MRPaperPro: Mixed Reality Interdisciplinary Design Prototyping Technique

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ABSTRACT

Mixed Reality (MR) gradually integrates into public consciousness, accelerating the need to develop commercial MR applications. However, the prohibitive cost of devices, the complexity of modelling software, the learning difficulties with programming languages, and the need for fidelity and interaction pose significant preliminary obstacles for developers and designers. Therefore, this paper intends to resolve the prototype obstacles in the early to mid stages by designing a rapid paper prototyping tool suitable for multidisciplinary designers to participate in developing mixed reality applications and environments. The MR paper prototyping (MRPaperPro) technique attempts to contribute to developing MR content that mediates between information-orientated and entertainment-orientated approaches by developing affordable, readily accessible, medium-high visual and interaction fidelity tools. It requires the construction of multilayer paper modules, repositionable model components, and spectacles that analogue the HMD's field of view to facilitate designers to interact with users directly and capture manifold responses. Finally, it elaborates on the findings of the experiments.

CCS CONCEPTS

• **Interface design prototyping**; • **Mixed / augmented reality**; • **Participatory design**; • **Online shopping**;

KEYWORDS

Rapid Paper Prototype, Mixed Reality, Participatory Design, Commercial User Interface

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1 INTRODUCTION

Mixed Reality (MR) has emerged as a prominent technological phenomenon in contemporary times. Notably, major tech conglomerates are progressing in developing more robust mixed reality devices. This trend has considerably stimulated investments across various sectors, including but not limited to retail, education, and healthcare. This technology has also entailed heightened participation from designers and developers and contributed to the proliferation of MR applications. Nonetheless, there is a necessity for collaborative deliberation among different stakeholders prior to software development to minimise the mismatch between users and the final design while bolstering the usability of the application. Prototyping serves to test ideas, and usability testing serves as the evaluative mechanism for assessing the accessibility and navigational fluidity of the user interface (UI) [1]. In the realm of two-dimensional (2D) UI and interaction design, paper prototyping has manifested as a traditional and extensively employed modality for prototype assessment [2]. It is often used in early-stage design, reducing workload and budget for team development, and is an easy, inexpensive means of user testing. Paper prototyping techniques are categorised as high fidelity and low fidelity. As the name suggests, the closer semblance to the eventual effect is known as high fidelity and, conversely, low fidelity [3].

Mixed reality based on different contexts has been generalised into six meanings [4]. This paper defines MR as a real-world with append virtual objects [5] and is an enhanced Augmented Reality (AR) effect. This interaction requires specific equipment or hardware, namely optical transmissive head-mounted displays (HMDs). In comparison, AR interaction occurs with screen displays. Existing prototyping technologies tend to be oriented towards AR and VR or AR and MR, which are compatible with the same prototyping techniques. Primary studies focused on demonstrating dynamic animations or standalone 3D objects for the development of highly entertaining applications. Considering the widespread availability of HMDs, diffusion in the retail sector has the potential to lead to faster and broader adoption among the general public. As designers and retailers turn their attention to commerce, they may need prototyping techniques that better serve retail applications, such as MR user interface prototyping for multi-layer and multi-product displays. And prototypes designed for interdisciplinary designers and retailers' collaboration and user-participatory design.

Therefore, this paper will introduce MRPaperPro as a multiparty participatory design prototyping approach to assist in early to mid-stage user studies of mixed reality systems and shop environments. The findings of pilot studies conducted with this prototype approach will be elaborated.

2 BACKGROUND

2.1 Mixed reality in commerce

This section will discuss the situating of mixed reality in commerce and its impact on multichannel retail development. As traditional brick-and-mortar stores and online retail gradually transition towards omnichannel retailing, technology emerges as a compelling

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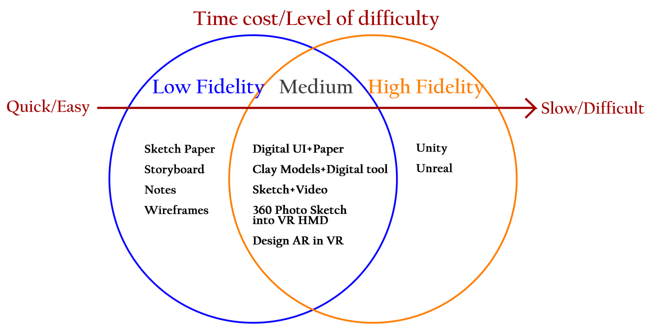

