extended reality experts also noted that data privacy regulations are closely linked to public policy (see also Jin, 2025, pp. 159-160). While these laws universally aim to protect personal data from unauthorised access, different regions enforce distinct regulatory standards. For instance, China implements the Personal Information *Protection Law of the People's Republic of China (PIPL)*[1], while the UK follows the European Union (EU)'s *General Data Protection Regulation (GDPR)*[2]. Consequently, companies must consider the regulatory requirements of both frameworks when handling personal data involving individuals from China and the EU.

Furthermore, whether MR advertising falls under traditional *Advertising Law*[3] or *Copyright Law*[4], protecting intellectual property within MR environments remains uncertain. Companies must also ensure secure and stable payment methods, as variations in payment options influence applicable regulations. For instance, the European Commission's Markets in *Crypto-Assets Regulation (MiCA)*[5], effective from June 2023, establishes guidelines on asset-reference tokens and e-money tokens (European Union, 2023). These considerations are essential for businesses planning to transition to MR integration.

Other social implications include potential changes in employment, such as whether MR will create demand for new MR service roles or reduce the labour need for retail assistants. Additionally, user education and international regulatory cooperation are also critical in implementing MR retail (Kour, 2024). These could be interesting directions for future research.

[1] Personal Information Protection Law of the People's Republic of China. https://personalinformationprotectionlaw.com/ (Accessed in March 2025)
[2] General Data Protection Regulation. https://gdpr-info.eu/ (Accessed in March 2025)
[3] Advertising Law of the People's Republic of China. https://www.chinalawtranslate.com/en/advertising-law-2021/ (Accessed in March 2025)
[4] Copyright Law of the People's Republic of China. https://www.wipo.int/wipolex/en/text/466268 (Accessed in March 2025)
[5] Markets in Crypto-Assets Regulation. https://www.esma.europa.eu/esmas-activities/digital-finance-and-innovation/markets-crypto-assets-regulation-mica (Accessed in March 2025)

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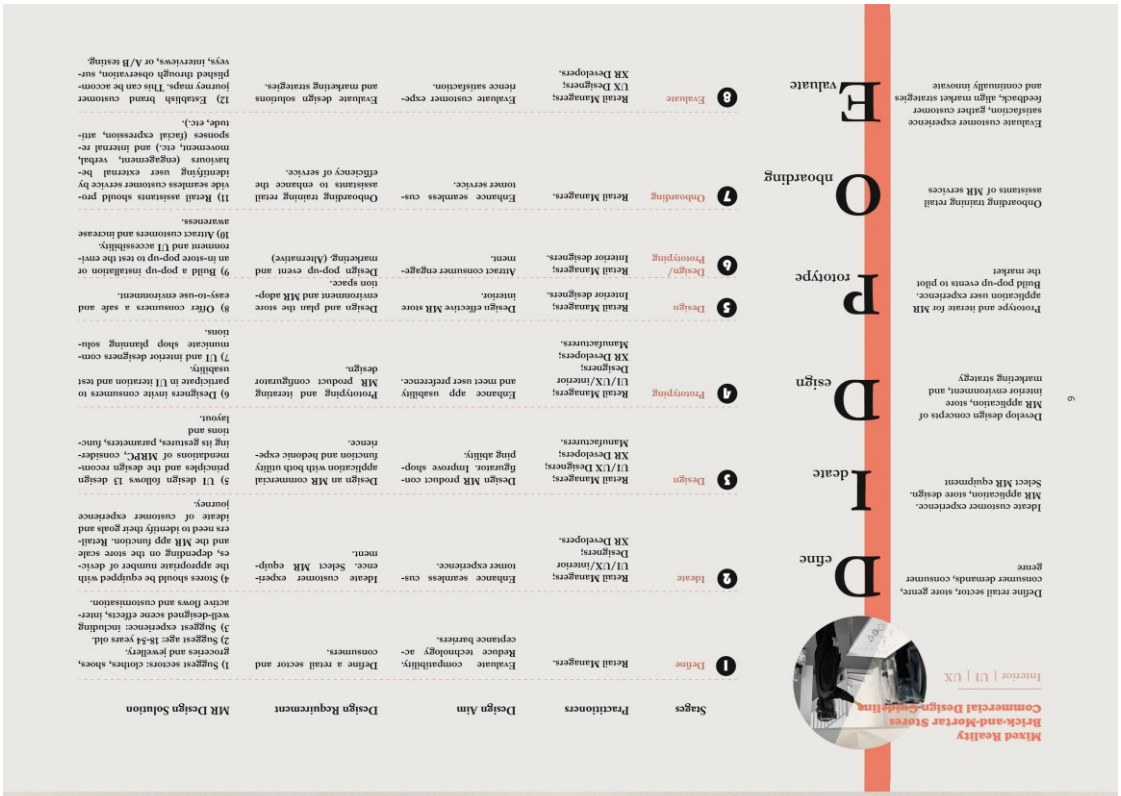
Section

00

Mixed Reality Commercial Design Guideline

This guideline is a flexible framework, a set of generalisable principles rather than strict metrics or rules. Retailers and design teams are encouraged to adopt the recommended guidelines to make their business strategies while tailoring them to align with their company identities and brand positioning.

To help retail managers develop brand strategies, they should read through the brochure, as some solutions may be incompatible with some retail contexts or are not involved in this research. This MR design guideline outlines sequential approaches, with targeted recommendations provided at each stage. The guideline introduces the principles of 'DIDPOE', which is structured into eight stages, each involving specific practitioners. This brochure will unfold the depiction based on this principle.


Mixed Reality
Brick-and-Mortar Stores
Commercial Design Guideline
Interior | UI | UX
D Define
Define retail sector, store genre, consumer demands, consumer genre
I deate
Ideate customer experience. MR application, store design, Select MR equipment
D esign
Develop design concepts of MR application, store interior environment, and marketing strategy
P rototype
Prototype and iterate for MR application user experience. Build pop-up events to pilot the market
O nboarding
Onboarding training retail assistants of MR services
E valuate
Evaluate customer experience satisfaction, gather customer feedback, align market strategies and continually innovate
Stages
Practitioners
Design Aim
Design Requirement
MR Design Solution
1 Define
Retail Managers.
Evaluate compatibility. Reduce technology acceptance barriers.
Define a retail sector and consumers.
1) Suggest sectors: clothes, shoes, groceries and jewellery.
2) Suggest age: 18-54 years old.
3) Suggest experience: including well-designed scene effects, interactive flows and customisation.
2 Ideate
Retail Managers; UI/UX/Interior Designers; XR Developers.
Enhance seamless customer experience.
Ideate customer experience. Select MR equipment.
4) Stores should be equipped with the appropriate number of devices, depending on the store scale and the MR app function. Retailers need to identify their goals and ideate of customer experience journey.
3 Design
Retail Managers; UI/UX Designers; Interior Designers; XR Developers; Manufacturers.
Design MR product configuration. Improve shop display.
Design an MR commercial application with both utility function and hedonic experience.
5) UI design follows 13 design principles and the design recommendations of MRFC, considering its features, parameters, functions and layout.
4 Prototyping
Retail Managers; UI/UX/Interior Designers; XR Developers; Manufacturers.
Enhance app usability and meet user preference.
Prototyping and iterating MR product configurator design.
6) Designers invite consumers to participate in UI iteration and test usability.
7) UI and interior designers communicate shop planning solutions.
5 Design
Retail Managers; Interior designers.
Design effective MR store interior.
Design and plan the store environment and MR adoption.
8) Offer consumers a safe and easy-to-use environment.
6 Design/ Prototyping
Retail Managers; Interior designers.
Attract consumer engagement.
Design pop-up event and marketing. (Alternative)
9) Build a pop-up installation or an in-store pop-up to test the environment and UI accessibility.
10) Attract customers and increase awareness.
7 Onboarding
Retail Managers.
Enhance seamless customer service.
Onboarding training retail assistants to enhance the efficiency of service.
11) Retail assistants should provide seamless customer experience by identifying user external behaviours (engagement, verbal, movement, etc.) and internal responses (facial expression, attitude, etc.).
8 Evaluate
Retail Managers; UX Designers; XR Developers.
Evaluate customer experience satisfaction.
Evaluate design solutions and marketing strategies.
12) Establish brand customer journey maps. This can be accomplished through observation, surveys, interviews, or A/B testing.
9
8
MIXED REALITY COMMERCIAL DESIGN GUIDELINE JOURNEY MAP
The guideline introduces the principles of 'DIDPOE', which includes six principles. Ideas, designs and prototypes should be circulated through the design process in multiple iterations. Each involves specific practitioners as shown.
1 Define
Design Directors
Product Managers
Define the product vision, product theme, UI style, UX functionality and shop style.
UI / UX Designers
Design the application interface visual, adjust the interface layout and size according to the product design's customisable function.
Product Designers
Design products and customisable components, setting customisation function conditions and scopes.
2 Ideate
3 Design
4 Prototype
Software Engineers
Assess the manufacturability of products, adjust solutions with product designers and provide 3D models of products to software engineers.
Factory Manufacturers
Assess the manufacturability of products, adjust solutions with product designers and provide 3D models of products to software engineers.
Constructors
Complete the construction following the interior designer's design plans.
Interior Designers
Design shop environment based on the brand style, product display and customer behaviours.
5 Onboarding
Retail Assistants
Training in the ability to use MR and service efficiency.
6 Evaluate
Customers / End-Users
1 Define
Before deciding to adopt a technology, it is necessary to conduct market research to identify the target region. This will help define the market potential between their retail category, XR technology, and the targeted customer segment.
2 Ideate
Retail Product Managers and UX Designers lead the product definition and ideation stage, ideating the customer experience journey and conveying design requirements to the design team and software engineering team.
3 Design
UI designers and software engineers conduct MR commercial application design following the commercial application, including rapidly iterating UI design and developing app functions. Interior designers and constructors recommend layout and seven design factors for store interior environments that make MR technology more accessible for public use.
4 Prototype
The UI designer iterates the interfaces using Unity, Figma, or Unreal Engine, and engineers to implement the application. Developers finalise the application user testing and delivery to product managers. Interior designers can also test their spaces to ensure MR aligns with brand application feedback and achieve the purpose of marketing.
5 Onboarding
Onboarding training retail assistants to enhance their service efficiency and familiarise using MR headset users' verbal and nonverbal behaviour and user companion types to refine their customer services.
6 Evaluate
Product managers can conduct market field-work to evaluate customer MR commercial experience strategies and design solutions feedback. By evaluating customer experience outcomes can provide valuable insights for each stage design solutions and refining services.
8

RM

Section

01

Define

Before deciding to adopt a technology, it is recommended to conduct a market survey in the target region. This will help define the market potential between their retail category, XR technology, and the targeted customer segment.

10

Introduce to XR: eXtended Reality

Virtual Reality (VR)	Augmented Reality (AR)	Mixed Reality (MR)
Users experience fully virtual interactive, multisensory, user-centred, 3D computer-generated environments, and blocking out the physical world.	Users are able to see digital and textual information superimposed on the real-world environment.	MR is also known as immersive AR or wearable AR in some contexts. Users use wearable HMDs to experience where hands interact with virtual objects, eliminating the need for touch screens or portable controllers.
Users are isolated from the real world through Head-Mounted Displays (HMDs) and can only interact with the presented digital content.	The experience added digital elements in smart devices, with the real world central to the experience and perceived low levels of local presence.	The fusion and overlay of the real and virtual worlds create a new environment where physical and digital objects interact and coexist in real time and perceive high levels of local presence.

Figure 2. Differences in comparison of AR, MR and VR. Adapted from (Technolush, 2019).

Extended Reality (XR) is the umbrella for all types of current and new realities, such as Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) (Adriana Cárdenas-Robledo et al., 2022; Rauschnabel et al., 2022a) (**Figure 2**).

- **Virtual Reality (VR):** It defined as fully immersive, interactive, multisensory, user-centred, 3D computer-generated environments and the technologies that construct such environments (Aukstakalnis, 1992; Cruz-Neira, 1998).

- **Augmented Reality (AR):** It is defined as a range of technologies that integrate real-world and virtual information to enhance a specific reality (Lamantia, 2009; Milgram and Kishino, 1994). AR involves the use of a non-immersive display-based interaction on which computer-generated images are overlayed electronically or digitally (Milgram and Drascic, 1991). In this thesis, AR is used to refer to mobile AR, which is near-physical reality (Microsoft, 2022).

- **Mixed Reality (MR):** It also namely as immersive AR (iAR) or AR headsets, is defined as an existing display system that displays both real and virtual objects (Microsoft, 2022; Zhang et al., 2021).

MR has high levels of immersion and local presence, which users can feel "being there"; AR has low levels of local presence, which is more "functional" integrated virtual content, such as textual information (Rauschnabel et al., 2022a). VR's telepresence presents the degree to which users perceive themselves as being in the virtual world independent from their actual reality (Rauschnabel et al., 2022b). The MR interaction requires specific equipment or wearable hardware, namely head-mounted displays (HMDs) (Speicher et al., 2019). Figure 2.5 represents the difference between VR, AR and MR.

11

The following **Table 1** provides a cross-sectional comparison of XR technologies.

	VR	MR	AR
Advantages	• Highly immersive interaction • Provide more extended information • Share experiences remotely and in real-time • High sense of presence in a fully artificial environment • Can view effects that do not presently exist, reducing the reliance on imagination • Can provide certain conveniences, such as virtual fitting	• High-mid immersive interaction • Provide more extended information • Share experiences remotely and in real-time • High sense of presence in a mixed artificial environment • Can view effects that do not presently exist, reducing the reliance on imagination • Can provide certain conveniences, such as virtual fitting	• Provide a certain extended information • Share experiences remotely and in real-time • Portable devices • Affordable devices • Equipment with less presence • Apps easy to access • Do not require additional space • Can view effects that do not presently exist, reducing the reliance on imagination • Can provide certain conveniences, such as virtual fitting
Disadvantages	• Battery life of HMDs • Holding hand controllers • Expensive HMDs • Equipment with a strong presence • Common physiological discomfort (neck, arms, eye fatigue) • Require onboarding • Require a lot of space • Common ethical concerns (e.g. privacy, data storage, personal data collection) • Development costs can be expensive • Detachment from reality/ distortion • Technology is relatively immature and technical errors may occur • Information overload due to advertising and irrelevant information such as spam • Over-glorification of virtual products may lead to customer dissatisfaction	• Battery life of HMDs • Expensive HMDs • Equipment with a strong presence • Common physiological discomfort (neck, arms, eye fatigue) • Require onboarding • Require a certain space • Common ethical concerns (e.g. privacy, data storage, personal data collection) • Development costs can be expensive • Technology is relatively immature and technical errors may occur • Information overload due to advertising and irrelevant information such as spam • Over-glorification of virtual products may lead to customer dissatisfaction	• Battery life of smart devices • Holding tablets or smartphones • Low immersive interaction • Low sense of presence in a mixed artificial environment • Common ethical concerns (e.g. privacy, data storage, personal data collection) • Development costs can be expensive • Technology is relatively developed but technical errors may still occur • Information overload due to advertising and irrelevant information such as spam • Over-glorification of virtual products may lead to customer dissatisfaction

Table 1. Comparison of advantages and disadvantages of XR technology in retail. Jin (2025), p.31

Before reading further, a QR code is attached to enable readers to watch the video of using the MR product customisation application example with jewellery as the pilot app proposed in this research.

Customer Preferences for XR Retailing

Extended Reality has more or less established applications in the retail sector. Given AR, MR, and VR technologies with distinct customer experience and investment, stakeholders should have clarity on the impact of implementing such tools on design, development, and return on investment (ROI). Most important is whether consumers would be willing to accept, access, afford, and derive the value return as desired from it. Therefore, it is necessary for retailers and companies to conduct market research before making decisions on which one is relevant to the sales sector where they are involved and to identify the technology preferences, intent to use, and intent to experience of their target user segments, thereby increasing the effectiveness of their investment. Once retailers confirm their demands and user demands, designers and technologists can develop the design modules and software for the XR technology according to the needs of the retailers and the design guidelines.

The extent to which a technology aligns with user expectations can significantly influence both its acceptance and the effectiveness of its implementation (Scherer and Craddock, 2002). Consumer satisfaction with and attitude to adopt the technology are factors that drive the adoption of technology by retailers (Alnawas and Aburub, 2016; Foroudi et al., 2018). Therefore, this section intends to facilitate retailers and managers to understand why choose MR technology, what retail sector might be relevant to the XR, what are the customer preferences for these technologies, who are those audiences, and what should be considered in investing in MR technology.

