Developing IoT-Based Rehabilitation Frameworks: A Mixed-Methods Study with Healthcare Professionals, Stroke Survivors, and Design Experts

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Declaration and Statement of Originality

I, Fayez Namnaqani, declare that this thesis, titled [Developing IoT-Based Rehabilitation Frameworks: A Mixed-Methods Study with Healthcare Professionals, Stroke Survivors, and Design Experts], and the work presented in it are my own and have been generated by me as the result of my own original research.

I confirm that:

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- All sources used or referred to have been fully acknowledged.
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Abstract

This thesis investigates the potential role of Internet of Things (IoT) technologies in post-stroke rehabilitation through a design research lens, focusing on perceived benefits, challenges, and resulting design implications. Stroke rehabilitation requires continuous, personalised care, which traditional models often struggle to deliver due to limited accessibility, reliance on in-person sessions, and the absence of real-time feedback. Reflecting my dual positionality as a design researcher with a clinical background in physiotherapy, the study adopts a human-centred approach to bridging the gap between clinical needs and design implementation. A mixed-methods design was employed, structured around five sequential phases: (1) an international online survey with healthcare professionals (n=67); (2) a primary participatory workshop with stroke survivors exploring foundational usability (n=18); (3) a secondary participatory workshop in the same location investigating advanced personalisation (n=18); (4) a validation study with healthcare practitioners (n=18); and (5) expert interviews with design researchers (n=4) to critique and refine the findings from a disciplinary perspective. The qualitative data were analysed using Reflexive Thematic Analysis to ensure a rigorous, iterative interpretation of stakeholder and expert discourses. Findings indicate that IoT is perceived as offering considerable potential to support rehabilitation by enabling remote monitoring, personalised treatment, and improved access for underserved populations. The primary contribution of this work to the field of Design is the articulation of a Four-Principle Framework: Adaptive Simplicity, the Human-in-the-Loop Service Model, Configurable Data Transparency, and Contextual Motivation. These principles informed the development of 11 design-informed recommendations—translated from stakeholder insights into actionable design guidance. While the study does not provide empirical evidence of clinical effectiveness, it makes a novel contribution by synthesising the lived experiences of stakeholders with the disciplinary insights of design experts. This integration is employed specifically to generate a robust set of design-informed recommendations and a structured framework. By combining these diverse perspectives, the research bridges the gap between the theoretical potential of IoT and the practical requirements for its implementation in stroke rehabilitation. This research addresses a critical gap in design and digital health literature and provides actionable guidance for developing inclusive, scalable, and clinically relevant IoT solutions.

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List of Abbreviations

Abbreviation	Meaning
ADLs	Activities of Daily Living
AI	Artificial Intelligence
BCI	Brain-Computer Interface
CIMT	Constraint-Induced Movement Therapy
DALYs	Disability-Adjusted Life Years
EHRs	Electronic Health Records
FES	Functional Electrical Stimulation
GDPR	General Data Protection Regulation
IoT	Internet of Things
OT	Occupational Therapy
PT	Physical Therapy
RPM	Remote patient monitoring
SLT	Speech and Language Therapy
VR	Virtual Reality
WHO	World Health Organization

Chapter 1: Introduction

1.1 Introduction

The Internet of Things (IoT) is a transformative force in healthcare, offering opportunities to enhance patient care through real-time data collection, remote monitoring, and personalised interventions. In areas such as chronic disease management and elder care, IoT technologies like wearable devices and home-based sensors have demonstrated significant benefits, for example by tracking health metrics such as heart rate, blood pressure, and physical activity to optimise treatment plans (Jones et al., 2020). Despite these successes, the integration of IoT in stroke rehabilitation remains underexplored, particularly from a design perspective. Stroke rehabilitation presents complex challenges, including the need for continuous, personalised care and remote monitoring to support recovery. Current rehabilitation methods often fall short, particularly for stroke survivors requiring frequent adjustments to therapy plans or for those living in areas with limited access to healthcare services. This research therefore focuses not on testing specific IoT devices, but on exploring how different stakeholders perceive their potential role in rehabilitation.