Figure 1: AR/MR Prototype techniques.

factor in retail enterprise competitiveness. Bourlakis et al. (2009) [6] have identified a shift in retail from being product-centric to consumer-experience-oriented. This transition presents both opportunities and challenges for businesses. Its strengths lay in the improved quality of consumption experience and the potential lifestyle convenience. Its challenges mainly arise from the high cost of development, substantial equipment investment, and the evolving nature of technology, which have contributed to hesitancy among businesses considering investments. Nevertheless, high-value merchandise vendors have embarked on initial forays into this realm; for instance, companies like Volvo have leveraged Microsoft HoloLens to provide customers with immersive test-driving experiences. Similarly, the real estate sector has experimented with MR-driven property viewing experiences. These instances underline the inexorable trend of the MR trajectory of omnichannel retail evolution.

2.2 Rapid prototype techniques for AR/MR

This paper classifies AR/MR prototyping technologies integrating four dimensions: physical and digital modalities, time cost, ease of production, and fidelity (Figure 1). The prototype testing techniques encompass physical, digital and hybrid approaches. Physical techniques, such as sketching, paper, and sticky notes, due to the low-visual precision, the discrepancy with the ultimate effect is high fall under the category of low-fidelity prototypes. High-fidelity models with high visual precision closely resemble the final effect, and digital techniques, exemplified by sophisticated software like Unity, enable the creation. Hybrid techniques blend physical and digital components using digital equipment to three-dimensionalise 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 prototyping involves simultaneous consideration of visual and interactive fidelity as it requires substantial interaction. Accordingly, in Figure 2, some cases of prototypes are analysed with interaction fidelity.

Figure 2 presents a comparative analysis encompassing several representative rapid prototype testing methods within AR and MR. Categorise into six tool types: sticky notes, paper, digital sketches, UI design software, clay models, and AR prototyping software. AR Paper Prototype (2020) [7] employs sticky notes to swiftly display product information, while PapAR (2014) [8] utilises an overlay of translucent paper-on-scene imagery to convey interface details. This type of approach makes it more suitable for use as information displays and less robust for hedonic experience displays. Pronto (2020) [9] employs sketches and video recordings to facilitate user interaction. Analogous to this display effect is Augmented Sketch (2019) [10], which entails photographing the physical world and superimposing sketch representations to elicit mixed reality effects. Also, its usage necessitates the prompt retrieval of pertinent photographs to participants from an album by the host, similar to WoZ. Another type is ProtoAR (2018) [11], which adopts clay to sculpt 3D models in conjunction with sketches UI, capturing and inputting them into the ProtoAR application to view 360°. Pencils Before Pixels (2008) [12] used similar materials such as clay, bricks and paper to create spatial experiences.

The benefits of these methods are that users can view 360° panoramic objects or panoramic environments. 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 the product outcome 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 performs AR effects that require the use of controllers. It is difficult for designers to observe the body performance of users directly under the MR context from their contact behaviours with these tools. Also, users with VR vertigo conditions may be limited in the prototyping stage.

MRPaperPro attempts to contribute 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. 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 information input for consumers to evaluate purchases and make decisions. Also, the interaction experience of users employing MR technology is one of the influences on user technology acceptance. As a result, MRPaperPro is a prototype technique for moderate-high precision visualisation of displays and high-fidelity MR interaction patterns.

3 METHODOLOGY: MRPAPERPRO AS A PROTOTYPING TOOL IN MR RETAIL DESIGN

3.1 MR paper prototype

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. This research endeavour 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

MR/AR prototype tools	Fidelity	Production time	Visual effects	Interaction	Tool types
AR Paper Prototype [7]	Low	Quick	Sketchy	Low	notes
PapAR [8]	Low	Quick	Sketchy	Low	paper sketches
Augmented Sketch [10]	Low	Quick	Sketchy	Low	digital sketches, photos
MRPaperPro	Mid-high	Medium	Vivid	High	paper-printed, digital UI
Pronto [9]	Medium	Medium/High	Vivid/Sketchy	High	digital sketch, animation
ProtoAR [11]	Low	Medium	Sketchy	Mid-high	clay, digital tools, app

Figure 2: Comparison of AR/MR rapid prototype techniques.