By conducting a market survey in 2022, with 807 respondents, the findings define the market development directions and user models for XR technologies and validate the feasibility and user preferences for MR in future retail. MR is considered the most promising XR technology for development in the retail market according to consumer preferences (**Figure 3**) (Jin, 2023). The limitation of VR technology is that many users suffer from vertigo with VR devices due to being fully immersive. This can significantly affect the experience or the frequency of return visits for the audience. Consequently, retailers should also consider the accessibility of the equipment when developing and investing in XR applications. For example, market analysis research needs to investigate what percentage of the user population suffers from VR vertigo and whether the proportion is acceptable. Both VR or MR applications will need to wear headsets/ head-mounted displays (HMDs), which would need to be planned with less visually intrusive and less rapid-moving virtual content to minimise the negative physiological response. Based on the above, this research will focus on adopting MR technology in retailing.

Figure 3 suggests that the age range of the consumer group adopting MR purchase might be between 18-64, but the aged 18-54 are greater accept (Jin, Dalton and Fagan, 2023). For AR, the results aligned with other studies showing that users between the ages of 18-34/35 are the major groups (Xue et al., 2020; Burke, 2002). The differences in users between MR and AR include a wider age range of users preferring MR, with females preferring MR over males and males preferring AR. For product categories, using MR to purchase groceries and customized jewellery are the recommended categories. Given the genre of retail suggested in this brochure (page 15), this brochure uses customised jewellery as the pilot study for testing the development of the MR purchasing system.

In addition, scene effects as customers highly intent on experience suggest attention to the integrated visualisation of hybrid environments instead of just virtual scenarios. This involves the cross-design of both physical store environments and virtual environments, which are user interfaces. Consequently, the brochure aims to provide comprehensive suggestions for design methods for MR purchase user interface design and MR retail interior environment design.

Extended Reality and Consumer Preferences Recommendations in Retailing				
Technology & Consumer Preferences	**Demographics & Intentions**	**Classification**	**Suggestions**	**Interpretation**
Mixed Reality (MR)	User Demographics	Gender	Female (52.7%) > Male (43.6%)	A statistically significant correlation exists between gender and MR preferences ($p<0.05$). Females (52.7%) significantly prefer MR technology than males (43.6%).
		Age	Aged 18-54	A statistically significant correlation exists between age and MR preferences ($p<0.01$). Consumers aged 18-64 prefer to use MR, while those aged 18-54 have a greater proportion.
	Consumer Intentions	Intent to Use	Shopping/Social media/Catch live shows/Work-related/Exercise	A statistically significant correlation exists between these use intentions and MR preferences ($p<0.01$). Consumer preferences (response rate): shopping (55.8%) > catch shows (45.7%) / exercise (45.5%) > social media (33.8%) / work-related (29.3%).
		Intent to Purchase	Clothes/Shoes/Groceries/Customisable jewellery/Skincare products	A statistically positive correlation exists between these five items and MR preferences ($p<0.05$). The response rate is: 76.5% of customers chose clothes, 56.8% for shoes, 48% for groceries, 39.4% for customisable jewellery and 24.75% for skincare products.
		Intent to Experience	Scene effects/Sound effects/Workshops	These three items are statistically positively correlated with MR ($p<0.05$). Consumer preferences (response rate): scene (76%) > sound effects (42.7%) > workshops (27.8%). Customisation, Personal recommendations and interactive sessions are not statistically correlated with MR. The customer preferences (response rate) are as follows: 48.7% of customers chose customisation, and 50.5% for interactive sessions.
Augmented Reality (AR)	User Demographics	Gender	Male (23.7%) > Female (13.1%)	There is a statistically highly significant correlation between gender and AR preferences ($p<0.001$). Males (23.7%) significantly prefer AR technology than Females (13.1%).
		Age	Under 18-34	There is a statistically significant correlation between age and AR preferences ($p<0.01$). Consumers aged under 18 to 34 significantly prefer to use AR, while aged under 18 to 24 have a greater proportion.
	Consumer Intentions	Intent to Use	Play games	Playing games has a statistically positive correlation with AR ($p<0.01$). AR has a statistically negative correlation with work-related ($p<0.05$). Shopping, social media, catching live shows/TV, exercising and exploring the world have no statistical correlation with AR ($p>0.05$). Consumer preferences (response rate): Play games (59.3%) > Shopping (49.6%) > Exercise (40%) > Explore the world (39.3%) > Catch live shows (37.8%).
		Intent to Purchase	Shoes	There are a statistically significant correlated with AR purchase for shoes ($p<0.05$). Skincare products have a negative correlation with AR, which is not recommended.
		Intent to Experience	Personal recommendations	Personal recommendations has a statistically positive correlation with AR ($p<0.05$), with a 40% response rate. Consumer preferences (response rate) for other not statistically correlated items: scene effects (63%), interactive sessions (53.3% %), customisation (52.6%), and sound effects (43%).
Virtual Reality (VR)	User Demographics	Gender	Female (30.1%) = Male (31.4%)	There is no statistically significant correlation between gender and VR preferences ($p>0.05$). There is no significant difference between females (30.1%) and males (31.4%) in preference for VR technology.
		Age	N/A	There is no statistically significant correlation between age and VR preferences ($p>0.05$). There is no significant difference between different age bands in their preference for VR technology.
XR Previous Experience	With XR Experience (14.3%) (n=115)	XR technology	MR (47.4%) > VR (43%) > AR (24.6%)	For MR, previous experience has no statistically significant differences in user preference ($p>0.05$), and users before and after use have not shown differences in preferences (retention of 47.4%). For AR, previous experience has statistically significant differences in user preference ($p<0.01$), and users who prefer it decrease (retention of 24.6%). For VR, previous experience has highly statistically significant differences in user preference ($p<0.001$), and users who prefer it decrease (retention of 43%).
		Intent to Use	Shopping/Live Show/Exercise	There is a statistically significant correlation between consumers who had XR experience and intent to use XR for shopping ($p<0.01$), catching live shows and exercise ($p<0.05$). Of consumers who have experienced XR, 60% chose to prefer to use them for shopping, 47% chose to catch a live show, and 48.7% chose to aid exercise.
		Intent to Purchase	Clothes/Furniture	There is a statistically significant correlation between consumers who had XR experience and intent to use XR for purchasing clothes ($p<0.01$) and furniture ($p<0.05$). Of consumers who have experienced XR, 80% chose to buy clothes, and 56.5% chose furniture.
		Intent to Experience	Customisation	There is a statistically significant correlation between consumers with XR experience and intent to use XR for experiencing customisation ($p<0.05$). Of consumers who have experienced XR, 57.4% chose to experience customisation.
		User Retention	5.3% of users might not be retained	5.3% of users who have had XR experiences have become disinterested in any XR technology after use.
	Without XR Experience (85.7%) (n=688)	XR technology	MR (49.8%) > VR (28.6%) > AR (15.5%)	For users who have not had an XR experience, 49.8% intend to try MR, 28.6% intend to try VR, and 15.5% intend to try AR.
		User Retention	12.7% of users might not try XR	12.7% of users who have not experienced XR indicate they prefer not to try MR, AR or VR.
Dislike XR	User Demographics	Gender	Male (13.9%) > Female (10%)	There is a statistically significant correlation between gender and dislike of any XR technology preferences ($p<0.05$). Among those who dislike XR (MR/AR/VR) technology, males (13.9%) have a statistically significant dislike of XR than females (10%).
		Age	N/A	For users who dislike XR, there is no correlation between age and XR preference ($p<0.05$).
	Consumer Intentions	Intent to Use	Shopping	12.8% of consumers are not interested in using XR shopping.
	Previous XR Experience	With & Without previous experiences	11.7% of consumers dislike XR	For all experienced consumers, 11.7% of consumers are not interested in using XR.
Data collection in 2022, surveys were distributed in the United Kingdom and China with 807 respondents.				

Figure 3. XR development consumer model, preferences and retail typology recommendations.

Mixed Reality Customer Experience in Omnichannel Retailing

Table 2 shows the significance of adopting the *MR Product Configurator (MRPC)* for mass customisation in brick-and-mortar retailing. It summarises consumer interview results that validate the significance of providing the MRPC to brick-and-mortar shops. Consumers with a high proportion of online shopping identified the advantages as time-saving and convenience and the disadvantages as a lack of perceived product size and haptic experience. To bridge the pain points between the two channels, design requirements need to include 1:1 3D product dimensions, virtual product fitting, etc (Jin, 2025, p.165).

Table 2. Three retail channels benefit and barriers

	E-commerce Channel	MR Brick and Mortar Channel	Brick and Mortar Channel
Benefit	• time-saving • convenience • price and promotion • elaborate price information • available stocking • less time pressure	• elaborate price information • agent knowledge • recommendation • social avoidance • work independently • less time pressure • increase engagement • sense of immersion • increase sactisfaction • accelerated decision-making • strength idea communication • uniqueness • creativity and attractiveness • preview outcome • larger product information display interfaces • knowledge acquisition • efficient cutomisation • virtual fitting • direct fulfillment of needs • design freedom • sustainable customisation display methods	• agent knowledge • build relationship • dyslexic customer service • recommendation • fitting • tactile experience
Barriers	• lack of haptic • agent service waiting • perceived product size • lack of experience • picture embellishment	• learn to use duration • comfort • environment accessibility • system accessibility • cost • slower decision making • queue for HMDs • privacy • product fidelity	• product information display • size • lack of fitting image • lack of efficiency • unwilling to fitting room • crowed • fitting room await • limit options • no stocking • product comparison difficulty • inconvenience on carry purchases • insufficient information • employee pressure • communication efficient • sustainability of supplies for customised effect displays

Prospective Retail Store Genres on MR Product Customisation Adoption

This section helps retailers further define whether they are ready to invest in adopting MR technology by following the recommendations for retailer genre and customer type as outlined below. By conducting in-depth interviews with seven retailers, analysis of retailers identified the following retail genres with prospects of investment and adoption on MR. The categories are explained by quoting partial interview evidence. Participants were anonymised and coded as R for retailers, E for XR technical experts, C for consumers, and D for designers. (Jin, 2025, pp. 169-171)

1) Retail associated with high-end brands or high-profit products. The investment cost of HMDs is a major challenge for the mass retailing of MR. 73% of the participants (n=26) emphasised that the price of the equipment affects their investment and purchase. Consumers highlighted this approach as a way to consider purchasing a high-end, long-lasting product with an accompanying good environment. 57.1% of retailers underlined that this approach is currently more relevant for product types that are highly profitable due to investment costs and returns. In addition, there is a need for more available application resources in the market. *"If the profit margin is not high enough and the population is not large enough, it's not going to support our entire team's operation" (R7). "If I'm a small time investor, I don't have the resources to get somebody to build or build an app or build something for me, so has to some sort of software needs to exist" (E2).*

2) The retail settings of product category, price range and brand image relevant to MR image. 28.6% of retailers stated it depends on the product category, and 57.1% believed it should align with the brand image and price range. R7 describes the specificity of the high-end jewellery stones inspection instrument. Therefore, the price range of the jewellery decides retailer usage of MR. MR fits fine jewellery, but not ultra-luxury jewellery. *"For gemstones, things like clarity, fire and cut really need to be examined using specialised tools, like a professional loupe. These details are mostly relevant to high-end or luxury jewellery, which is why the price tends to be quite expensive. Brands that operate with a lower price point, say under £2000 or £3000, can't offer that level of service."*

3) Retailer demographics relate to an investment in and acceptance of mixed reality technology. Retailer age impacts MRPC acceptance, with 57.1% of retailers in the 29-35 age range (R1/2/4/7) showing higher acceptance of the technology and 42.9% of retailers aged above 46 showing lower acceptance (R3/5/6).

4) Retail shops situated in geographic areas with high technology penetration and larger cities. Retailers interpret the urban scale to correlate with customer consumption patterns that impact investment. Seven participants commented on technology penetration and urbanisation in the acceptance of technology. Consumer C5 (50-year-old, lives in Beijing) also expressed the correlation between technology penetration and acceptance. *"I don't play games much, and I'm not particularly great with tech stuff either. But after seeing how you handled it, I found it pretty easy to use. I think it's because of your product design and development of this idea, straightforward, not complicated. Even kids and elderly wouldn't find it hard. Nowadays, you see lots of older people who are pretty good with smartphones, I'm kind of in the middle. [...] I think it's mostly just the popularity of electronic devices. That kind of stuff is everywhere".*

5) Product design and environmental experience-orientated retailing. The results show that 57.1% retailers prioritise perceived product design and environmental design over service quality were more acceptable to MR (R1/R2/R4/R7). On the other hand, 42.9% of those who prioritise service quality over product and/or environmental design have a negative attitude towards MR (R3/R5/R6).

6) Business modes relate to the following three types (a/b/c). From seven retailers, four modes were identified: a) A production model where the retailer cooperates with factories and operates in a front-end

and back-end manner. b) Retailer that possesses their own design department and manufacturing line. c) Independent artisanal designers who run businesses from design and production to sale. d) Finished merchandise sourced directly from the supplier. Among the retail modes applicable to MRPC are the first three, which have the ability to manufacture customised products. Participant R1 (Mode C) describes the reason that matches the business *"So when a client describes a colour very imaginatively, [...] It might come across as a different feeling in the person, so it's in that when you're doing semi-customisation, both the individual and the merchant are taking a risk [...] The time spent on this process is a time cost lost. So I think that if there is a solution to make the guest's expression more concrete, or for the designer to understand the guest's situation, to be able to more clearly express what kind of alteration or customisation the designer can bring to the client, I think it's a better bridge of communication."*

7) Retail brands that offer product customisation as a service can use MRPC as a futurism sustainable solution. Providing brands with a sustainable customisation display approach through using MRPC as a futurism method to reduce the wastage of plastics. Participant D1 describes a customisation experience in a chain shop. *"This is a laser thing on a plastic card, which is like where we can do this laser thing. So they are using plastic for that, but they are not doing it on the metal ring, so those plans when that sheet will get filled, they will just throw it and then they will take another sheet to display and show it to you. In that way, they will use a lot of plastic to showcase to the customers how the alphabet is going to look on your ring. But I think that way, if I get another option of just deciding on an interface, I will get a demo of the product and how it is really going to look. I think that's a more sustainable way for the future, also that does move also a futuristic and sustainable solution to anything".*

Prospective Consumer Genres on MR Product Customisation Adoption

To pinpoint brand user segments to design more targeted user experiences and sales, retail executives can further gauge whether their brand can maximise the benefits of using the MRPC.

1) Demands for unique product consumers. Consumers emphasise the importance of product uniqueness, and repeat customisation behaviours emerge in purchases based on such needs. *"Because I like customising most of my things […] If I design it for myself, it would be my unique design. So I like to be that unique person when you buy a product" (C6).*

2) Experiential consumption and novelty-driven consumers. Consumers emphasised experiences as an important reason to go in-store or to deplete waiting time. *"100% It has to be experienced-led because everything's cheaper online, so it has to be. They have to get an experience out of it; otherwise, it's just not worth doing. [...] Something felt social, something exciting, and something different" (C9).*

3) Acquisition of knowledge and information-based consumers. Consumers perceive the MRPC approach as a channel for acquiring knowledge in practice. *"For example, that ring you just had, I think the top seems to be too complicated, I want to be minimalist, and then what kind of that base is going to be [...] so here in the process it grows knowledge again, and knows how to make this thing" (C5).*

4) Consumer motivation for the demand for commit or memorable purchases. Consumers shop for products with symbolic meaning over public festivals, or relationship-driven customers shop for products with added significance. A participant mentioned *"I think a couple can just decide their things together. It's based on the relationship" (D1).*

5) Fashionistas with a willingness to create and participate in design. This type of consumer is endowed with a strong willingness to participate and creative thinking, with confidence in their design ability or high satisfaction with the products they design participation. Participants suggested that *"Even if I want something, even if it may be a very ugly design in the eyes of others or professionals, as long as I like it, it feels unique and special to me, and I still like it" (C1).*

6) Services optimisation-oriented consumers. Consumers prioritised the MRPC's ability to simplify the in-store purchase process regarding time-saving, product satisfaction, purchase efficiency, and communication. In addition, partial consumers indicated that the agent can provide a refined quality of customised service by manipulating on their behalf. *"So because he was using Photoshop to do that, he was going to use the laser technique to embed on that bracelet, but the character which was designed, he was just asking me, OK, do you need these, this, this and after like 10, 20 times of changing that character, I felt that OK, do whatever you want [...] (MRPC) I can choose the character or give an example of how I need, and I think that will be a better experience than in-store" (D1).*

7) Social avoidance and work independence consumers. Consumers perceive that the MRPC enables them to escape from socialisation pressures, and users inclined to complete purchases independently show a high level of interest. *"I usually stroll in this kind of shopping mall, and I don't want the sale to follow me to introduce things. I don't like this kind of other people to greet you or what. If I can have this technology to be able to go explore to find the answer myself, I am still looking forward to it" (C3).*

MRPC Conditions for Store Adoption

Retail Interior Environment

The shop interior environment is a crucial factor in the accessibility of MR in brick-and-mortar shops. XR experts, interior, and UI designers mainly described how the environment affects the usability of the MR during usage. Consumers interpreted how the environment affects the sensory and attractiveness of experiences. Retailers, on the other hand, mainly paid attention to the design of interior environments and the factors that are influencing sales.