There is a substantial body of design literature exploring the role of technology in healthcare, including studies on user-centred design in elderly care (Clarkson et al., 2013), co-design methodologies for health services (Bødker, Grønbek and Kyng, 2020), and the application of inclusive design principles to digital health tools (Mountain, Hawley and Stott, 2020). Within the specific domain of the Internet of Things (IoT), research has highlighted several theoretical advantages, including the potential for continuous remote monitoring to support home-based care (Chen et al., 2020), the capacity for real-time data collection to enable personalised and adaptive interventions (Patel et al., 2022), and the promise of connected devices to enhance patient engagement and self-management (Taylor et al., 2022). However, within the specific context of stroke rehabilitation, and especially from a user-centred and participatory design perspective, the practical implementation of these theoretical advantages remains underexplored. This creates a clear research gap that my study aims to address. Furthermore, many participants involved in this research—especially stroke survivors—may not have prior experience with IoT technologies. The study therefore focuses on capturing their perspectives on potential benefits, barriers, and design considerations rather than evaluating existing IoT use.

This thesis presents a comprehensive investigation into how IoT can be conceptualised and designed for stroke rehabilitation settings to benefit both patients and healthcare providers. Rather than evaluating clinical effectiveness, the study explores the feasibility, usability, and acceptability of IoT technologies from the viewpoints of stroke survivors, healthcare professionals, and design experts. It takes into account both restorative strategies (aimed at functional recovery) and compensatory strategies (focused on helping patients adapt to ongoing limitations), ensuring a holistic understanding of rehabilitation goals. Additionally, this research examines how IoT could improve access to rehabilitation services in underserved populations, such as those in rural or remote areas where specialised care is often inaccessible.

The study is structured around five distinct phases of data collection: (1) an international online survey with healthcare professionals, focusing on the UK and Saudi Arabia; (2) a primary participatory workshop with stroke survivors in Saudi Arabia exploring foundational usability and initial reactions to IoT devices; (3) a secondary participatory workshop in the same location, building on previous insights to investigate advanced personalisation—such as adaptive feedback, system-driven tailoring to recovery progress, and user-configurable interface options; (4) a validation study with healthcare practitioners to assess the clarity and feasibility of the emerging recommendations; and (5) expert interviews with design researchers in the UK to evaluate the recommendations from a disciplinary design perspective. This sequencing ensured that insights were gathered iteratively—from professional perceptions, to survivor experiences, to validation, and finally to design critique—so that recommendations were refined at each stage. Each phase contributed a distinct perspective on the utility and design considerations of IoT-based stroke rehabilitation solutions. At its core, this thesis provides design-informed recommendations grounded in stakeholder perspectives, directly addressing the gaps identified in Chapter 2 regarding user needs, healthcare professional insights, and the integration of design expertise. In doing so, it contributes not only to healthcare innovation but also to strengthening the role of design research in rehabilitation technologies.

1.2 Overview of Stroke and Rehabilitation Challenges

Stroke remains a significant global health concern, contributing to long-term disability and loss of independence for millions worldwide (WSO, 2023). Survivors often face challenges with mobility, communication, cognition, and emotional regulation, which can severely affect their ability to perform daily tasks (Garcia and Lee, 2022). Rehabilitation therefore plays a critical role in helping patients regain function and improve quality of life. Typically delivered by multidisciplinary teams, rehabilitation is highly individualised but often extends over months or years, requiring sustained engagement and resources (Smith and Johnson, 2022). Despite its importance, traditional rehabilitation methods face persistent limitations (Langhorne et al., 2011; Winstein et al., 2016) . Many stroke survivors lack continuous feedback and support once discharged from clinical settings (Chen et al., 2020) , leading to slower progress and reduced adherence to therapy (Miller et al., 2019; Johnson & Smith, 2020). Access to regular therapy is particularly difficult for those in rural or underserved areas, where the shortage of specialists and the burden of travel present major barriers (Krishnamurthi, Ikeda and Feigin, 2018; WHO, 2023). These challenges highlight the need for new approaches that extend care beyond clinical environments and provide more adaptive, user-centred support.

The Internet of Things (IoT) has been widely applied in areas such as chronic disease management and elder care, where it enables real-time monitoring, personalised feedback, and adaptive interventions (Taylor et al., 2022). In stroke rehabilitation, however, IoT's role remains underexplored, especially in terms of design and user experience (Patel et al., 2022; Chen et al., 2020) . While wearable sensors and home-based systems could theoretically support continuous engagement (Cramer et al., 2019; Laver et al., 2020) , their usability, accessibility, and integration into daily life are not well understood (Liu et al., 2021; Johnson et al., 2020). This study therefore investigates stroke rehabilitation challenges not only as medical or logistical issues, but as design challenges. It focuses on exploring how survivors, healthcare professionals, and designers perceive IoT's potential, and what features or barriers they identify as critical for meaningful adoption.