Figure 3: MRPaperPro hierarchical display and simulation field of view.

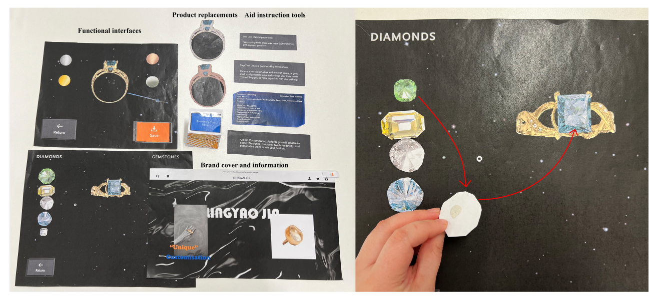

Figure 4: MRPaperPro subset of design aid tools (left). Parametric portable components (right).

Figure 5: Experiment environment preparation.

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 3).

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 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 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 4). This heightened flexibility enables real-time communication between designers and users, facilitating swift collaboration on shifting or modifying UI layouts.

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° [13]. For participant experiences, we have prepared experimental spectacles designed to simulate the HoloLens 2, maintaining a 4:3 viewing area while obscuring the surplus portions.

Furthermore, we elected to conduct the testing on a vertical whiteboard instead of a horizontal tabletop, owing to the inherent orientation of HMDs (Figure 5). Because under the HMDs, users' heads and eyes are generally aligned straight ahead. In contrast, traditional smart devices like smartphones or PCs prompt users to tilt their heads downward during 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 the user-headset and user-retail worker interaction modes.

3.2 Design goals

Testing MR shop environment perspectives. MRPaperPro prototyping provides the user with contexts in a real-world environment. Interior designers could accomplish the A/B test of the consumer's interior design demands in this session and collect the consumer's preference for the physical space and spatial interaction behaviours.

User interface usability and design. Based on the flow design and aesthetics of the interface, evaluate and identify the logistic fluency, navigation, and task usability of the system through the user's flow of operations. UI designers obtain UI feedback and aesthetic comments through live communication.

Provision of participatory design and innovation. The product and UX designers capture the expectations of consumers for mass-scale customised product design under participatory design. Designers discover the generation of repetitive user behaviours and innovative interaction behaviours from observation.

3.3 User demographics

The pilot studies were conducted from July to December 2023 at Lancaster University, UK. A total of three rounds of testing were conducted (n=15). In each cycle of user testing, five participants were recruited, which is a reasonable number of participants to identify problematic issues in user testing [14]. The experiment recruited participants in the UK using posters and snowball sampling. Participants were targeted to the age range of 18 to 54, demonstrating a high interest in MR [15]. Diverse ethnicities attempted to be recruited in each cycle by considering the cultural context of user perspectives. Gender included nine males and six females. It was ensured that each age group included at least one participant. The ages 18-25 consisted of six participants, 26-34 had five participants, 35-49 had one participant, and 50-64 had three participants. There are three participants with design-related works, namely A3, C11 and C12. Participant A5(C13) with a computer science background (Figure 6). None of the participants had previously used or had background knowledge of mixed reality, and two participants had previous VR experience. The study was conducted under ethics approval from the Lancaster University Ethics Committee. Participants reviewed the participant information sheet before the start of the experiment, and consent was obtained for audio and video recording. Recruitment was voluntary, and refreshments were provided to participants during the one hour of activity.

3.4 Experiment design

MRPaperPro used the mixed method to construct the experiment, including a storyboard, paper prototyping, a semi-structured interview 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. To achieve this, the experiment provided participants with explanation storyboards. Participants were allocated time to peruse the storyboards, ensuring their grasp of the operational procedures and the shopping process they might encounter in practical scenarios. Following this, participants were guided through the utilisation of the UI to complete assigned tasks and verbally speak their actions aloud. The finalised MRPaperPro workflow was established (Figure 7) after three iterations (Figure 8).

Experiment 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

Figure 6: User demographics.