By stakeholders' interviews, 24 interior design factors are identified, which include traditional store design and MR-related environment concerns. Lighting emerges as the most critical factor (16%), followed by shop layout (9%) and product display (9%), and followed by space dimensions (8%), safety environment (7%), and environment acoustics (6%). Then followed by a sense of attractiveness (5%), surrounding distractions (5%), environment quality (5%), traffic flow design (4%), privacy (3%), decoration style (3%), interior colour tone (3%), and separate isolated space (3%). Each accounts for 2% of shop hygiene, temperature, security, and temperature. Each accounts for 1%, including visual order, matching product and interior, environment comfort, functional partition, signage and weather conditions.

For shop layouts, retailers considered more difficult-to-access layouts to ensure merchandise security (R5). Interior designers emphasised layouts for leading traffic flow and spatial navigation (D2), and product display layout could affect the visual order and UI design layout (D2/R4/5/R6/R7). XR specialists considered the importance of clear layouts for AR to recognise locations and provide the correct information (E4). Spatial dimensions include shop dimensions and the space available for movement when employing MR (D2/E1/E4). The safety environment involves setting space boundaries to resolve conflicts in the physical environment (E7). Surrounding environment distractions come from the behaviour of other shoppers, observe from space users, communication noise, music, HMD speaker noise and lighting distractions (E1/E2/E4).

System Development

System development refers to the design, development and deployment of the MRPC, including evaluating existing functionality, improvements, and future development. The subcategories coding include the considerations of function design (49.3%), UI design (33.2%), product design (4.3%), privacy policy (2.8%), user experience (9.5%), and back-end development (1%).

Under function design, virtual fitting (18.3%) is the most frequently mentioned, followed by preview design results (6.7%), learn-to-make tutorial (6.7%), and co-design (5.8%). Other mentions are comparison products, video instruction for use, and learning to make videos, at 2.9% each. Adaptive fitting, handcraft skills, measuring size, product resizing, visual aids, and shareability follow at 1.9% each. Lastly, each at 1% mentions has real-time pricing, multi-angle presentation, sound assistance, UI comfort, favourite function, audio reading, interactive gestures, packaging customisation, self-image avatar, and UI teleportation.

The UI design includes extensive product information (12.9%) and a simplistic UI style (10%). This is followed by ease of use, usability, usefulness, UI navigation, mental effort, multi-screen, scene effects, animation elements, and gamification with shopping tasks, which account for 5.7% each. Privacy policies include considering general data protection policies and the impact of mall policies (shops in a mall) of each account for 33.3%, methods of storing information, and online purchase terms and conditions policy of each account for 16.7%. Product design includes product fidelity (44.4%), jewellery (product) designers' delivery methods (model-making) should be accessible (33.3%), and 3D product visualisations (22.2%). User experience design includes non-verbal service experience (46.7%), sustainable product customisation experience (26.7%), event-based theme experience (13.3%), and customer psychology experience (1.3%).

MRPC provide a manual virtual fitting function. However, experts and consumers raise opinions for an adaptive fitting as an improvement. An expert E5 suggested *"The advantage is you can overlay virtual items. In the real world, unless I can put it on my hand and actually see it on my finger. Then I think it's kind of not really using the full potential of XR. So then, if we are going to do that kind of machine vision where I can track my finger and put a ring on it in that kind of detail, I think that's going to take a few years to realise."*

Retailers consider the ability to preview design results to be a cost-reducing. R4 stated *"Clients often come up with really wild and imaginative ideas, like wanting something like a rainbow black. But with this (MRPC), you've already set up a pretty comprehensive framework for them to play around with. So they're like, oh, this is actually my own jewellery that I've made as well. Because I've taken this kind of order before to give people to do custom, they feel that they have a lot of ideas, and they'd throw in all sorts of ideas and then you get this version, he felt oh good, and then maybe after a few days, he felt that, hey, there is a new idea and ask for changes. From a designer's perspective, time is also money, so constantly making revisions isn't ideal."*

Marketability

Marketability refers to the possibility and influence factors of MRPC's mass adoption in the retail market. Considerations for the marketability of MR include perception of MRPC (15.3%), hardware issues (14.5%), demand motivations (14.2%), investment (13.8%), consumer affective motivation (10.9%), potential benefits (9.8%), social factors (9.5%), public cognition (9.1%), and consumer behavioural impacts (2.9%).

Perceptions of MRPC include factors such as mental effort, eye fatigue, technology acceptance, perceived complexity, perceived quality of MR services and perceived irreplaceability, and shape marketability. Hardware issues are problematic and mentioned in many aspects, including accuracy, battery charge speed, battery life, frame rate, HMD appearance, field of view, glitches, price, recycle sustainability, resolution, size, wear comfort, weight, intraocular distance, motion sickness, processor speed, resolution, technology accessibility, and technology usability. Investments include consideration of needs in hardware and software investments by retailers, long-term costs, profits, availability of HMDs, demand-driven, availability of basic apps, HMD depletion and preservation, HMDs quantity, city size and demographics, HMD production ability, product category and effort, profit margin, and product category's sustainable.

Potential benefits are stakeholders' speculative opinions on its future possibilities, such as customer retention, identifying problems before manufacturing, reducing logistics, saving time on pickup, saving space, unlimited location, etc. Social factors include the influence factors in consumer brand consciousness, loyalty, brand image, service quality, trust, HMD accessibility in shops, and the influence of market self-regulation. Public cognition (consumers and retailers) includes stakeholders' cognition for technology penetration, usage value, trust towards the brand and the technology, social acceptability, perceived experience value, familiarity, effort on use, camera privacy, and sustainability of energy consumption. Consumer behaviour impact includes different desires for the location of use (at home and in-store), in-store dwell time, and return to use.

Management Strategy

Management strategies are divided into before launch (52%) and during usage (48%). Before launch strategies include shifts in retail business mode and reduced storage space and expenses. Training of assistants shifted from traditional Photoshop skills to operating MR. Ensuring sustainable trade manufacturing to enable timely supplies of merchandise. Pop-up events could be used as a speedless marketing method. To coincide with geo-policies and collect shopper product preferences through MRPC. Designer D1 suggests, *"This is what the people want, and so they can, with concern, maybe get the idea off of the customer and then take it to the manager or something, and then they can discuss, is this what we should be selling instead? [...] It's gonna be better as well because you can actually see what people find interesting, and so you can use that as a way to draw customers in instead of assuming what people like."*

During usage management, the strategy includes keeping HMD hygiene, providing incentives for use, on-the-spot production, onboarding complexity, system maintenance and frequency, updating app functions and databases, and retailer share screen devices. On the other hand, system maintenance is affected by the application framework of the back-end build during system development.

Summaries

This section prioritises the readership from retail management and aims to help RM better understand XR technology feasibility in omnichannel retail. It aims to provide retailers and brands with a futuristic approach to product customisation for multi-channel retailing and provides potential audience genres as a guide to the market. These results contribute to helping RM understand: What is XR (AR/MR/VR)? Why use MR in brick-and-mortar stores? What type of retail stores are more suitable for invest MR? Who can be their MR audiences? What should be noticed before adopting MR in-store?

RM can have a preliminary awareness of relevant stakeholders who may need to be involved in subsequent programmes, foundation managerial considerations, and the fields of relevant financial expenditures. RM is able to propose brand-aligned design requirements to UI and interior designers and MR function development requirements to developers and engineers based on these customer demands.

On the other hand, it provides direction for technology developers to research MR retail function requirements driven by market experience. It also provides UI, UX, and interior designers with consumer and investor requirements to assist designers in identifying stakeholder needs prior to designing in order to create end-to-end solutions for users.

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Section

02

Ideate

Retail Product Managers and UX Designers select appropriate development devices at this stage, ideating the customer experience journey and conveying design requirements to the design team and software engineering team.

Apparatus

To develop a **Mixed Reality Product Configurator (MRPC)**, the software can use ***Unity, Visual Studio,*** and ***Mixed Reality Toolkit (MRTK)***. The hardware can use ***Microsoft HoloLens 2***. Some open-access resource models can be retrieved from the Unity Asset Store. Unity supports product models use the FBX format. The ***HoloLens Emulator*** allows apps to be tested on the PC without the physical device. The ***Microsoft HoloLens*** app allow external devices to view the synchronised user interface content. If retailers intend to leverage different devices, they will need to choose development software adapted to the device specifications. **Table 3** are some available MR headsets for consideration so that stakeholders can further familiarise themselves with the hardware available in MR. In addition to the device brand, retailers will need to consider the device quantity. This can be referred to the space dimension (area) recommendations for MR use in Section 5 and recommendations for devices used by retail assistants (tablet/headset).



Unity Hub



Visual Studio


HoloLens Emulator


Microsoft HoloLens

Table 3. Current VR headset specifications and price as of July 2024

Name	Specifications	Price
Meta Quest 3	• Type: Standalone • Battery: Up to 2.2 hours on average • Weight: 515g • Resolution: 2064 × 2208 pixels per eye • Refresh rate: Up to 120 Hz • Field of view: 110° W × 29°H • Can wear glasses	£479.99
Microsoft HoloLens 2	• Type: Standalone • Battery: Up to 3 hours • Weight: 566 g • Resolution: 1440 × 936 pixels per eye • Refresh rate: 60 Hz • Field of view: 43° W × 29°H • Can wear glasses	£3,349
Magic Leap 2	• Type: Standalone • Battery: Up to 3.5 hours • Weight: 260 g • Resolution: 1440 × 1760 pixels per eye • Refresh rate: 120 Hz • Field of view: 44.6°W × 53.6°H • Cannot wear glasses	£3,370
Apple Vision Pro	• Type: Standalone • Battery: Up to 2 hours • Weight: 600-650g • Resolution: 23 million pixels (approx. 3,660 × 3,200 pixels per eye) • Refresh rate: 100 H • Field of view: No release • Cannot wear glasses	£3,499
Varjo XR 4	• Type: Tethered • Weight: 665g + headband 356g • Resolution: 3840 × 3744 pixels per eye • Refresh rate: 90 Hz • Field of view: 120°W x 105°H • Can wear glasses	€5,990

Ideate Customer Experience

Customer experience maps depict a holistic perspective on general customer behaviour from end-to-end in an experience in a time sequence (Lemon and Verhoef, 2016). Customer experience and journeys are primarily applied to marketing and service design, which is divided into three general stages: pre-purchase, purchase and post-purchase (Kalbach, 2020; Lemon and Verhoef, 2016). There are many sub-phases that can be refined, which retailers can adapt to fit their experience design needs. To understand the MR experience of customers, the pre-purchase stage includes awareness, consideration and engagement. Post-purchase includes retention and advocacy.

Figure 4 summarises 12 days of comparative observations in a fashion retail store in the UK in 2023. Depicting the differences in customer experience between traditional and brick-and-mortar shops integrating MR, and identifying customer behaviours in the six stages of the customer experience process, including actions, touchpoints, key performance indicators (KPIs), pain points, and possible solutions. The MR service enhances the customer experience by addressing pain points throughout multiple stages of the traditional brick-and-mortar transaction process. For example, during the purchasing phase, some customers seek to semi-customise products and ask retailers to contact the designer for remote ordering. MR customisation apps streamline this process by offering a self-design communication approach. Additionally, after engaging with MR, customers advocated for the brand by sharing their in-store experiences on social media. By engaging the customer in the design increases touchpoints, promotes communication with retailers and lengthens dwell time.

This framework combines two experience lines that trace a complete customer lifecycle, providing retailers and customer experience managers (CEM) with a reference for the customer's MR experience journey. It can also be used as an MR customer experience map template for customer experience (CX) and user experience (UX) designers in marketing to design a seamless experience.

		Awareness	Consideration	Engage	Purchase	Retention	Advocacy
Actions	Traditional CX	Discover on windows, ads, social media	Browsing, compare products, fitting	Engage with retail worker, or skip this step	Select products, wait for packaging make payment	Return and stay loyal to the brands	Recommends to friends
	Mixed Reliaty CX	Discover on windows, ads, social media, MR booth	Browsing, compare products, fitting, seek alternatives	Engage/onboard with the MRPC and retail worker	Customise products, select packaging, ask for payment method	Return, reuse and stay loyal to the brands	Recommends to friends and post social media
Touchpoints	Traditional CX	Social media, word of mouth	In-store price lables	Retail worker	Retail worker, till, brand QR code	Back to physical shop, online shop	Social media, word of mouth
	Mixed Reliaty CX	Social media, word of mouth, in-store booth	MR headsets, ads of MR, app	Retail worker, app, app instant price, customisation preview, virtual fitting, photography	Retail worker, till, brand QR code		Social media, word of mouth
KPIs	Traditional CX	Number of people reached	Increase number of new visitors	Positive sentiments, dwell ime	Conversion rate, turnover	Retention rates, order frequnecy	Customer sactisfaction
	Mixed Reliaty CX	Number of people used	Increase number of new MR users	Positive sentiments, usage duration	Conversion rate, shopping cart value, dwell time	Retention rates, headset use frequency, dwell time, positive attitude	Customer sactisfaction
Pain points	Traditional CX	Customers stopping outside the shop	Cannot find desired product, out of stock, fitting queue in line, lack of information	Ask retail workers to help fit, await serve, knock products over	Do not have proper size in stock, customisation needs, decision difficulty	Retention difficulty as changed site location	No follow-up about product satisfaction
	Mixed Reliaty CX	Users remain to observe; fail to notice the MR experience	Headset fitting queue in line, need employees to assist	Onbording of headsets, ease of use, tripped, processing speed	Rapid or slower decision, checkout unavilable on MRPC	Available MR apps and shops	No follow-up about the MR shop
Possible solutions	Traditional CX	Design for window displays,	Build in-store online shops, ask employee for information	Increase employees, increase fitting in-store technology (IST), modify shop layout	Increase customisation service, IST to assist	Retention difficulty as changed site location	Send experience survey to understand customer satisfaction
	Mixed Reliaty CX	Design for signage	Browsing, compare products, fitting, seek alternatives	Increase number of headsets, training employee to assist, design MR space	Add MR online payment method	Available MR apps and shops	Send experience survey to understand customer satisfaction

Figure 4. Comparison of customer experience map in traditional and MR stores

Mxied Reality Customer Experience in Brick-and-Mortar Stores

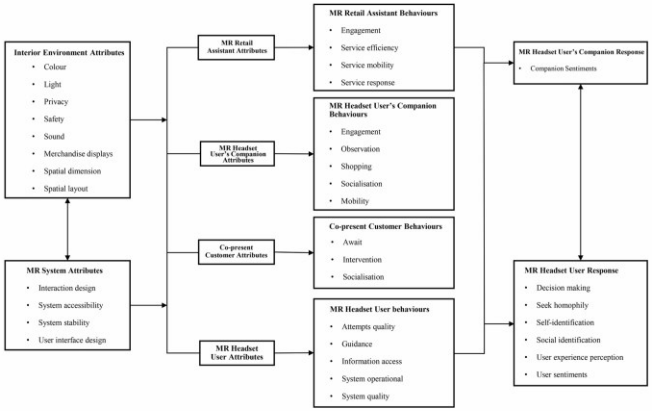


Figure 5. Mixed reality retail brick-and-mortar store user experience model

With an understanding of a complete customer experience lifecycle, **Figure 5** depicts the barriers, challenges, and user behaviours when customers experience MR shopping (Jin, 2025, pp. 206-217). This model indicates interior environment design, MR system design, and the interplay between the parties of space users influence different parties to produce different behavioural and emotional responses. That is the importance of user experience quality during the engagement and purchase stages. UX, interior, UI designers, and customer experience managers should take a holistic understanding of these processes to ideate and design optimal experience strategies.

Customer experience observation results show that applying existing retail brick-and-mortar environments straight to MR purchases would encounter eight factors affecting user experience quality. *Colour, lights, privacy, safety, sound, merchandise display, space dimensions and space layout* represent four dimensions of user experience satisfaction (accessibility, preferences, distraction and interference). It is found that incorporating an MR experience straight into a traditional medium-sized shop has the potential to impact the accessibility of the environment through lighting, security, space dimensions, and space layout. Merchandise display layout and colours could affect customer preferences. Distraction and interference influences come from sound, privacy, and spatial layout factors.