1.3 The Role of Technology in Healthcare

The integration of technology into healthcare has accelerated significantly in recent years, with digital health, telemedicine, wearable devices, and data analytics expanding the reach of care beyond traditional clinical settings (Smith et al., 2020). Remote monitoring and virtual consultations are now common tools, particularly valuable for patients in remote or underserved areas (Garcia and Lee, 2021). While these innovations extend access, they often provide only intermittent support and lack the capacity to deliver continuous, adaptive, and personalised rehabilitation. The Internet of Things (IoT), defined as a network of interconnected devices capable of collecting and exchanging data in real time (Jones et al., 2021), offers a distinct opportunity to address these gaps. In healthcare, IoT has already shown value in chronic disease management and elder care, where continuous monitoring and feedback are essential (Taylor et al., 2022). In stroke rehabilitation, however, IoT remains largely experimental, with most studies focusing on technical performance rather than user experience or design integration (Dicianno et al., 2015; Liu et al., 2021). This technological emphasis has meant that questions of usability, accessibility, and integration into daily life remain underexplored (Johnson et al., 2020).

Wearable sensors and smart home devices could, in theory, track recovery progress, support home-based exercises, and provide feedback to both survivors and clinicians. Yet, the challenge lies not only in technical feasibility but in designing systems that are acceptable, usable, and adaptable to the diverse needs of stroke survivors. Data privacy, cost, and integration with existing healthcare workflows remain significant barriers (Brown et al., 2020). Moreover, while consumer devices like fitness trackers have gained popularity, their translation into clinical rehabilitation contexts is limited by the lack of user-centred design and integration with professional practice (Lewis, 2020). This thesis therefore does not attempt to test IoT's medical effectiveness but instead examines its role through the perspectives of stroke survivors, healthcare professionals, and design experts. By foregrounding issues of usability, acceptability, and design, the study contributes to understanding how IoT technologies can move from experimental prototypes toward meaningful, real-world rehabilitation tools.

1.4 Introduction to IoT in Rehabilitation

Stroke rehabilitation requires a highly personalised approach that adapts to the evolving needs of each individual (Veerbeek et al., 2014; Teasell et al., 2020) , reflecting the heterogeneous nature of stroke impairments and recovery trajectories (Winstein et al., 2016). Unlike chronic disease management, which often focuses on maintaining stability, stroke rehabilitation prioritises continuous progress to help survivors regain functional independence (Jones et al., 2021). The primary goals of rehabilitation encompass two complementary strategies: restorative strategies, which aim to recover physical and cognitive abilities, and compensatory strategies, which support survivors in adapting to long-term impairments (Smith, 2020). IoT technologies could support both approaches by providing continuous monitoring, adaptive feedback, and home-based assistance (Cramer et al., 2019; Chen et al., 2020; Patel et al., 2022) . However, their use in stroke rehabilitation remains at an early, exploratory stage and has not yet been translated into routine practice (Johnson et al., 2020; Liu et al., 2021; Dicianno et al., 2015). Existing research highlights technical possibilities—such as wearable sensors tracking gait and balance, or smart home systems supporting independence— but there is limited evidence of how such tools can be designed to meet the real needs of users, with studies often neglecting the experiential, usability, and accessibility factors that determine real-world adoption and sustained use (Liu et al., 2021; Johnson et al., 2020).

The central gap lies in the limited attention to user-centred design and participatory approaches. Most studies emphasise what IoT devices can measure, but not how survivors and professionals envision using them, what barriers they anticipate, or what design features would make them acceptable and meaningful. Issues such as cost, technological literacy, and data privacy further constrain adoption (Garcia and Lee, 2019). This study therefore shifts the focus from testing specific products to understanding perspectives. By engaging stroke survivors, healthcare professionals, and design experts, it seeks to identify design considerations that can inform the development of practical, user-driven IoT solutions. The emphasis is on generating design recommendations that reflect lived experience and clinical realities, ensuring that IoT integration in rehabilitation is both feasible and meaningful.

1.5 Motivation for the Research

My motivation for this research is rooted in the significant unmet needs of stroke survivors and is informed by my specific positionality as a design researcher with a clinical background in physiotherapy. This dual perspective—merging a professional understanding of rehabilitation challenges with design research methodologies—has fundamentally shaped the trajectory of this study, from the initial framing of research questions to the thematic interpretation of stakeholder insights. By adopting this stance, the study moves beyond evaluating the clinical efficacy of individual devices. Instead, it explores how key stakeholders—including stroke survivors, healthcare professionals, and design experts—envisage the role of the Internet of Things (IoT), the barriers they anticipate, and the design features they value. My clinical experience provides the context for framing meaningful, real-world questions, while design research principles provide the framework for interpreting findings into actionable insights. This approach aims to generate design-led recommendations that can guide the development of more inclusive, adaptive, and human-centred rehabilitation technologies.