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. Before the 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 a need to hypothetically enter a brick-and-mortar shop to use this HMD and select a preferred scenario from amongst them. The researcher raised questions about research aims using prepared interview questions during the prototyping stage.

3.5 Data processing

Video and transcription datasets were imported into NVivo 12 for qualitative analysis. The analysis themes were categorised into three goals and one technique feedback based on the research objectives. The questions for the technique feedback are listed.

• Please describe three advantages and disadvantages of using this paper test.

The study results were analysed at the end of each cycle, and the method was optimised. At cycle C, it was found that participant responses no longer generated further new codes, resulting in a determination of theoretical saturation. The following will elaborate on the progression and insights of three cycles of experiments. In Chapter 4, the results of user feedback with this approach will be analysed.

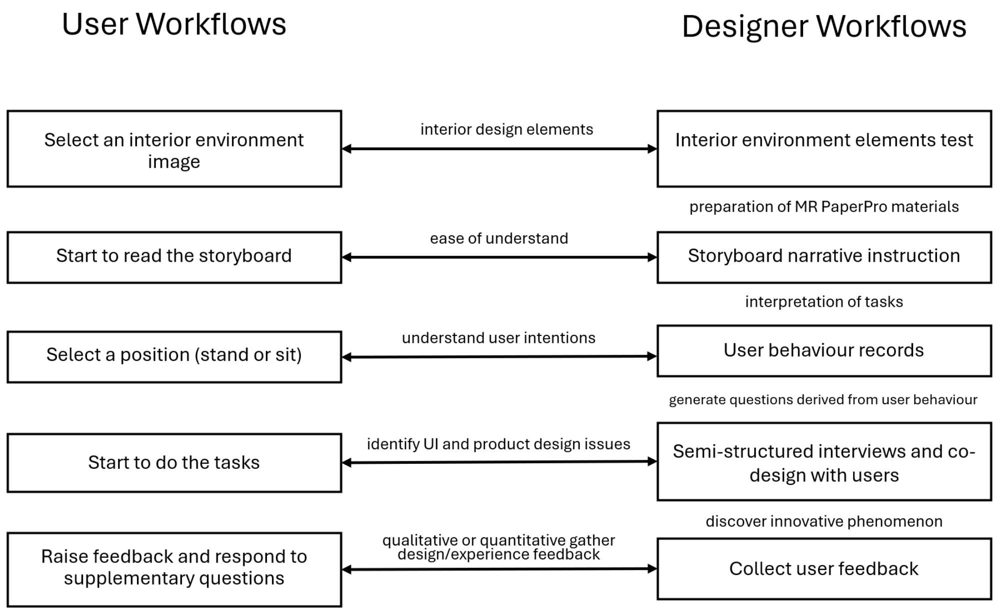

Figure 7: Workflows of MRPaperPro experiment.

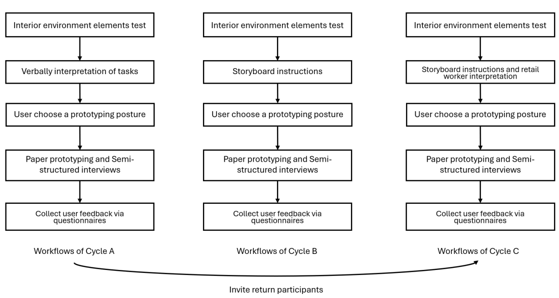

Figure 8: Three cycles of pilot workflow iterations.

3.6 MRPaperPro to test MR commercial customisation system

Figure 8 interprets the experimental workflow of the three cycles of the MRPaperPro tool, which was optimised by participants' feedback. Furthermore, the MR interface design was modified by leveraging the tool to test the system's usability.

Cycle A prototyping

In the first cycle of the experiment, the experimenter explained the concept of mixed reality and its operation to the participants using a verbal narrative. Subsequently, after the participants indicated they understood, they were asked to choose a standing or sitting position for the test. This allowed designers and retailers to understand the user's behavioural demands. In this round of the experiment, participants were given a straightforward design task and a design effect image of the product. Users were expected to achieve the effect shown in the image without time restriction. The researcher aptly formulated the prepared semi-structured questions based on the participants' performance. These included the rationale behind the choice of in-store ambience, UI design, and experience perception.