These design factors align with those in traditional shop design but take on distinct meanings, highlighting key considerations specific to MR environments. While conventional retail design focuses on factors such as aesthetics and efficient space utilisation, MR retail spaces prioritise environmental usability to address the unique challenges of MR interactions. For example, traditional retail emphasises colour schemes that stimulate purchases, lighting that enhances product attractiveness, and layouts that facilitate easy navigation.

In contrast, MR shop design needs to consider how background colours aid in system accessibility and virtual product clarity, how lighting conditions affect virtual product readability, and how to provide gaze privacy when users engage with virtual elements. Also, it needs to consider designing safe spaces to reduce risks of collisions or injuries while maintaining adequate movement flow for other shoppers. To help users distinguish retailer instructions amongst shop music, conversation noises, and MR device speakers. To minimise visual clutter and browsing comfort when displaying virtual and physical products in parallel. To define the minimum footprint of the space required and spatial layout matches the scale of the MR and to plan the assistant's service position. Therefore, even though traditional and MR shops share environmental design factors, the design objectives differ significantly. This shows the significant contribution of this study in defining MR store experience barriers.

As an innovative transaction pattern, the MR retail shop aims to facilitate decision-making by providing consumers with meaningful entertainment and efficiency. Providing consumers with an extraordinary brand experience (Gupta et al., 2024) and developing affective connections and enhanced brand memories (Dwivedi et al., 2024; Kolbl et al., 2020; Sharot et al., 2004). Retailers should provide a narrative, accessible, and inclusive retail environment to create an interactive spatial experience. Based on these design elements, it is recommended that designers undertake individual interior environmental design planning to adopt MR to create more inclusive public retail spaces.

Four factors can influence the experience quality of MR systems in both hedonic and practical aspects: *interaction design, UI design, system accessibility, and technological stability*. Interaction and interface design play a vital role in promoting the attractiveness and uniqueness of the immersive experience. Accessibility and stability are related to the UX quality utility assessment. The results report user behaviours that cause errors, and it is beneficial for retail assistants to be aware of error-prone points of use to identify the reasons for user failures to use rapidly.

Along with survey results of the User Experience Questionnaire (UEQ) evidence that the theoretical model of the MR retail store user experience has satisfactory reliability and validity. The UEQ results evidence that the theoretical model of the MR retail shop user experience has satisfactory reliability and validity. The results validate the user behaviour and the retailer model's perspective that MRPC brings a highly appealing and hedonic experience. Also, it is suggested that actions include improving factors of the pragmatism dimension, perspicuity (easy to learn and use/understandable/clear) (μ=0.94), dependability (μ=1.07) and efficiency (μ=1.10). Specifically, perspicuity should enhance ease of use (interface design and operation) and clarity (MR interface, flow of use, and retail assistant assistance). Dependability should be improved by improving predictability (interface aid design and experience flow). Efficiency by improving speed (system responsiveness).

Summaries

In sum, retailers should determine the devices for the brand to utilize at this stage, and then the CEM should ideate and design a complete lifecycle customer experience journey with a focus on UI/Interior designers solving accessibility issues during the customer engagement stage by increasing the experience quality. This suggests that enterprises and retail shops who are considering establishing an MR retail shop or integrating MR technology in existing retail shops should design the interior environment, plan the software and hardware of the MR system, and train the customer service to improve the quality of the MR experience.

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Section

03

Design

UI designers and software engineers conduct the design of an MR product configurator commercial application. UI designers should consider the MRUI design principle and can rapidly iterate using the Section 4 approach where engineers can prepare functional portions of development.

Mixed Reality Product Configurator

In commercial design, consumer research is an indispensable strategy for design and development. Consumer shopping patterns are categorised into two fundamental motivations, buying for a specific goal and pleasure seeking. This represents two different types of consumers, pragmatic and hedonistic. This results in different types of e-tailing consumers shopping diversely. It also depends on the product category, digital technology and consumer typology. For low-value products, consumers may be willing to spend considerably fewer attempts to complete their purchase goal. Whereas, with high-value products, consumers may encompass considerations of premium pricing, and they could potentially spend more time and anticipate a higher quality experience and service.

Web-based product configurators are an example, and there are plenty of commodities that already use configurators to support the online customisation of personalised products, such as furniture, jewellery, cars and shoes. Product configurators refer to a range of activities that allow mass customisation of specific consumer needs to provide product variety (Forza and Salvador, 2006). Users who use product configurators are undoubtedly experience-orientated; they are more interested in visualising and personalising their experience, and therefore, they devote more time to completing the configuration of the product. However, with the development of augmented reality, 2D online shopping is no longer sufficient to provide a compelling experience, and 3D marketing appears to be the industry of the future. Therefore, this section will introduce the design of a mixed reality based 3D product configurator to fulfil the market demand for in-store immersive mass customisation.

This ***Mixed Reality Product Configurator (MRPC) Design Principles Toolkit*** is a repeatable and generic framework that combines heuristics and design solutions. Through a series of research activities (survey, prototyping, interviews, field observations, and experiments), collected consumer requirements, invited customers to participate in the MRPC design process, and inducted user feedback to generate the design principles (see Jin, 2025, PhD thesis for the details of the studies). This toolkit attempts to aid UI designers and software developers in the development of commercial mixed reality product configurator systems (**Figure 6**). When developing and designing a commercial product configurator, designers and programmers would be advised to consistently review whether their application fulfils the thirteen design principles at different stages of the design process. This card toolkit can be used in a variety of scenarios: the usability testing (user testing) stage to work with users to evaluate the usability and experience value of the system. Used as a qualitative tool to conduct workshop activities with stakeholders (retailers, UX designers, interior designers, consumers) after completion of development to collaborate on evaluating the outcome of the application. As a quantitative tool - a questionnaire survey framework to scale the system in thirteen dimensions and used repetitively throughout the design and development workflow.

The research finding indicates that the more well-designed the UI on the application, the more positive the attitude towards its use. UI design consists of three aspects: visual user-friendliness of the layout, clarity of navigation, and clarity of the UI hierarchical structure. Ease of use of technology correlates with user attitudes towards use but barely impacts attitudes towards use. Usefulness, on the other hand, affects changes in user attitudes and purchase intention. Using the MR configurator App to complete a customised product purchase enabled users to have a sense of usefulness, which includes the fulfilment of purchase demands, increased purchase efficiency and ability of decision making, and the satisfaction of expectations from the customised functionality. The more positive the attitude towards using the MR configurator app, the more it will increase the behaviour of the consumer to use it and increase the consumer purchase intent. When users perceive using this MR configurator in the shop as easy, it will positively influence their affective and behaviour. Ease of use will not cause an uplift in intention to buy, but it will cause consumers to perceive in-store use of the HMD and system as useful for purchasing behaviours and will be reflected in an increase in system access behaviours. Prospective consumers who judge MR purchases as easy to use and useful tend to browse and purchase using an HMD. Equally, users who intend to use the MR configurator augment the tendency to purchase products. These evidences support the significance and design value of MR UI in commercial design.



Figure 6. MR design principle toolkits

The subsequent sections will further elaborate on how the thirteen design principles can be implemented through design suggestions and the MRPC design method from both a pragmatic and hedonic perspective. For example, parametricity (Principle 01), using the jewellery configuration parameters as an example, describes the parametric range and quantity based on ring parameters. It also introduces the method for deciding the parametric, which suggests product managers and designers follow online product configurator parameters of their retail categories. Comfort (Principle 03), by providing an ergonomic MR UI layout and distance design solution, coupled with environmental design (Principle 13) (Section 5) to enhance commercial viability. Comparability and beyond reality value (Principle 04/07), refer to customer requirements for system functions and experiences development which provide product managers and engineers in developing applications (pp.33-35).

Layout and Distance

From a commercial design perspective, the MR UI requires to be used in a retail environment and therefore the UI design needs to be aligned closely with the interior design. The UI layout and distance design (**Figure 7 and 8**) can be used with the spatial dimension requirements in Section 5 (**Figures 15 and 16**).

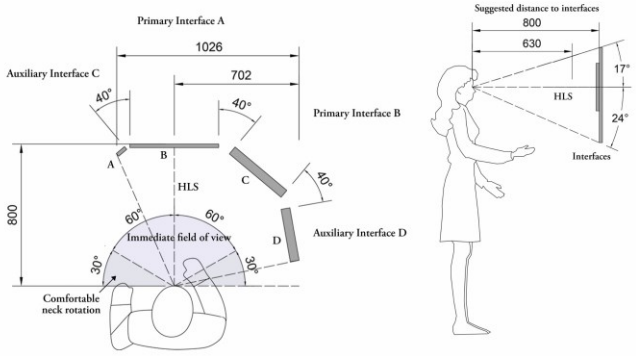


Figure 7. Top and Side Perspective of MR UI

1) A distance of 630-800 mm from the user interface to the horizontal line of sight. The ergonomic eye-to-screen distance is 500-990mm, whereas the average is between 630 mm and 740 mm (Jaschinski, 2002; Jaschinski-Kruza, 1991). Hence, a comfortable range for use modes that accommodate tangible and remote rays is 630-800mm. In order to gain a wider FOV, the multi-interface design for HoloLens 2 is recommended to be 800mm from eye to interface. Figure shows the application camera set to ensure that the distance remains constant at each launch.

2) The overall length of the interfaces is less than 1600mm and less than 800mm unilaterally, with eyes as the centre point. The MRPC has an overall length of 1026mm, which is an adaptable dimension. According to the need to distribute the three primary interfaces, this dimension remains a moderate (no narrow or wide) value. Although larger display users perform better at completing space tasks (Tan et al., 2003), the longer the length, the more space it needs to occupy. Therefore, the interface length can be reasonably trimmed down if space is limited.

3) The interface position of height should be at the horizontal line of sight of users. A 40° angle as horizontal FOV, which presents a natural encircle shape and allows users to turn their heads to see the interfaces comfortably.

4) Reserve one side space for retail assistants, and do not let consumers get lost in virtual content. In a standard retail environment, consumers may require in-store retail assistant service during use. The agent could stand in the reserved position to minimise interference with the user during the service. Leave spaces for consumers to notice the real world situation.



Figure 8. Example of Front Perspective of MR UI

Natural Interaction Behaviour

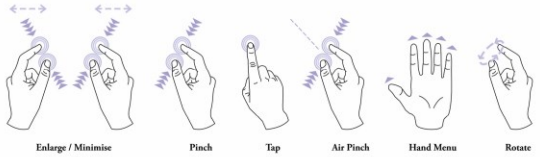


Figure 9. MR Naural Interactive Hand Gestures in HoloLens

MRPC implements the standard gesture resources by MRTK (Microsoft Learn, 2021) (**Figure 9**).

1) Enlarge/Minimise. Customers need to pinch the virtual product with both hands to scale the product inward or outward. The virtual product is displayed in 3D, and the initial effect is a magnified size of the product to facilitate users' locating it. Therefore, customers try on the product to scale it down to the appropriate size and configure it to enlarge it to view the product details.

2) Pinch. Proximity pinches the virtual content to select the object and then drags the object to change its position.

3) Tap. Users can tap buttons to trigger functions at a close distance. For example, tap the shopping cart widget to open a new window. Tap on the save icon to store the current configuration parameters.

4) Air pinch. When a user points to a distant object, a ray appears, and at a certain distance, the user can pinch to select the object and drag the selected object. When the user moves position or height (standing/sitting) or intends to compare the effect of a virtual product from a distance, the Air pinch can grab and move the virtual object.

5) Hand menu. Users unfold a single palm (left or right) parallel towards the sightline (within visible range of the HMD camera), and a small hand menu panel emerges. It contains two buttons: position reset and come over. Keeping the hand unfolded, the user taps one of the buttons with the other hand to trigger a response.

6) Rotate. The user can rotate the virtual object by twisting the wrist after selecting a virtual object for a 360° perspective of the product details.

Product Configuration Parameters

This system prototype design uses jewellery as a prototype type for testing. The parameters are derived from brand data of semi-customised jewellery available for sale online. **Table 4**, compares four jewellery brands that have online configurators. The quantity of combinations of parametric configurations reveals that the greater the range of parameter types and number of elements, the greater the variety of combinations. For consumers, more combinations represent more creativity possibilities and product uniqueness. For retailers, this means a potential increase in warehouse capacity and manufacturing costs, but there could be a corresponding decrease in customer returns (Alford et al., 2000). The problem of optimal sizing and positioning of inventory is a challenging issue for mass customisation (Mourtzis, 2016). Therefore, these analyses are tried to provide additional considerations for retailers. The configurator makes product diversity and leanness and supports mass customisation through modular product design, flexible processes and integration between supply chains (Fogliatto et al., 2012).

The MRPC involved customisation, assembly and learning to make platforms. The customisation platform allows customers to select a designed ring to personalise products. The assembly platform allows customers to select a ring mount, and place select stones on the ring setting area to assemble more creatively. The learning platform allows customers to watch videos of the brand and provide tutorials for learning to make products.

With the basis of existing brands on the market, **Table 5** shows the suggested ranges for parameter design on a prototype system for a jewellery product configurator based on rings. The configuration platform includes: the four base parameters of materials (four types), stones (ten types), engraving (n1 with four letters, n2 with 2 fonts), sizes (twelve sizes), shape (n1 with four textures, n2 with add additional two stones) and gift packaging (four styles). These metrics are included in developing the MRPC as fundamental configuration parameters.

Although brands vary in design and scale of operation, I will develop a foundational MR application based on these parameters, allowing retailers to develop it further to meet their specific needs. Retailers will need to redesign the MRPC based on consideration of the scale of their brand, product types, manufacturing capabilities, capital investment, brand positioning and so on. However, jewellery retailers can still use this parameter design to gain greater benefits for developing their business.

Table 4. Ring parameters in various brands and combination possibility

Brands	Model	Stone	Size	Materials	Engraving	Design style	Stone Quantity	Stone size	Thickness	Combination
A	n=4	n=15	n=38	n=4	/	/	/	/	/	9120
B	/	n=10	n=12	n=8	22≤n≤38	/	/	/	/	960
C	/	/	n=88	n=4	n≥4	n=5	/	/	n=3	5280
D	/	/	n=16	n=7	n≤20	/	n=3	n=4	/	1344

Table 5. MRPC parameter design

Product Type	Platforms	Parameters					
		A	B	C	D	E	F
Rings	Customisation	Materials (n=4)	Gemstones (n=10)	Engraving (n1≤4/n2=2)	Size (n=12)	Shape (n1=4/n2≤2)	Gift packaging (n=4)
Rings	Assembly	Materials (n=4)	Gemstones (n=10)	Engraving (n1≤4/n2=2)	Size (n=12)	Shape (n=4)	Gift packaging (n=4)

Function and Experience Design

Some fundamental features are established based on the product configurator parameters summarised in the existing e-commerce and online configurator platforms. Subsequently, a series of studies, including interviews, user testing, MRPC testing in real retail stores, and post-experience interview evaluations, are used to iteratively improve and build new experience features. **Table 6** describes the existing designed features of the MRPC. **Figure 10** shows the outcomes of several MRPC features. These features can contribute to inspiring product managers and retailers to design and construct their own branded systems.

Table 6. Function design, characteristics and requirements

Attribute	Design Function	Description	Characteristic	Demand Improvement
Functional	Material	Change the manufacturing material of the ring mount.	Optional with silver, rose gold, etc. Pinch a material that overlaps the ring to replace it.	a) Customers can instantly try on the customised product on hand, whereas online retail cannot. This helps customers find products that suit their skin tone. b) Display a single product physically, which reduces storage space. c) Shareability d) Ability to compare both physical and virtual products.
	Gemstone	Change the stone of the ring.	Customisation: users can change stones in designated places and quantities. Assembly: users can add more stones and move stone positions on the plain ring mount. The spacing between stones has been preset.	
	Engraving	Capable of engraving four letters and two font settings.	A right panel shows enlarged letters/symbols for enhanced readability. One product shows the input letters, and users can view the personalised effect instantly.	
	Size	Selection size of the ring mount.	Customers with known sizes can choose directly and unknown sizes can ask retail agents for advice.	
	Shape	Change the texture of the ring. Add extra diamonds.	Texture such as matte or embossed. Customers can add extra diamonds at preset places.	
	Gift packaging	Select a packaging for products.	The ability to match products and packaging at the same time.	Strengthen consumer decision-making and judgement capabilities by providing information.
	Comparison (dual products)	Two virtual product displays together.	Provides an adjustable virtual product and an additional saved product effect. Users can compare the two designs.	
	Shopping cart	With product effect, parameter content and price.	The shopping cart provides an informative interface that gives the user an overview before making final decisions.	
	Position reset button	Reset all the changes and movement of the interfaces.	Position reset restores initial interfaces when changing to the next customer or when interfaces are messy.	Increase the mobility and flexibility of 3D interfaces.
	Come over button	Summon the app to come in front of sight.	When the customer moves position or height, the button allows interfaces to teleport to the default horizontal sightline.	
	Pin button	Interfaces follow with the head movement.	Allow the entire interface to follow the movement of the customer wherever the user goes.	
	Interface mobility	Interfaces can move position.	Allow users to manually move interfaces to a new position.	
	Instruction text	Instruction notes are shown next to the feature panel.	Instruction notes are shown to guide users to the next step.	Aid usability and navigation in usage.
	Sound aids	System beep	When the user successfully selects and drags a product, the system beeps to inform users that the action was successful.	
	Video	Showcase information on brand news and the jewellery production process.	On the Learn to Make platform, customers can watch the manufacturing processes and follow to craft at workshops.	Providing additional information to fit user interests.
Experiential	Visual aid	Gamification pointer for indicate replacement.	When users pinch a parameter object to approach the replacement object, a gamification sign (a sword) appears, indicating the location of the replacement when detected within the recognisable boundary.	Enhanced gamification, playfulness and immersion values that cannot be experienced in a physical environment or online.
	Picture cursor hover	Two images at the same cursor position.	When one finger points to a flat image, the current image shows a different image. When the finger is left, the original image is resumed. For display multiple information.	
	Special effect	3D animated characters and dynamic scenes.	Special effects panels and 3D animated characters will display dynamic atmospheric scenes when tapped, such as floating snow.	

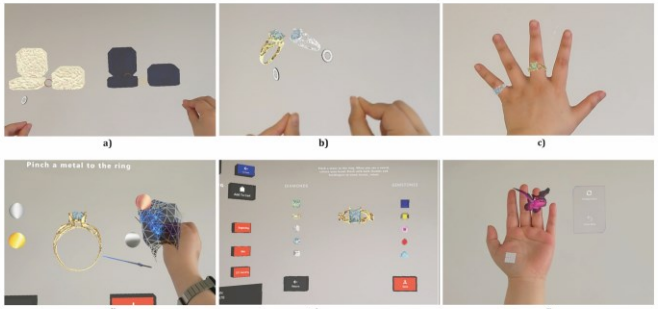


Figure 10. a) Compare packaging; b) Compare customisation products; c) Virtual fitting; d) Changing material with visual aid; e) Stone parameter platform; f) Hand menu

Table 7. Iteration and improvement of design recommendations for MRPC

Attribute	Original Design	Improvement	New Design Features
Original	Material	Improve the realism of textures closer to actual products, such as features of gloss and colour differences.	×
	Gemstone	×	×
	Engraving	×	×
	Size	Adapt product fitting better to the body.	Automatic detection of product adsorption to the body and size recommendations.
	Shape	Improve the realism of textures closer to actual products.	×
	Gift packaging	×	×
	Comparison	×	×
	Shopping cart	×	×
	Position reset button	×	×
	Come over button	×	×
	Pin button	Partial users report that it causes vertigo, improves the transparency of UI during movement, or eliminates this feature.	×
	Instruction text	×	×
	Sound aids	×	Audio for product information
	Video	×	×
	Visual aid	×	×
	Picture cursor	×	×
	Special effect	Changing the unified style of special effects to match the brand's style.	Add recommendation function combined with special effect cartoon/avatar
	Natural interaction gestures	Mainly on hardware issues: improving hand recognition accuracy, resolution, crash, speed of response, frame rate and stability.	×
	UI ergonomic comfort	×	×

After user testing, **Table 7** shows the areas for improvement based on customer evaluation and the new features proposed based on these original features. The x in the table indicates that the user did not mention a need for improvement or did not consider a need for improvement currently.

Table 8. New features of design recommendations for MRPC

Attribute	Function Design	Design Features
Additional New Features Requirements	Assembly parameter bar	Add parameter bars to assembly platforms to help users change parameters such as edge radius, thickness, etc.
	Automatic information recognition	Add the function of identifying physical products and providing information.
	Automatic windows folding	The interface should shrink automatically or with a tap when some windows are not in use.
	Drawing scan	Scanning of hand drawings, uploading and parameter modifications to provide a fully bespoke product.
	Recommendation	Provide a complete package of outfit matching and usage scenario suggestions based on the user's product choice.
	Payment	There is a need for a quick and fun MR payment experience, such as app-independent payments or a combination of apps and till.
	Outfit scene	When a user tries on a product, be able to try on other products simultaneously (e.g. apparel/footwear).

Table 8 illustrates customer requests for completely new design features that are not included in this system. These customer requirements (**Table 6**/**7**/**8**) can help product managers and retailers understand what MRPC can achieve and what customers desire, which can assist product managers in conceptualising their brand-related requirements. This leads to further development requirements for the programme developer during the development stage. Moreover, developers could use this information as foundational documentation and develop new functionality based on these market requirements. For example, customer requests for hand detection and adaptive fitting may require the integration of Artificial Intelligence (AI), which is yet to be incorporated into the system. The inclusion of AI may require a greater financial investment, along with the constraints associated with regulations such as the Data Protection Act of their country or region. Therefore, retailers should consider with discretion taking into account multiple factors.

Summaries

This section provides design recommendations for the MR Product Configurator. The guideline identifies system design features and ergonomic UI design solutions for commercial mass customisation. It includes current features and improvements (undeveloped) in this design study that ***software engineers*** can develop functionality based on consumer demand through the recommendations of this study. ***UI designers*** can incorporate brand images and corresponding new product layouts based on this study. The outputs of ***product/jewellery designers*** would require the provision of models in MR available format and continuous communication with the ***manufacturers*** on the feasibility of the outputs of the design proposals. Product designers also need to collaborate with programmers to achieve the functioning of interactive features. ***Retailers*** and ***product managers*** can benefit from this design proposal to understand customer demand and MRPC functions, conceptualise their user experience, and obtain quotations from programme evaluators and app developers based on function requirements.

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Section 04 Prototype

The MR product configurator design and iteration should be completed at this stage. The UI designer iterates the interfaces using MRPaperPro and transfers them to developers to implement the application. Developers finalise the application user testing and delivery to product managers.

This is an optional implementation section and a flexible toolkit. The ***Mixed Reality Paper Prototype (MRPaperPro)*** toolkit can be used to assist UI designers in testing the usability of systems prior to development using economical tools (Jin and Fagan, 2024). Even if UI designers have no programming knowledge, they can also complete the user testing of MR UI. It can also be used for iterative design of interactions both halfway and post-development of an MR system to reduce the time cost of constant modification of programming.

In addition, it can be used for multi-party participatory design, where product designers are able to collaborate with shoppers to design customer-centred products, and interior designers get feedback from visitors on their preferences for the interior design of the MR shop. Getting customer responses to various aspects of a brand's mixed reality shopping increases user satisfaction with the final experience (Jin, 2025, pp. 147-164).

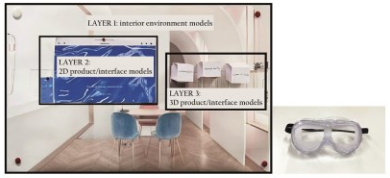


Figure 11. MRPaperPro hierarchical display and simulation field of view.

MRPaperPro proposes technology that incorporates multi-layered paper and tangible 3D models, enabling users to experience a simulated MR in-store customisation experience by replacing widgets with pinching actions. The first layer is an environmental atmosphere simulation, situating users with a contextual reference for their interaction environment. The second layer encompasses interface design visuals like web page graphics and product information. The third layer comprises tactile and 3D conceptual models (**Figure 11**).

Due to the touchable nature of MR, responsive reactions (sounds and colours) are triggered upon pressing the buttons. Consequently, certain buttons can be designed as boxes with two sides, simulating touch-responsive behaviour. Following the button presses, the moderator flips the box to orient the responsive surface towards the user. The main interface utilises magnets as movable attachment tools, affording users the flexibility to reposition the interface in line with their requirements, thus simulating gestures like dragging and pinching. The small components can be affixed with clay on the back to stick on the canvas to mimic the customisation operation (**Figure 12**). This heightened flexibility enables real-time communication between designers and users, facilitating swift collaboration on shifting or modifying UI layouts.

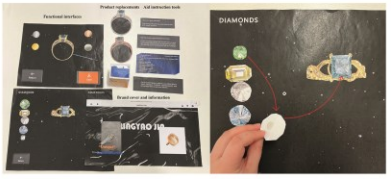


Figure 12. MRPaperPro subset of design aid tools (left). Parametric portable components (right).

In a case without available HMDs for the design process, to design ergonomic UI perspectives, the technique also proposes the preparation of a spectacle that mimics the same field of view ratio as MR HMDs to

simulate the UI and spatial range that one would naturally observe. The application hardware will be implemented in the Microsoft HoloLens 2 HMDs. This particular HMD features a field of view with a display ratio of 4:3, a diagonal of 52°, a vertical measurement of 29°, and a horizontal measurement of 43° (Skarredghost, 2021). For user experiences, the moderator should prepare experimental spectacles designed to simulate the HoloLens 2, maintaining a 4:3 viewing area while obscuring the surplus portions. It is recommended that the experimenter adjust the field of view size of the mock-up spectacles according to the device with which they plan to import.

Furthermore, testing should elect to conduct the testing on a vertical whiteboard instead of a horizontal tabletop, owing to the inherent orientation of HMDs and UI design layout. Because under the HMDs, users' heads and eyes are generally aligned straight ahead. These steps are essential for emulating the consumer in-store experience and provide the UX designer with considerations for the user-headset and user-retail worker interaction modes.

MRPaperPro used various methods to construct the activity, including a storyboard, paper prototyping, a semi-structured interview and a questionnaire. Moderators can design data collection content based on their design aims. Before commencing the activity, participants needed to attain a relatively consistent level of cognitive understanding, comprehending the experiential flow and usage method of the MR user interface. To achieve this, moderators should provide participants with explanation storyboards. Participants should be allocated time to peruse the storyboards, ensuring their grasp of the operational procedures and the shopping process they might encounter in practical scenarios.



Figure 13. Sketches on the product (left). Mimics the hand movement (right)

Participants should be guided through the utilisation of the UI to complete assigned tasks and verbally speak their actions aloud. The MR purchase system includes gestures such as pinching, tapping, zooming, shifting, and rotating. To facilitate the assessment of these interactions through paper prototype testing, which needs to prepare different size product images and UI interfaces to represent the zooming function. (Interior design) Moderators can prepare images representing various typologies of retail interior environments as the first layer of the paper prototype to mimic the environment in which customers shop. These images should be intentionally chosen according to the interior designer's research goals, factoring in interior furnishings, colours, dimensions and layout (**Figure 13**). Users should be informed of a need to hypothetically enter a brick-and-mortar shop to use this HMD and select a preferred scenario from amongst them.

Summaries

Commercial development may involve substantial model-making components or sketches to produce merchandise. As such, MRPaperPro toolkits in the prototyping stage are an efficient method to avoid repeatedly revising programmes and enable rapid testing of the usability of UI and consumer preferences. MRPaperPro contributes to developing MR content that mediates between information-orientated and entertainment-orientated approaches by facilitating the development of affordable, readily accessible, medium-high fidelity tools suitable for multidisciplinary stakeholders.

The advantages of using MRPaperPro consist of being inexpensive, handy, fast, re-readable, fewer space constraints and no background knowledge needed. Disadvantages of this technique include the need for participant imagination, lack of virtual satisfaction and waiting for replacement.

• **Repeat and re-read**: This method enables participants to easily repeat and re-read the content when they intend to return to previous content.

• **Handy and fast:** The papers are easy to access and quick for making tasks. "You don't need to other than arranging some tools … You can have your paper. It's very handy. You can make it immediately."

• **Fewer space constraints**: This toolkit is less constrained by the testing environment, so designers do not need to put much effort into arranging space.

• **Imagination**: This method needs participants to have certain knowledge or imagination of using MR.

• **Lack of virtual embodiment**: The toolkit is lack of 3D visualisation or immersive effects.

In summary, this prototyping toolkit is applicable as a participatory design for developing MR for interdisciplinary design, which allows designers to exploit their work. However, designers must have certain auxiliary abilities to aid users in understanding and conceptualising the role of paper prototypes. It also suggests designers be familiar with the procedures to minimise discontinuity when replacing parts. There are some limitations designers should be aware of, such as MR headsets' interactions, including remote ray-targeting and proximity direct taps, which cannot be reflected within paper prototyping. Finally, where circumstances are affordable, designers can multiply the number and angle of whiteboards to mimic interface tilt angle in space.

D
RM

Section

05

Design

Interior designers using these seven design factors (background colour, colour temperature, illumination, privacy, product display, spatial dimensions, and spatial proportions) design store interior environments to make MR technology more accessible for public use.

Mixed Reality Retail Store Interior Environment Design Guideline

Figure 14 shows the MR retail interior environment design guidelines. It indicates the importance level of design factors from top to bottom, with 1 representing the most important, 2 representing the second importance and so on. It summarises the findings and suggests the most optimal solutions for the design factors that user characteristics will influence. Comprehensive recommendation solutions are given for general hybrid retail shops without a defined target consumer group. Designers are encouraged to reference and approach the design of MR retail spaces accordingly (Jin, 2025, pp. 285-286).

The design guideline proposes in this brochure providing designers with the fundamental data sources to offer insights on which to base their designs on these benchmarks. However, ***the design factor of space dimension requirements should only fit and be applied to interfaces with this UI layout design recommendations or smaller than the recommended dimensions*** (see Section 3). If the distance of MR interfaces is beyond the recommended range, this spatial recommendation may not be compatible. For example, it may appears users cannot use proximity tap gestures to virtual contents, the walking distance will vary, and potential safety hazards could occur when adopting MR face-to-face if the virtual content exceeds the planned safety distances. Therefore, if MR application developers and UI designers design a system that exceeds this range, they should inform interior designers and update the design of space dimensions based on the measurement methods of this study. (**see Figure 7**).

- The finding of the high weighting of spatial dimensions raises the implication for establishing robust guidelines for ergonomic and embodied spatial layout planning. Designers can utilise the results that spatial dimensions can be incorporated with spatial ratios to design small-scale MR retail spaces. **Figure 15** illustrates the recommended minimum dimensions for MR space design. The left column displays the minimum area required for standing and seating, while the middle and right sections show the area needed for walking. User heights are based on values of 178 cm and 186 cm. Height data indicates that 95% of women range between 150.6 cm and 178.9 cm, while 68% of men fall between 170.8 cm and 186 cm (Jelenkovic et al., 2016; Roser et al., 2013). For shops with limited space, a design accommodating a height of 178 cm is generally sufficient. However, when space allows, using dimensions suited for 186 cm is advised to better meet the needs of broader customers. Generally, a 178 cm design can be used for shops with predominantly female customers, whereas shops with mostly male customers may benefit from the 186 cm design. The findings of a physical store experience indicate a natural walking range of MRPC is typically 2:4 steps. Considering store space limitation is able to reduce the walking range to 2:3 steps (**Figure 15**). This means users can take one step to the left and right, one step back, and two steps forward. Therefore, designers can use symbols or signs to instruct or guide users to an optimal starting position.
- The findings highlight the distinct weight of seven design factors. Where conflicts arise, designers can prioritise the higher important factors to design environments with greater accessibility (**Figure 14**). Therefore, **Figure 16** includes designs for both situations. The space scale is 1:1, with a minimum floor area of 3.24 m^2 can be used when the retail staff serves opposite. The 1:1.8 floor area is used when the retail staff serves beside customers, with an area of around 3.77 m^2. Designers can plan according to the topography of the store.
- Designers can understand which design values can be applied directly to non-gender and non-age groups of users and which design factors have a similar effect when confronted with different demographics (**Figure 14**).
- The findings emphasise that gender will not be a significant factor in design, but age is a major factor in design differentiation. Designers are not required to design separately for users of different genders. However, an age-friendly design for a more inclusive community will be required when considering the large-scale design of MR shops (**Figure 14**).