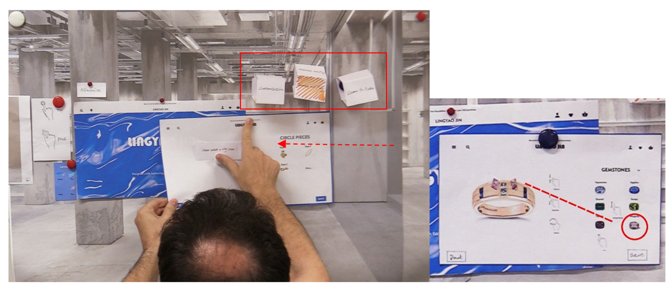

Figure 9: Paper UI movement and alternate product components.

The MR UI functional concept incorporates semi-customised products and product assembly. The experiment was designed with two tasks. Task A was to customise a ring, and Task B was to assemble a new ring. Participants were not restricted to the time frame of the task. Most participants completed it in less than 30 minutes, and only one took 36 minutes to complete the tasks. Figure 9 captures the perceived mobility of multitasking interfaces that participants envisaged when engaging with the tool and preferences for gemstone mounting placements for the product design.

Cycle B prototyping

After the first round of pilot results, we progressed the interface design and created new interface widgets. The participants consisted entirely of novices. In cycle B, the oral explanation was replaced by a storyboard. This was because participants in the first cycle emerged from the prototyping with confusion about mixed

Figure 10: Demonstrate MR gesture practices to a user (left). Mimics the hand movement (right).

Figure 11: Sketches on the product (left). Replaced components (right).

reality and its manipulation (A1, A3). Hence, a visualisation illustration was provided in this cycle to help improve narrative cognition. This open-ended cycle with no explicit design effects was required, and users were encouraged to utilise the system as they intended in the reality scenarios.

Cycle C prototyping

After the former cycle iterations, the UI design was determined in Cycle C, with additional components and modifications. We recruited one participant from the first round who was available to return for this experiment, and the others were new participants. After previous modifications, there were noticeable improvements to the design, and it was beneficial for this design strategy and design outcome to engage the participants from the first cycle to re-evaluate and compare the design results. Cycle C focused more on in-depth user behavioural analysis than the former tests, with more qualitative interview content invested in the participant co-design process. Additionally, it is worth noting that the development guidelines for the Microsoft HoloLens 2 indicate that pure white can be excessively bright and discomforting for users, while black will appear transparent [16]. Participants were informed that the black background presents a semi-transparent texture in the real system. This emphasises partial visual effects that can not be rendered compared to an actual MR HMD, such as semi-transparent texture and laser beam. Hence, designers should reckon with the fact that when working with paper prototypes.

Figure 10 shows the experimenter explicating the HoloLens 2 interaction to the participant and mimicking the hand behaviour intervention in the participant's cognition. Figure 11 shows users' perspectives on the product design, including advice on the engraving function's auto-generated typographic positions and capture of the user's decision-making process as a co-designer when replacing widgets.

4 FINDINGS

4.1 Testing MR shop environment perspectives

This rapid prototyping method proved to be able to gather user preferences concerning the retail environment. The influential factors in the shop environment include colour tone, layout, furniture, atmosphere, lighting, user posture, retail worker position, and service. In total, six participants opted for the seated position, while nine chose to stand during their experiences. Different postures exerted certain constraints on users. In the standing position, users exhibited greater flexibility in adjusting their orientation to accommodate the interface's position, naturally seeking the most suitable alignment. Conversely, participants who chose the seated posture spontaneously adjusted the interface to align with their line of sight rather than relocating their seating position. Consequently, individuals with limited mobility or those who prefer a seated approach need to consider more profound UI mobility. For the majority of users who tend to stand, designers ought to rationalise the spatial boundaries for users to ensure that the regular consumer and the consumer utilising the device avoid interference with each other. By comparing the position of the retail worker on the user's left and right, it was found that, as the interface is designed to unfold to the right gradually, the retail worker's position on the user's left side would serve the right-handed user more efficiently. However, for left-handed users, the position of the retail worker had no significant impact.