Mixed Reality Retail Shop Interior Environment Design Recommendations					
Factor Rank	**Design Factors**	**Demographics**	**Rank & Range**	**Design Values Recommendation**	**Explanation**
1st	**Light Illuminance**	Overall	1st	200 lux + 414 nits HMDs intensity	High intensity of HMD with dim background (μ=3.85). Users chose a dim ambient light paired with a high-intensity device luminance for clearer optics.
			2nd	500 lux + 414 nits HMDs intensity	High intensity of HMD with bright background (μ=3.49) can be used for a secondary option.
			3rd	200 lux + 221 nits HMDs intensity ≈ 500 lux + 221 nits HMDs intensity	Medium intensity of HMD results in similar experience satisfaction on dim (μ=2.93) or bright (μ=2.93) backgrounds.
2nd	**Spatial Dimension (Pose)**	Overall	N/A	Sit ≈ Stand ≈ Walk	There is no statistically significant difference between the three postures used: sit (μ = 3.81), stand (μ = 3.60) and walk (μ = 3.39). However, user age bands assessed sitting and standing as being significantly greater than walking. This suggests the necessity for retailers to establish seats for customers, and designers are encouraged to design an inclusive ergonomic space for both sitting and standing use. If the store has sufficient space, consider designing MR usage areas that can accommodate three postures.
		Age	18-25	Sit ≈ Stand ≈ Walk	Sit (μ = 3.57), stand (μ = 3.90) and walk (μ = 3.53) remained statistically consistent in customer experience satisfaction. This suggests that designers can design MR spaces with multiple combinations of usage postures.
			26-35	Sit > Stand > Walk	Higher average score on sit (μ = 4.06) versus stand (μ = 3.40), sit versus walk (μ = 3.16). This suggests that retailers should establish seats for customers if the target customers are aged between 26-35.
			36-55	Sit ≈ Stand ≈ Walk	Sit (μ = 3.15), stand (μ = 3.65) and walk (μ = 4.35) remained statistically consistent in customer experience satisfaction. This suggests that designers can design MR spaces with multiple combinations of usage postures.
3rd	**Light Colour Temperature**	Overall	N/A	3000K (Warm) ≈ 4000K (Neutral) ≈ 5000K (Cool)	Neutral (μ = 3.55), cool (μ = 3.36), and warm (μ = 3.37) light remained statistically consistent in customer experience satisfaction without considering demographics.
		Age	18-25	3000K (Warm) ≈ 4000K (Neutral) ≈ 5000K (Cool)	Warm (μ=3.69), neutral (μ=3.40), and cool (μ=3.22) light remained statistically consistent in customer experience satisfaction among those aged 18-25.
			26-35	4000K (Neutral)	Customers aged 26-35 are more satisfied with experiencing neutral (μ=3.73) than warm light (μ=3.18).
			35-55	3000K (Warm) ≈ 4000K (Neutral) ≈ 5000K (Cool)	Warm (μ=3.30), neutral (μ=2.95), and cool (μ=4.05) light remained statistically consistent in customer experience satisfaction among those aged 35-55.
4th	**Colour walls**	Overall	1st	Blue	Blue (μ=3.60) has a significant difference from red (μ=2.98). Interior designers should flexibly ideate their designs according to the product's colour palette. For example, if the product's primary colour is blue, they could use a white background to contrast the colour.
			2nd	White ≈ Red	White (μ=3.33) and red (μ=2.98) remained statistically consistent in customer experience satisfaction. Designers can choose a design based on the colour contrast between the virtual product's primary colours and the background wall colour.
5th	**Merchandise Display**	Overall	N/A	Vertical display ≈ Horizontal display	It should be noted that the experiment used a 566-gram headset. The duration of wearing and the weight of headsets from different brands may affect customers' perceptions. Considering the natural physiological curvature and comfort, if retailers intend to increase the dwell time in adoption to use HMDs, they might need to consider the group of consumers who had cervical spondylosis symptoms. It is recommended that vertical displays be more ergonomic for using a standing posture
6th	**Spatial Ratio (Service mode)**	Overall	N/A	Landscape space (Retail assistant on beside) ≈ Longitudinal space (Retail assistant on opposite)	Landscape space (Retail assistant on beside) (μ=3.40) and Longitudinal space (Retail assistant on opposite) (μ=3.34) remained statistically consistent in customer experience satisfaction.
7th	**Privacy**	Overall	1st	Share screen when needed (assistant access only)	Customers are more satisfied with MR services on the public's inaccessible screens, such as tablets or HMDs (μ=3.81).
			2nd	Share screen when browsing (public access screen)	Customers are less satisfied with MR service on screens that the public can view, such as monitors and TV screens (μ=2.82).
	Screen Share Devices	Tablets and/or HMDs	Retail assistants can use either type of device or a mixture of both when providing MR customer service. 67.2% of users prefer that the assistant use tablets, 60.9% prefer that the assistant use an HMD, and 31.3% prefer that the assistant use a PC screen. Retail assistants can use tablets to replace HMDs for viewing. However, having at least one assist-HMD in a store is still necessary when the user needs assistance with operating apps.		

Notes:
1. Average score (μ) criteria: 1- strongly no prefer, 3 neutral, 5-strongly prefer.
2. Overall refers to all user preferences. Gender, education and occupation (employed or unemployed) have no statistical difference with user preferences.
3. This data is derived from experiments with jewellery products and may not be representative of all product categories.
4. Data was collected in the UK in 2024, and the sample size is 64.

Figure 14. Mixed reality retail shop interior environment design recommendations

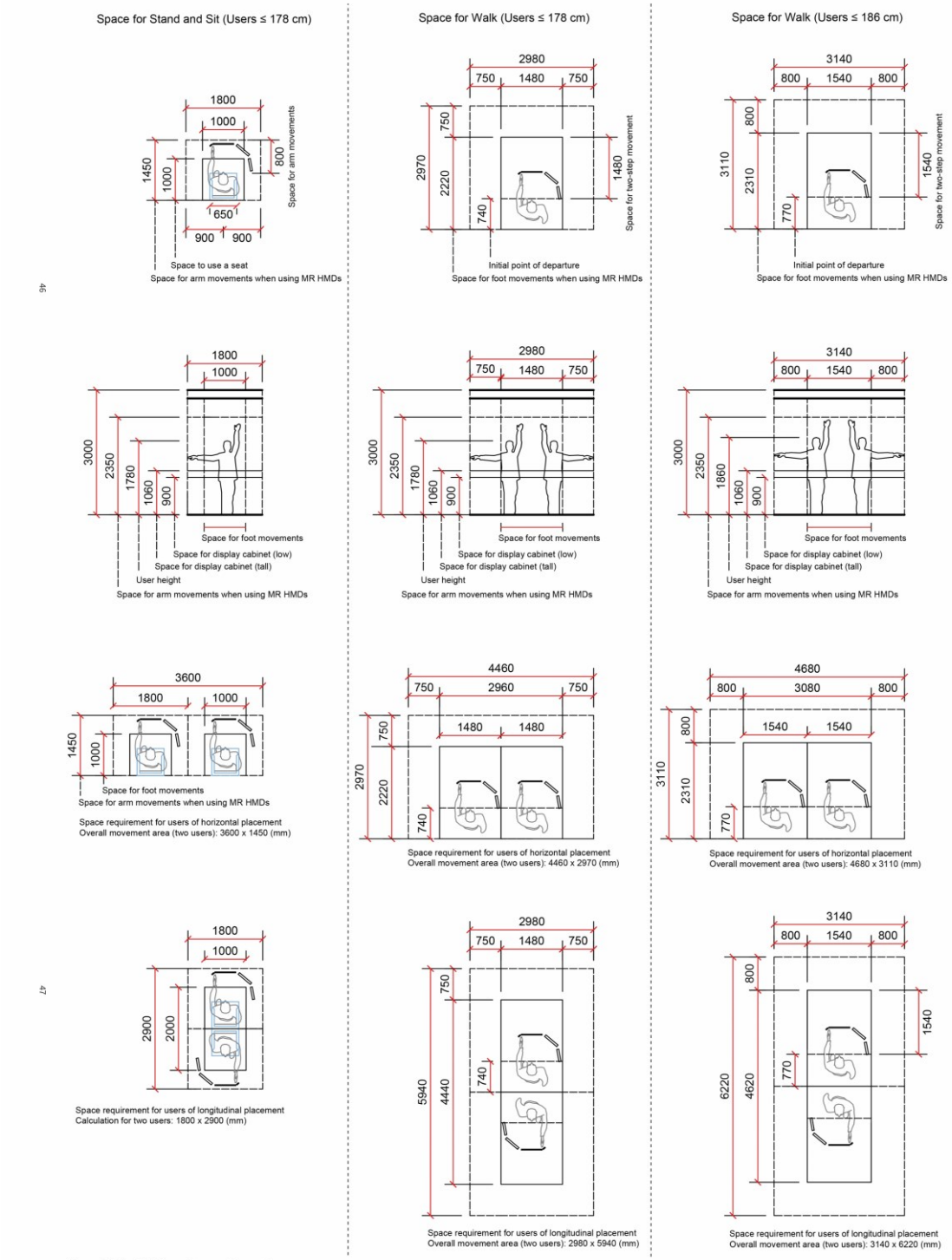


Figure 15. Spatial dimension requirements

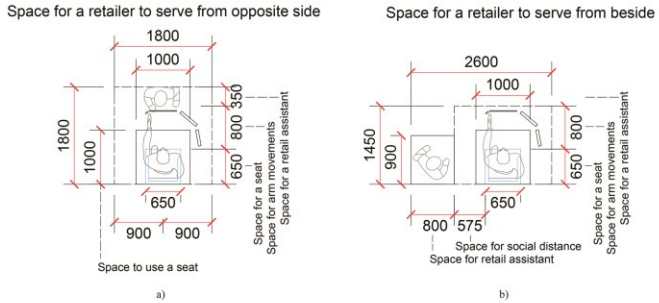


Figure 16. Spatial ratio requirements. a) a retailer serves on opposite. b) a retailer serves on beside

Using the proposed spatial dimensions as guidance, the following four exemplary layouts, based on store use scenarios, are provided to demonstrate to interior designers how the above recommendations can be applied. **Figure 17** presents four speculative layout concepts for a medium-sized (70 m^2) jewellery store to inspire interior designers. It includes dimensions for three typical jewellery display cabinets: 1500×450 mm, 950×450 mm, and 450×450 mm, with typical heights ranging from 900 to 1060 mm. Designers should ensure sufficient floor space for foot movement while minimising hand movement space waste by positioning display cabinets (under 106 cm in height) to optimise space utilisation.

The following layout designs consider five types of usage scenarios: standing and sitting, or all postures; small groups or individual customers; MR space at the main traffic flow or the edge; equipment quantity (1 or 2); and the service position of retail assistants. For example, Layout A is designed for individuals' stand and sit postures. Since a place needs to be allocated for a seat, only one of the postures can be applied to the space. In this case, a chair can be placed in one space, and the other space is empty for standing. The display cabinets can be used to separate usage and service areas for two users and space for retail assistants service is beside. Layout B can be used for three postures, requiring more space than Layout A. It could employ display cabinets to create a semi-enclosed MR space where customers can see each other across height differences, allowing for a certain privacy without complete enclosure. Layout C highlights designated areas for single and group customers, the retail assistant could stand opposite. Layout D can accommodate users in two separate spaces, and placing the MR area at the traffic centre increases its attractiveness to customers crossing the area. In layouts A and B, the MR space is positioned in a corner, supporting custom assistance-oriented store types. In contrast, layouts C and D place the MR space at the centre, aiming for immersive stores focused on MR customisation. Moreover, layout design can consider planning with function areas, such as layouts A and B utilise grid form, while layout C utilise free form and D uses racetrack layout. Designers should also consider the placement and storage size of the cabinets to ensure appliance safety.

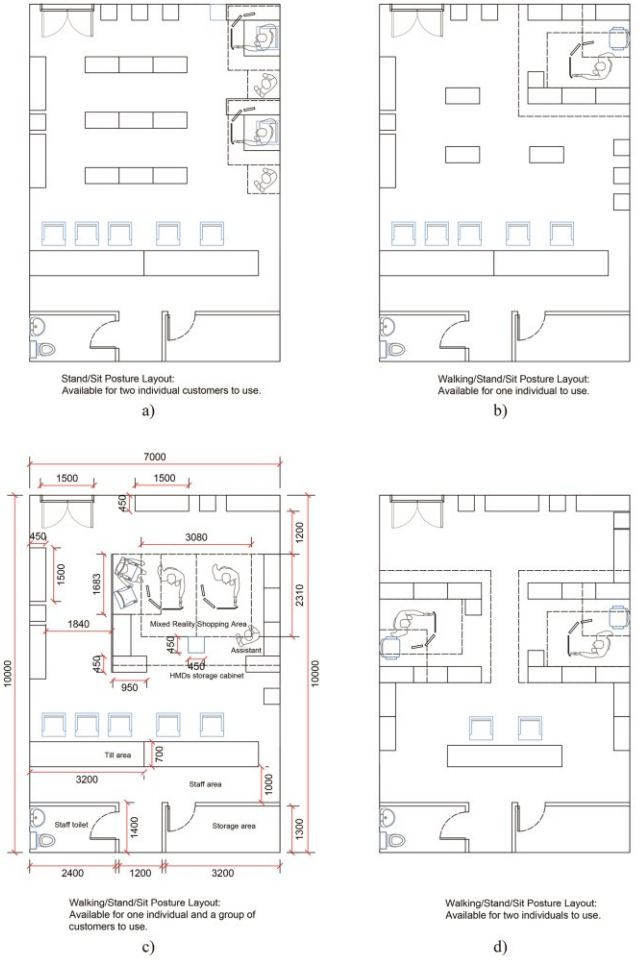


Figure 17. Speculative layout design. a) available for stand and sit postures. b)/c)/d) available for walk/stand/sit postures

Summaries

This section provides recommendations for MR interior environment design, which interior designers can develop based on this guideline and retailer requirements. Meanwhile, it is notable that the results in **Figure 14** represent generalisable guidelines, whereas the spatial requirements (**Figures 15**/**16**/**17**) only match within the range of the MR UI scale recommended in this study. Therefore, before undertaking MR interior design, interior designers need to communicate with UI designers to confirm the scale of the MR system. Interior designers also should establish the design context (usage scenarios, quantity of devices and shop scale) and target customer demographics (gender, age) with the retailer in order to design a brand-specific shop environment.

Retailers could gain insight from this section into the minimum usage space scale requirements before launching an MR shop to gauge whether there is adequate space available for the MR experience. They can also conduct market research on the customer segments according to this guide such as whether the customer segments are mostly groups or individuals. Is there a need for shared screens (multi-users) in terms of the product category such as commitment wedding rings/furniture, or individual jewellery, shoes or bags? These design requirements influence interior designers to design spaces for individual or multiple clients, enclosed or semi-open spaces.

Section

06

Design/ Prototyping

Interior designers can design pop-up events for MR experience to test brand application feedback and achieve the purpose of marketing.

Pop-up stores are temporary stores that operate for a limited period. They are considered a new experiential marketing tactic aimed at attracting consumers (Niehm et al., 2006). Pop-up stores typically intend to engage participants in a series of dramatic, pleasure-oriented, and memorable experiences (Pine and Gilmore, 1998). By offering entertainment and interactive environments, they create experiential value and a joyful atmosphere (Klein et al., 2016).
The emergence of pop-up stores brings potential benefits to the industry. Retailers are expected to test new purchasing strategies and expand new markets through pop-ups (Yu et al., 2018). Therefore, the combination of short-term, small-scale pop-up retail with MR purchasing is an opportunity and channel for retail innovation.

BUILD A POP-UP STORE TO TEST YOUR BRAND



MR Pop up / Temporary Store

In this section, a minimum-scale MR space was built which mimics a pop-up MR retail store. Retailers could based on this design recommendation launch an MR experience store or installation to test new products, organize brand events, or pilot branded MR experiences. **Figures 18** and **19** illustrate the MR interface effects in the installation and pop-up installation effects.



Figure 18. Mixed reality effects for Jewellery stores

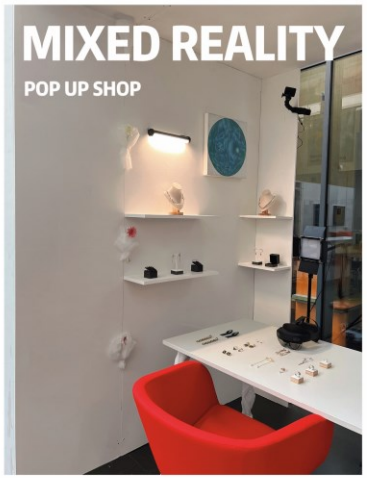


Figure 19. MR pop up store interior atmosphere

Pop-up stores, although temporary and small-scale, still exhibit various distinctions. Pop-up stores come in many different display formats, location settings and objectives. Design-oriented pop-up stores are distinguished into short-term standalone stores, short-term kiosks, pop-in stores, invisible pop-ups (AR/application-based pop-ups), virtual walls and collaborative pop-ups (Yu et al., 2018). Location-oriented pop-up stores can be categorised as guerrilla stores, nomad stores, pop-ups in shopping malls and event-driven pop-ups (Yu et al., 2018). Objectives-oriented pop-up goals can be identified as communicational, experiential, transactional, testing and institutional (Yu et al., 2018). However, not all types of pop-up stores are suitable for employing MR. The following will discuss the types of pop-up stores that are suitable for implementing MR.