Referring to the shop layout and atmosphere, one participant discussed that:

> "(the monochrome tone minimalist 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 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)

The results demonstrate the ability of MRPaperPro to generate valuable insights for interior and shop designers, assisting designers in exploring the physical environment of mixed reality use in the early to moderate stages through in-depth studies with small sample sizes.

4.2 User interface usability and design

Accessibility, interactivity, novelty, efficiency, and cultural attributes of the product were the key factors influencing the decision-making process for consumer adoption. Mixed reality technology is incorporated as a means to facilitate consumers in situations where they remain undecided or unprepared to interact with an agent by affording the consumer more space and time to prepare. So that one can decide whether to engage in a social connection with a people to commence with. Participants articulated a view of the transition between virtual and real space. A1 and A3 both state they mostly shop online because in-store try-ons pressure them. A1 believes web page layout can influence an individual's usage frequency. Added engagement and ease of shopping enables her to turn her attention from online to offline.

Accessibility, novelty, efficiency.

> "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)

UI designers can examine the priorities of consumer attention in mixed reality retail from rapid paper prototypes and refine the system flow by iteration.

4.3 Provision of participatory design and innovation

Users involved in the design developed innovative interaction behaviours or expanded their creativity. The paper prototypes encouraged the participants to imagine new interactions without having experienced equipment. Apart from the designed gestures, the participants developed new interaction gestures, such as swiping the palm to unfold and collapse the interface (C14). There were other extensions, such as virtual game animations for image symbolism and interaction means. Furthermore, participants elaborated ideas for other future retail purposes of the application. For example, the baking sector for customised memorial cakes (B6) and the toy manufacturing sector for customised toys (A2).

This highlights that designers engaging with users in MR prototyping provides designers with multi-dimensional creativity before users have experienced the equipment. Designers gauge user needs from the ground during participatory observation practices.

4.4 Area of improvement

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.

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

Handy and fast.

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

Less space constraints.

> "You don't have to get any specific space to make this research done, you don't need to make a room differently, very separate to have this even you can make it in public space. You need as not much isolation, just need your participant to get engaged with those things and to get engagement, and that's all. Through here, I didn't find that I can't do it on the outside. " (C11, designer)

Imagination.

> "The participant needs to be imaginative to think why communicating with this paper website in reality. . . The participant himself or herself should imagine that I am pressing this, and there is a screen then coming down, 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)

Virtual satisfaction.

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

In summary, this prototyping technique is applicable as a participatory design for developing mixed reality for interdisciplinary design. It brings facilities for designers to exploit their work. Still, it also requires designers to have certain auxiliary abilities to aid users in understanding and conceptualising the role of paper prototypes. It also requires designers to be familiar with the procedures to minimise discontinuity when replacing parts.

5 DISCUSSION AND FUTURE WORKS

The limitation of this study is that the MR system has the potential to be embedded into the wall during user experience due to the physical environment or manipulation, which cannot be monitored within prototype testing. Therefore, accurate system tests in a brick-and-mortar shop are necessary to conduct and make corrections before launching into mass markets. Second, HoloLens 2's interactions include remote ray-targeting and proximity direct taps. In this method, the study simulated a direct trigger interaction, but the current technique's inability to perform manipulations using remote ray gestures is a weakness. The lack of a tilt angle for expanding the interface is also a section that could be improved. Where circumstances are affordable, designers can multiply the number and angle of whiteboards to mimic interface angle variations in space, albeit not as a necessary option. We will continue using this approach to complete more tests and invite designers and developers researching MR participatory design to use it.

MRPaperPro works well for commercial applications and environments but can also be used for prototyping in other contexts with similar MR functionality and scenarios. Although we conducted multidisciplinary data collection through MRPaperPro for shop interior design, UI design, and UX design, standalone disciplines are feasible to complete more targeted MR prototyping with this technique. For example, interior designers could collect insight into the impact of interior design factors on MR apps by iterating through more interior environment layers. UI designers could produce sophisticated user interfaces and conduct flow tests, and UX designers could prioritise evaluating the user experience of collaborative multi-players.

This work presents several intriguing directions for future research. We intend to explore more adaptive spatial layouts and ergonomics of the MR UI to accommodate a broader range of diverse types of merchandising and encourage mass retailers to invest in this mode of purchase.

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