Mixed Reality Pop up Store Typology

Table 9 concludes the pop-up typology that matches the adoption of MR HMDs (more analysis see Jin, 2025, pp. 57-65). The market niche for MR is currently more suitable for medium to large retailers due to the high cost of the equipment. Consequently, guerrilla and kiosk pop-ups prioritise affordability and convenience and are not applicable for MR implementation. Their limited investment scope and insufficient space for MR usage make them unapplicable for input MR.

Secondly, in-store and mall-based pop-ups face challenges in implementing MR, primarily due to restrictions on altering lighting conditions and the need to comply with mall regulatory policies. In contrast, standalone and event-driven pop-ups are more suitable for MR, as they offer independent spaces, adjustable lighting, and matching financial resources.

Table 9. Pop-up store types applicable to mixed reality HMDs

Pop-up Store Typology	Applicable inputs MR	Reason for MR HMDs Adoption	Design Consideration
Short-Term Standalone Store	Yes	• Sufficient space for movement; • Adequate finance in system development and maintenance; • Adequate finance in HMDs investment; • Adequate employee assistance; • High traffic flow.	• Safty boundary of usage • Salespeople HMDs training
Short-Term Kiosk/Nomad store	No	• Lack of space for movement; • Finance restricted in investment; • Insufficient manning.	• Safty boundary of usage • Salespeople have no knowledge of HMDs • Finacial limitation • Shopping mall/Public area policy • HMDs security • Obstructed passage
Pop-In Store	Yes	• Restricted space for movement; • Adequate finance in system development and maintenance; • Adequate finance in HMDs investment; • Adequate employee assistance; • Need to direct traffic.	• Safty boundary of usage • Salespeople HMDs training
Collaborative Pop-Up/ Event-Driven Pop-Up	Yes	• Sufficient space for movement • Adequate finance in system development and maintenance • Adequate finance in HMDs investment • Adequate employee assistance • High traffic flow	• Safty boundary of usage • Salespeople HMDs training • High traffic flow • HMDs security • Waiting area
Guerrilla Store	No	• Finance restricted in investment	• Expensive devices • Technology investment
Pop-ups in Shopping Malls	Yes	• Restricted space for movement • Adequate finance in system development and maintenance • Adequate finance in HMDs investment • Adequate employee assistance • High traffic flow	• Safty boundary of usage • Salespeople HMDs training • High traffic flow • Shopping mall policy • HMDs security • Waiting area

Minium Size of Mixed Reality Stores

In the section on pop-up shop design, I suggested an approach to build a pop-up installation. It suggests a minimum MR space proportion of a minimum of 1.8m x 1.8m, accommodating users below 1.83m in height and based on an arm span of the person at 1.83m. The build framework of this pop-up space aids retailers in replicating this mock-up for brand market testing.

Figure 20 diagrams the process of building the experimental environment for the pop-up installation. **Figure 21** illustrates the experimental installation of timber panel dimensions and assemblies. It shows the floor plan layout of the installation and provides the elevation dimensions. The walls were made of 20 mm thick plywood, and the ceiling plywood was 15mm thick. A total of seven standard plywood panels were supplied.

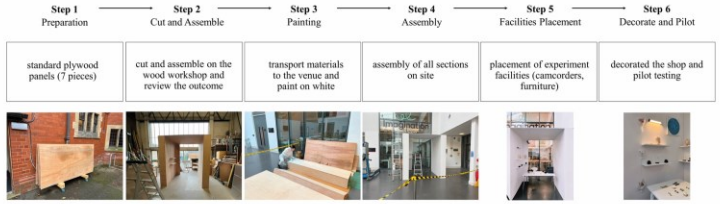


Figure 20. MR pop up store build process

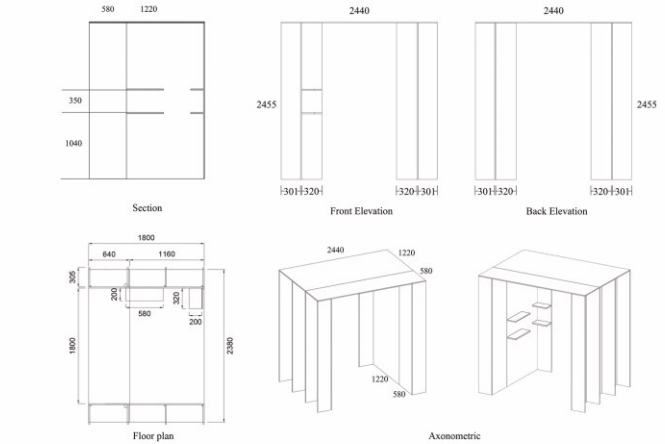


Figure 21. MR minimum space dimension drawings

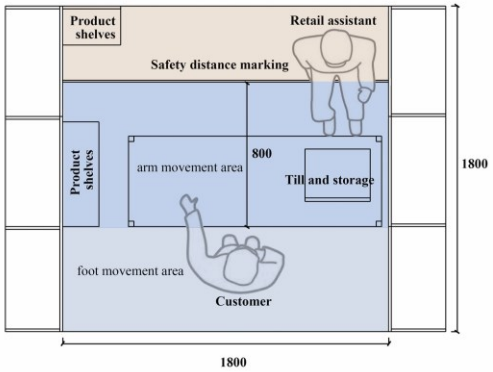


Figure 22. MR minimum pop up store floor plan with layout (right)

In a pop up store with a minimum usable space of 1.8m by 1.8m for two people, using a table spacing out the user and the retail assistant by an ergonomically sized safety distance for face to face layout user's arm movement (**Figure 22**). A safety distance of 0.8 metres, an average arm's length, was measured from the edge of the table in the direction of the user to the direction of the retail assistant. The distance boundary could signalled with hazard tape on the floor on the retailer's side to ensure no physical collision between the two parties involved in using the device. Following these suggested dimensions, interior designers can either redesign to create brand-conscious pop-up installations, or build a basic pop-up installation using this design scheme.

Summaries

This section is recommended for interior designers, retailers and manufacturers. It describes brands can test MRPC market acceptance and brand strategy by designing pop-up events. A minimum MR space dimension is proposed along with a set of basic building methods. Retailers are able to foresee effects and develop branded pop-up activity based on this design scheme. Interior designers are able to develop designs based on this framework to create a more attractive store atmosphere. Manufacturers can benchmark this design solution with interior designers to quote, build and construct for retailers.

RM

Section

07

Onboarding

Onboarding training retail assistants to enhance the efficiency of service, including recognising MR headset users' verbal and nonverbal behaviour and user companion types to refine their customer services.

Inevitably, users may encounter various problems when using MR, and the effective support of retail assistants can greatly enhance the efficiency and experience of users. Therefore, MR training for retail assistants is essential for a seamless MR retail transaction journey. In the previous **Figure 5**, it was highlighted that the physical environment, the MR application and the hardware influence the accessibility of the MR experience. Consequently, physical environment design recommendations are presented in order to facilitate accessibility. Nevertheless, it is impossible to avoid errors in software and hardware completely. Effective and efficient customer service can compensate to moderate degrees for system errors, delays, or when users are not proficient in usage. The following paragraphs describe obstacles to the use of MR systems as examples for retail assistants to recognize. By practising the operation of MR more frequently, retail assistants can improve their customer service skills.

MR Headset User-oriented Customer Service

MR systems are a primary component that provides a hedonic experience for customers; however, when the system design and device are inaccessible, lead to negative sentiment is outweighed by positive sentiment, and decision-making will be affected. The empirical evidence from the observations in-store reported four factors: *accessibility* and *stability* (technical latency, accuracy, hand recognition, stability), *interaction* and *interface design*.

System accessibility and system stability, values incorporating direction incorrect, incapable targeting, incorrect gesture, miss trigger, position incorrect and uncontrollable beam projection. The system interfaces are unable to target virtual objects when the angle relative to the person is inappropriate. Users fail to be aware that the position should change or are unable to move due to limited paths. P16 mentioned, ''I think the angle is wrong''. Inability to aim at objects, including buttons not responding, laser beam aiming through background (ceiling, wall). Gesture errors, where users create new gestures that are not recognised by the system, such as system pinch setting (from the outside in) while users (flick) spread their fingers from the inside out; unrecognised fingers caused by using the thumb and middle finger when pinching, and spreading the other fingers. Mis-touch, such as clicking background, mis-triggers spatial recognition and moves the finger before it is recognised and released. Uncontrollable beam projection, laser beam sticking to the background and unable to release, and laser beam unable to focus on near objects and projection on background. System stability, such as system errors and jitter occur. Users reported that:

''It's sort of going the ''fufufu'' background.'' (system slightly jittery) (P34)

Unintentionally flicked off the virtual product, and the ring flew away. The user was finding the ring (P18).
Interaction design and UI design, including gamification attractiveness, system complexity, visual cues and multi-screen task interfaces. There are some gamification scenes (animation avatars) in the MR system to augment the appeal of the application, such as the dragon featured as a guardian of the treasure. Users interact with the animations and are engaged with positive sentiments. Users suggested that the operation of the system is complex. Users are distracted and interfered with by the physical environment and ignore the visual aids provided by the system. Users commented on the design of the multi-screen task interfaces.

MR headset user behaviours include *attempt quality, guidance, information access, system operation* and *system quality,* where these behaviours lead to inner response. Attempt quality involves success, failure, unconscious attempts, repeated attempts, and invalid attempts to perform a task. Guidance-seeking users are partly inquiring about usage, while others look for tasks and next-step instructions. Information access, where users generate a dialogue with the retail assistant, includes enquiring information about the retail assistant's background, the app, designers, devices, products, the shop activity and the system's functionality.

System operational behaviours consisted of users focusing on the real-world environment while using the system, describing their behaviours, finding and locating the virtual product, shifting their position in space, and trying on products. System quality, where users reported the system errors during use. Some users asked for information of system function and HMDs price:

''Can you put it on? Can make it small enough to like.'' (P14)

''How much is this headset like that?'' (P5)

The above external behaviours elicited the below internal responses. Users' decision-making process, where they constantly compare product customisation effects and try all options. Seek homophily, self-identification, and social identification consists of the user recommending and inviting companions to participate in the experience, self-evaluating their design outcomes, and seeking evaluation and endorsement of their design outcomes from the retail assistant and their companions. User experience perceptions, that is, user evaluations of the MR purchasing experience, included comments on exercise ability, ease of purchase, innovativeness, learning to use, aligning individual interests, sound effects, and future feasibility. Some users commented that:

''It's rather like playing the piano. You need to learn.'' (P22)

''It is fun like even the characters are just […] it's like if I take my glasses off, I wanna be shocked that there's not like three screens in part of me. So, it's very well done.'' (P24)

These system issues and user behaviours encountered by users can provide retail assistants with insights into possible scenarios in real retail environments, allowing them to pre-plan their strategies for tackling obstacles.

MR Headset User's Companions-oriented Customer Service

MR headset user companions' behaviours are performed through *engagement, mobility, observation, shopping, and socialisation*, which generate internal response *sentiments*. Engagement behaviours include positive (making suggestions and interaction), negative (urging, and unconscious triggering and interfering with the HMD hand recognition). Other behaviours include movement in space, photography, queueing, shopping, and social conversations. Based on these findings, user companions are categoried as four types of customer groups that can provide different customer strategies.

- **Motivated hedonic-orientated companions** who generate positive sentiments and continue interacting with the user, queuing up for the experience and exchanging design outcomes. For example, sentiments: *''You look cross site is so funny (Laughing)''*. Conversations: companion A talked to companion B *''He's shopping''* then asked the user, *"Are you shopping?" ''I'm looking at a few things. That's so crazy, it looks like real!"*
- **Passive aim-orientated companions** who are disinterested in engaging in the shopping process and urge their peers to leave to complete their purchase task. An example, companion: *''We're gonna go pay. Hurry up.''*
- **Neutral observer companions** who are less motivated only observe the user from the sidelines.
- **Self task-oriented companions.** Focus on individual shopping tasks and act separately from their companions. A conversation example: A user's companion changed into new clothes and showed the user. The user lifted up the glasses and walked two steps forward. Companion: *''Look. I might just last T-shirt with a nice bottom.''* User: *''[talking to the companion]'.*

Third-party customer behaviours involved await, intervention and socialisation. Await, where shoppers wait in queues or stay on the sidelines to observe the user. Intervention, for instance, speaks to the user/retailer while they are using. Socialisation includes dialogue with other retail assistants and other companions next to the user.

Unlike traditional retail shops, agent behaviour is shown as engagement, service effectiveness, mobility, and responsiveness. Engagement includes adjusting the device, demonstrating methods of use, assisting, and providing social communication. Retail agent service quality, such as the ability to effectively instruct users, gesture recognition of miss activation by retail assistants, and the retail agent's path of movement in space and active service, flexibly reposition themselves to avoid interfering with user movements and traffic flows of other shoppers influences the quality of the customer experience.

Summaries

This section discusses user MR utilise issues and user companion types. By identifying the behaviours of these two customer segments, MR retail assistants are able to deliver refine customer service through pre-practice. The following recommendations are for retailers and assistants:

1) Retail assistants should be able to share the user's screen during first-time use to guide the user to learn and control the MR operation. In addition, assistants should be able to quickly navigate the user interface through additional devices to provide immediate service when the user seeks assistance halfway.

Figure 11 (p. 40) introduces the use of devices (tablelets and MR HMDs) while assistants serve can be used. Additionally, if customers prefer an assistant to operate on their behalf or to co-design (multi-users), assistants will need to use MR HMDs rather than tablets, and will need to be able to synchronize scenes and alter effects in real time between the HMDs. This functionality will require retailers to inform software engineer in advance before develop it.

2) Retail Assistants are expected to be systematically trained to use the MR system and devices to provide efficient and effective MR in-store service. Assistants should be capable of:

- Quickly identifying barriers encountered by users, through both non-verbal and verbal behaviour of users.
- Fast solve MR operational problems that users encounter.
- The ability to instruct new users onboarding.
- To provide comprehensive professional knowledge (see Figure 5 and Jin, 2025, pp. 206-217).
- Service to user companion in order to convert them to become the next user.

Section 08

Evaluation

Product managers can conduct market fieldwork to evaluate current MR customer experience strategies and design solutions feedback. By evaluating customer experience outcomes continuously innovating each stage design solutions and refining services.

The evaluation in this section includes the results of the MRPC customer experience in a traditional brick-and-mortar store, and the results of the user experience of a mock retail store (see Jin, 2025, pp. 202-204, 280-281). This result demonstrates short-term studies of customer experience responses in brick-and-mortar stores. It provides a series of methods to help retailers in evaluation

The evaluation assesses shifts in user behaviour and sentiment in terms of the MR experience for consumers. This can help retailers better comprehend the potential profit of store adoption of Mixed Reality technology for their brand. The evaluation dimensions included user in-store dwell time, sentiment shifts, and user experience findings. The evaluation methods use in-store observations and questionnaire surveys (see Jin, 2025, pp. 202-204, 280-281). These methods can also be combined with customer experience maps (Section 2) to continuously compare barriers and pain points in the holistic customer experience (from pre-entry to advocacy) and the user experience (stages of MR engagement). This enables brands to continuously adapt their marketing strategies to constantly evolving consumer demands.

Dwell Time and Duration of Use

Based on the calculation of the overall dwell time of customers (groups and individuals) from entry to exit, it was found that the average in-store dwell time of customers was 4.12 minutes. 5.16% of customers (groups and individuals) dwelled for ten minutes or more in-store, and 57.89% of customers dwelled for less than 10 minutes in-store. Customers who spent more than 10 minutes in the shop groups account for 8.72% and individuals account for 31.94%. Customers who stayed in the store for less than 10 minutes in groups accounted for 91.74%, while individuals accounted for 68.06%. For those who remained in the shop for more than ten minutes, by relationship-oriented, friends cohorts accounted for 10.17%, couples accounted for 4.84%, and family groups (with children) accounted for 1.18%.

The average duration of use for all customers (individual and group) using MRPC is 5 minutes, with the average duration of use for group customers 5 minutes and for individual customers 5.32 minutes. Among group customers, the average duration of use is 5.15 minutes per person while companions wait on the sidelines and an average of 6.87 minutes for users whose companions are shopping or fitting.

The above results indicate that the average length of in-store dwell time in this shop is short, with the majority of customers leaving within ten minutes. Individual shoppers stay longer than group shoppers, and friend-oriented shoppers are the dominant group for long dwell times. In addition, the MRPC adoption duration approves that it enables an increase in additional effective customer dwell time. Similarly, the average duration of use is longer for individual customers than for group customers, and the usage purpose of waiting for companions (6.87 minutes) is notably higher than the average duration of use (5 minutes).

Sentiment Analysis

Performing a sentiment analysis using transcripts of customers using MRPC and employing manual labelling rather than traditional machine learning sentiment classification methods. The manual process consumed more time but allowed the semantic information of the contextual text to be fully utilised, resulting in higher accuracy for implicit sentiment analysis (P. K. Jain et al., 2021). Four types of sentiment were identified: positive, negative, neutral and confusion. Positive emotions such as P13 stated, ''I think I'm pretty happy with my AR experience.'' Negative emotions such as technical stability issues, P14 stated, ''Maybe I messed it up, lost. It seems to be moving too much for me to grab things.'' Neutral emotions, for example, P19 mentions the lagging nature of the technology ''Because it's also lagging a little bit, but it's cool.'' P21 was confused about usage because it forgot its operating method ''So should I pinch one of the pitchers or one of these blue screens?''

79.17% of customers produce positive sentiment, each experiencing an average of 6.9 times positive sentiment while using the MRPC. 54.17% of customers respond with neutral sentiment. 3.75% of customers produce negative sentiment, with each an average of 2.3 times of negative response. 4.17% of customers feel confused while using the MRPC, with an average of 1.7 times of confusion per capita. User companions (both using the MRPC and non-users) sentiments were identified as three types: positive, negative,

and neutral emotions. When observing users accessing the MRPC, 46.15% of companions expressed positive sentiment, while 7.69% showed neutral and 7.69% showed negative sentiment, respectively. Positive sentiment correlates with the quality of the user intent. User intentions are categorised into five types: successful intentions, unsuccessful intentions, invalid intentions, unconscious intentions and repeated intentions. Successful intent is when the user completes intended actions successfully, and unsuccessful intent is when the user fails to complete the intent. Invalid intent is when the user tries to perform a task using an invalid action, such as a self-created gesture undetectable by the hardware. Unconscious intent is the action triggered by accidental touch, such as moving the interface without awareness. Repeated intent is when users attempt to complete an action unsuccessfully and retry repeatedly. Among users coded into successful intentions, an average of 15.2 successful intentions per capita were generated. Comparably, unsuccessful intentions occurred 9 times per capita, invalid intentions 2 times per capita, unconscious intentions 1.8 times per capita, and repeated intentions 6.5 times per capita.

The results illustrate that successful attempts and the positive sentiments of users are positively influenced. The success rate of users is 1.69 times higher than the unsuccessful rate. Positive sentiment (79.17%) was generated significantly more than negative sentiment (3.75%) when the user engaged in use. Companions were also influenced to generate positive sentiments like laughing, taking photographs, and being curious about the sights of users while observing. Negative sentiments were derived from waiting time, awaiting comfort (standing/sitting), and emotional reactions to observing the user using barriers such as urge, impatience, and prodding.

User Experience Satisfaction

The survey result indicates that the more well-designed the UI on the application, the more positive the attitude towards its use. UI design consists of three aspects: visual user-friendliness of the layout , clarity of navigation, and clarity of the UI hierarchical structure. Ease of use of technology correlates with user attitudes towards use but barely impacts attitudes towards use. Usefulness, on the other hand, affects changes in user attitudes and purchase intention. Using the MR configurator App to complete a customised product purchase enabled users to have a sense of usefulness, which includes the fulfilment of purchase demands, increased purchase efficiency and ability of decision making, and the satisfaction of expectations from the customised functionality. The more positive the attitude towards using the MR configurator app, the more it will increase the behaviour of the consumer to use it and increase the consumer purchase intent. When users perceive using this MR configurator in the shop as easy, it will positively influence their affective and behaviour. Ease of use will not cause an uplift in intention to buy, but it will cause consumers to perceive in-store use of the HMD and system as useful for purchasing behaviours and will be reflected in an increase in system access behaviours. Prospective consumers who judge MR purchases as easy to use and useful tend to browse and purchase using an HMD. Equally, users who intend to use the MR configurator augment the tendency to purchase products.

Furthermore, the result shows that 78.1% of users showed optimism about using MR to purchase in the future, and 60.9% are likely to commit to a practical engagement when operating in the MR retail marketplace in the future. 71.9% of consumers intend to use Mixed Reality and the MRPC app to complete purchase missions. 59.4% believe that this innovative retail approach is practical and that its usefulness directly positively contributes to boosting consumer purchase intent. Moreover, while ease of use of technology has a positive impact on user usage behaviour, usefulness has a relatively more significant impact on consumers both in terms of attitude and behaviour. In other words, technological obstacles to use are less critical compared to consumer cognition of the purchase task from a utilitarian viewpoint since usefulness is almost 3.4 times more influential on purchase intent than ease of use. 62.5% of users found the MRPC easy to use, and 6.3% found it challenging. Users' behaviour of browsing with MR in a physical shop drives their purchase intent, and purchase intent also drives users to experience the MR HMDs. Therefore, increasing the frequency of users' MR adoption behaviours can be considered a means to augment consumer purchase motivation.

Summaries

The MR retail experience creates a complex retail environment compared to traditional retail environments. Users, user companions, retail assistants and third-party customers are influenced by their mutual behaviours when using a shared space. Therefore, the consideration of evaluation focus on the customer experience. However, designers should evaluate independent sections of the design before evaluating the customer experience. For ***UI designers and software development engineers***, some common evaluation methods are system usability testing (user testing), prototype iterative design, A/B testing and heuristic evaluation. For ***interior designers***, finalizing a solid interior design is time-consuming and costly. The evaluation methods are relatively limited, such as A/B testing of renderings, or prototype a scenario using the recommended minimum space dimensions in this guide for testing. For ***CEM and UX designers***, available evaluation methods have such as measuring dwell time and duration of use, customer experience/journey maps, service blueprints, UEQ/AttrakDiff questionnaires, return on investment (ROI), eye tracking and galvanic skin response (physiological response monitoring). The effectiveness of the customer experience may vary in part depending on the brand and the design scheme of retail stores. Therefore, after completing the holistic MR commercial design, I recommend that retail managers and designers purposefully re-evaluate the customer experience results for individual brands. As stated that this guideline provides a series of design principles and design management recommendations, but it is not a strict set of metrics or rules to be adhered to. However, following this design guideline has the possibility of helping businesses achieve sustainable and long- term success.

Based on variations in consumer behavioural patterns such as dwell time, positive sentiment and footprint of use, it is indicated that the benefits of the MR experience involve positive sentiment for most customers (79.17%) (n=68). However, negative sentiment cannot be eliminated. Negative sentiment could be reduced by improving the usability and stability of the equipment and software, proficiency in using the technology, and the accessibility and comfort of the environment. In other words, there is a need to avoid user interface jitter and provide timely responses, set security boundaries when the users are unfamiliar with the technology, and provide options for users and their companions to stand and sit to enhance accessibility and inclusiveness. In addition, only 2.94% of the users in the study had prior experience with MR, and 97.06% were first-time users. There are yet to observe a single case of a customer who did not successfully operate the device at least once. However, increasing the pervasive use of the device, the frequency of use, and the ease of use of the application can help enhance the successful use by the customers, which in turn can minimise their negative sentiments. Further issues that should be tackled include optimising the interior environment design to minimise user interference with other customers. Whilst there is a design recommendation for interior design, the usage space design, such as open, semi-open or enclosed situations, needs to be adapted to the business strategy. These findings based on field data provide a productive case study and practices that can provide suggestions and inspiration to practitioners and restate the importance of the MR brick-and-mortar channel as a futuristic retail channel research. By induction of consumer behaviours, identify the implications of the MRPC retail experience are:

- **Satisfactory decisions.** Users are able to continually compare 3D product customised outcomes during the MR experience, and this decision-making process can help consumers make more satisfactory decisions.
- **Sentiments.** User interactions with retailers and companions increase, positively impacting user sentiments (laughing, excitement, pleasure).
- **Uniqueness.** Multi-sensory retail environments immerse consumers in a brand-created place of dialogue, which increases the value of uniqueness in the physical retail shop. By using the MRPC, customers can customise more personalised and exclusive products.
- **Products and brand image added value.** The positive impact emerges from the distinctiveness of the immersive brick-and-mortar environment experience and the high engagement of the user, which strengthens the value potential of products and brand image.
- **Futuristic and sustainable solution for customisation.** Providing brands with a sustainable customisation display approach through using MRPC as a futurism method to reduce the wastage of plastics in traditional semi-customisation effect display (engraving).

D

RM

SD

PA

Section

09

Conclusion

This *Design guideline brochure* explores how to implement MR product configurators in brick-and-mortar retail stores through research and design. It aims to enhance consumer accessibility to use, dwell time, decision-making and experience satisfaction, thereby increasing offline retail conversion rates. The benefit of wearable MR technology over VR and AR is that it liberates the hands, eliminating the need for handheld controllers or hardware devices. This flexibility is fundamental to retail market adoption. Relying on ephemeral sensations and temporary experiences is insufficient for the MR channel to develop sustainably and lastingly in the market. Therefore, the MRPC of mass customisation and increased in-store experience accessibility is proposed to improve the practical functionality of MR retail. The brochure proposes user-centred designs that meet user needs by engaging consumers in each design stage. Doing so minimises the risk of designers and retailers relying on personal preferences. It provides practical design solutions by integrating MR into the retail shopping environment. If stakeholders follow these guidelines, they may achieve long-term success.

Although this research was conducted in the UK and China, it is oriented toward worldwide consumers and can help implement business practices in other countries with similar contexts (see thesis methodology and limitations). In summary, MR product customisation in retail can significantly impact customisation sustainability, sales, customer engagement, customer experience, brand image and store spatial planning. By providing a futuristic retail tool creates an immersive, highly interactive and pragmatic shopping approach. MR can attract new customers, increase customer retention, effective in-store dwell time, enjoyment and conversion rates. It can also help provide alternative solutions to the environmental sustainability issues of customising jewellery in traditional retail stores. Despite the many benefits, the dark side of MR has also been mentioned, including data security, dissociation from reality and cyber attacks (see Jin, 2025, pp. 70-71). As well as the possibility that if retailers are unable to provide an intriguing MR in-store experience, consumers may prefer to purchase their own MR headset and play at home, which could cause a new challenge for brick-and-mortar stores. Therefore, retailers could follow this design guideline to catch the opportunity design refine MR in-store experience to engage customers to return to brick-and-mortar stores.

From a micro perspective, this design brochure is beneficial to interior/user interface/user experience/ product designers, retailers, MR/AR developers and researchers. The proposed design toolkits, design recommendations and the demonstration case can provide them with design concepts, frameworks, solution proposals and implementation approaches. By systematically reading this brochure, it is envisaged that investment executives could strengthen their understanding of the MR channel retail strategy to accelerate the market development of this channel. The design and management considerations highlighted can assist stakeholders in developing productive strategies for effectively integrating MR within physical retail spaces.

On a macro level, the design brochure encourage people to reflect on the sustainability of trade modes, the fashion industry, and carbon emissions. It encourages policymakers and retail managers to reassess and adopt MR, guiding policy development to maximise business opportunities. Government support for small- and medium-sized independent retailers could help them invest in MR shopping facilities to support their specialised and strategic growth. Large retail chains could leverage MR to drive local economic and technological advancement and enhance social impact. Public policymakers are able to contribute to developing socially inclusive and sustainable innovative retailing through the MR mean. Furthermore, when applied on a large scale in commerce, there is a need to promote the policy development acceleration between different regional government regulations, such as the development of ethical and moral regulations.

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Appendix G. Sample of Consent Form and Participant Information Sheet

Lancaster University

Participant information sheet

Research on the consumer's future retail purchase patterns based on mixed reality user experience

I am a PhD student at Lancaster University, and I would like to invite you to take part in a research study about Research on the consumer's future retail purchase patterns based on mixed reality user experience. Please take time to read the following information carefully before you decide whether or not you wish to take part.

What is the study about?
This study investigates mixed reality in the retail industry's future trends and design possibilities. To collect and analyse consumers' perceptions of future shopping method changes and the reasons influencing their use of 3D headset shopping. The data collected was used to analyse and develop shop designs.

Why have I been invited?
I have approached you because I am trying to understand customers' behaviour when they shop and move in the shop, and what customers experience in a virtual shopping platform. I would be very grateful if you would agree to take part in this study.

What will I be asked to do if I take part?

If you decide to participate, you will be involved in the following events. You will participate in this study, which involves wearing a headset to watch the shop environment modify and provide your feedback via a questionnaire during this task, which takes 1 hour.

What are the possible benefits from taking part?
Taking part in this study will enable you to share your experiences of using innovative technology to shop and if you take part in this study, your insights will contribute to our understanding of the experience of innovative mixed reality experience in a retail environment.
Do I have to take part?
No. It's completely up to you to decide whether or not you take part. Your participation is voluntary.

What if I change my mind?
If you change your mind, you are free to withdraw the data at the time during your participation in this study and within 2 weeks after you took part in the study. If you want to withdraw, please let me know.

What are the possible disadvantages and risks of taking part?
It is unlikely that there will be any major disadvantages to taking part. Taking part will mean investing in doing a task in a headset and completing a questionnaire.

Will my data be identifiable?

After the activity and interview, only the research team will have access to the audio and video recordings. However, I may publish papers or articles that are based on that data. Although I may use direct quotations in those publications you will not be identifiable from them. The video/audio recording will include your views (virtual website) in the headset (recorded by the headset itself). And also your movement in the space. However, I will not use direct video or audio in the publications. I will manually blur your face, tattoo or any feature that could identify you in any photos, all the data will be transcribed with no

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identifying information. All people appearing in the photos will be blurred with the identifying features.

I will keep all personal information about you (e.g. your age and other information about you that can identify you) confidential, that is I will not share it with others. I will remove any personal information from the written record of your contribution. All reasonable steps will be taken to protect the anonymity of the participants involved in this project. The headset video and camera recordings will take place for recording the data, but we will blur your face when using the photos that include you.

How will we use the information you have shared with us and what will happen to the results of the research study?
I will use the information you have shared with me only in the following ways:
I will use it for research purposes only. This will include e.g. my PhD thesis and other publications, for example, journal articles. I may also present the results of my study at academic conferences.

When writing up the findings from this study, I would like to reproduce some of the views and ideas you shared with me. I will only use anonymised quotes (e.g. from my activity with you), so although I will use your exact words, all reasonable steps will be taken to protect your anonymity in our publications.
If anything you tell me in the interview suggests that you or somebody else might be at risk of harm, I will be obliged to share this information with my supervisors. If possible I will inform you of this breach of confidentiality.

How my data will be stored
Your data will be stored in encrypted files (that is only research team will be able to access them) and on password-protected computers. I will store hard copies of any data securely in locked cabinets in my office. I will keep data that can identify you separately from non-personal information (e.g. your views on a specific topic). In accordance with University guidelines, I will keep the data securely for a minimum of ten years.

For further information about how Lancaster University processes personal data for research purposes and your data rights please visit our webpage: www.lancaster.ac.uk/research/data-protection

What if I have a question or concern?
If you have any queries or if you are unhappy with anything that happens concerning your participation in the study, please contact me: l.jin11@lancaster.ac.uk, Lancaster University, The LICA Building, Bailrigg, Lancaster LA1 4YW. Supervisors: Des Fagan: d.fagan@lancaster.ac.uk, Lancaster University, The LICA Building, Bailrigg, Lancaster LA1 4YW; Ruth Dalton: ruth.dalton@northumbria.ac.uk, Northumbria University. If you have any concerns or complaints that you wish to discuss with a person who is not directly involved in the research, you can also contact Alan Marsden (Head of Department): a.marsden@lancaster.ac.uk, 01524 510817, Lancaster University, Bailrigg, Lancaster LA1 4YW.

This study has been reviewed and approved by the Faculty of Arts and Social Sciences and Lancaster Management School's Research Ethics Committee.

Thank you for considering your participation in this project.

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CONSENT FORM

Lancaster University

Project Title:

Name of Researchers:
Email:

Please tick each box

1. I confirm that I have read and understand the information sheet for the above study. I have had the opportunity to consider the information, ask questions and have these answered satisfactorily.	☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time during my participation in this study and within two weeks after I took part in the study, without giving any reason. If I withdraw within two weeks of taking part in the study my data will be removed.	☐
3. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher, but my personal information will not be included, and I will not be identifiable.	☐
4. I understand that my name/my organisation's name will not appear in any reports, articles or presentations without my consent.	☐
5. I understand that any interviews/activity will be audio-recorded/video-recorded/photography and transcribed, and that data will be protected on encrypted devices and kept secure.	☐
6. I consent to use these photos in publications but these photos will not include any of my identifying features. All my identifying features will be blurred.	☐
7. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study.	☐
8. I agree to take part in the above study.	☐

Name of Participant	Date	Signature
_____	_____	_____

I confirm that the participant was given an opportunity to ask questions about the study, and all the questions asked by the participant have been answered correctly and to the best of my ability. I confirm that the individual has not been coerced into giving consent, and the consent has been given freely and voluntarily.

Signature of Researcher /person taking the consent_____ **Date**_____

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

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