While IoT technologies have shown promise in broader healthcare contexts, such as chronic disease management and elderly care, their application within stroke rehabilitation remains significantly underexplored from a design perspective. Much of the existing literature prioritises technical performance and data accuracy, often overlooking usability, accessibility, and the lived experience of the end-user. This creates a critical gap within design scholarship, where the primary objective is to translate complex user needs into practical, empathetic solutions. The comparative focus on Saudi Arabia and the United Kingdom provides further motivation. These two healthcare systems differ significantly in terms of infrastructure, policy, and rehabilitation access, offering a unique opportunity to examine how diverse cultural and systemic contexts shape stakeholder perspectives. Insights from these contrasting settings ensure that the resulting recommendations are not only theoretically robust but also sensitive to the realities of different healthcare environments. Ultimately, this study is driven by the conviction that design is a critical mediator in shaping digital health technologies that are usable, acceptable, and equitable.

1.6 Barriers to the Implementation of IoT in Stroke Rehabilitation

Drawing on both the existing literature and my professional experience in rehabilitation, this section outlines key barriers to IoT implementation that warrant investigation. The integration of IoT technologies into stroke rehabilitation faces several systemic and user-centric challenges; understanding these is essential if IoT is to be usable and acceptable in real-world settings. The following discussion identifies these barriers as they are currently documented in digital health research and clinical practice.

One of the most significant barriers is technological literacy. Many stroke survivors—particularly older adults or those with cognitive impairments—have been found to experience uncertainty when using digital devices without continuous support (Mountain et al., 2020). While literature highlights the potential benefits of connected health, there are persistent concerns regarding system complexity. From my professional experience as a physiotherapist, this underscores the necessity for simplified interfaces, clear visual cues, and inclusive design features, such as voice commands or caregiver-assisted options, to prevent technology abandonment (Clarkson et al., 2013). Healthcare professionals also require adequate training and resources to integrate IoT into clinical workflows, which necessitates institutional commitment alongside individual adaptation.

Cost and access present further obstacles. Research indicates that budgetary constraints within national health systems act as a significant limitation, while those in rural or underserved areas often face barriers linked to unreliable internet infrastructure or the high cost of specialised hardware (Krishnamurthi et al., 2018; WHO, 2023). These issues reinforce the need for IoT solutions that are both cost-effective and adaptable to low-resource settings. Data privacy and trust are also recurring themes in the literature. Both survivors and clinicians prioritise secure data handling, as concerns regarding data breaches can significantly diminish user confidence (Alwashmi et al., 2021). Furthermore, the absence of clear, localised IoT-specific regulations in certain regions may hinder the adoption of these technologies, pointing to the importance of establishing robust ethical and legal frameworks.

Finally, clinical literature emphasises significant interoperability challenges (Chen et al., 2020). Without standardised protocols, IoT devices remain difficult to integrate into existing electronic health records and clinical decision-making systems. While these are not technical issues this study can resolve, their identification in the literature highlights where design and policy must focus. This research does not attempt to solve integration or regulatory challenges at a technical level; rather, it seeks to investigate how these known barriers are perceived by stakeholders and what design considerations are necessary to make IoT meaningful in a rehabilitation context. By grounding this investigation in both professional clinical insight and established research, this study aims to contribute design-informed insights that bridge the gap between IoT's theoretical promise and its practical application.

1.7 Research Objectives

The primary objective of this research is to investigate the potential for the integration of IoT technologies in post-stroke rehabilitation, focusing on the possibilities to enhance daily living activities and improve recovery outcomes for stroke survivors.

Rather than conducting clinical trials or evaluating device efficacy in controlled environments, this study adopts an exploratory and user-centred approach to understand the perceived value, challenges, and requirements for IoT adoption from the perspectives of stroke survivors, healthcare professionals and design experts. To achieve this goal, the study is guided by the following specific objectives:

- Evaluate the Feasibility of IoT in Stroke Rehabilitation: This research assesses the practicality of using IoT technologies in real-world rehabilitation settings. By exploring the usability and accessibility of IoT devices from the perspectives of stroke survivors and healthcare professionals, the study identifies factors that facilitate or hinder successful implementation. It also considers contextual differences across healthcare environments, particularly between the United Kingdom and Saudi Arabia, to understand how infrastructure, digital health maturity, and policy frameworks influence IoT feasibility. This objective provides a foundation for understanding how IoT can be effectively integrated into rehabilitation programs.
- Understand User Perceptions of IoT Technologies: Surveys and workshops will gather insights from healthcare professionals and stroke survivors to explore their experiences with and attitudes toward IoT in rehabilitation. This objective highlights how IoT can address clinical goals while aligning with user preferences, ensuring solutions are both effective and user-centred. Special attention is given to the socio-cultural context of users, recognizing that beliefs about technology, caregiver support, and healthcare accessibility may influence perceptions and expectations.
- Explore the Potential for Personalization in IoT Solutions: Personalization is a key advantage of IoT technologies, enabling rehabilitation plans to adapt to individual progress, abilities, and needs. This research examines how IoT devices can support tailored rehabilitation, with a focus on enhancing relevance and effectiveness for diverse stroke survivor populations. This includes evaluating whether personalization features are clearly understood and welcomed by users with varying levels of technological literacy.
- Identify Key Barriers to IoT Adoption: Building on findings from workshops and surveys, this objective explores critical barriers to IoT adoption, such as technological literacy, cost, data privacy, and the integration of devices with

existing healthcare systems. Understanding these challenges is essential for developing strategies that promote widespread adoption in rehabilitation settings. These barriers will be interpreted through a pragmatist lens, emphasizing real-world usability and contextual adaptability over ideal or universal solutions.

- Develop Actionable Recommendations: Based on research findings, the study will propose practical recommendations for integrating IoT technologies into stroke rehabilitation. These recommendations will prioritize accessibility, usability, and personalization to address user needs effectively. They will also reflect variations in healthcare delivery models and digital maturity between the UK and Saudi Arabia, offering flexible guidance suitable for both resource-rich and resource-constrained environments. Additionally, this objective will identify areas for future research, emphasizing the need for continuous innovation in IoT-based rehabilitation solutions. In line with the participatory design approach, recommendations will be grounded in the lived experiences of stroke survivors and the practical constraints faced by healthcare professionals as well as the feedback from designers.

1.8 Research Approach

This research adopts a mixed-methods approach to explore the potential role of IoT technologies in stroke rehabilitation, combining quantitative and qualitative methods. The study was structured into four main phases:

- An international online survey with healthcare professionals – to capture familiarity with IoT, perceptions of benefits and barriers, and potential willingness to adopt IoT in rehabilitation practice.
- Two participatory workshops with stroke survivors in Saudi Arabia – to explore lived experiences, rehabilitation challenges, and responses to IoT demonstrations, focusing on usability and accessibility.
- A validation survey with healthcare professionals – to assess the feasibility, clarity, and relevance of the IoT-based recommendations developed from the earlier phases.
- In-depth interviews with design experts based at a UK institution – to examine how the recommendations could be interpreted, critiqued, and extended within design research, adding originality and disciplinary contribution.

Rather than evaluating the clinical effectiveness of IoT devices or conducting formal trials, the study focuses on understanding the perceived utility, usability, and acceptability of IoT technologies. Guided by a pragmatist paradigm, the research uses the most suitable methods to address real-world questions, ensuring that findings reflect the experiences of different stakeholders.

The online survey gathered perspectives from healthcare professionals internationally, with a particular focus on the UK and Saudi Arabia. These contexts were chosen to reflect different stages of digital health maturity and to compare how infrastructure, resources, and policies shape readiness for IoT adoption. The workshops provided an immersive opportunity for stroke survivors to engage with IoT technologies through guided demonstrations. As most participants had little or no prior experience of IoT, the workshops were designed to elicit informed feedback rather than test prior usage. Conducted in Saudi Arabia (in line with ethical approval), these sessions highlighted the importance of accessibility, personalisation, and user-centred design. The validation survey allowed healthcare professionals to review and comment on the proposed recommendations. Rather than testing the devices themselves, this phase examined the clarity, feasibility, and practical value of the recommendations for clinical application. Finally, the design expert interviews contributed a disciplinary lens, situating the research more firmly within design by exploring speculative and critical perspectives on the role of IoT in rehabilitation. This ensured that the findings extend beyond clinical practice to contribute to broader debates in design research.

Overall, this multi-phase, mixed-methods approach bridges the gap between IoT’s theoretical potential and its user-informed application in stroke rehabilitation. By integrating perspectives from stroke survivors, healthcare professionals, and design experts, the study contributes actionable and design-informed insights that can inform future development and integration of IoT in rehabilitation contexts.

1.9 Significance of the Study

This research is significant because it places the perspectives of stroke survivors, healthcare professionals, and design experts at the centre of examining the potential role of IoT in stroke rehabilitation. Unlike many existing studies that focus primarily on technical capabilities, this thesis highlights how different stakeholders perceive usability, acceptability, and design priorities for future rehabilitation technologies. A further contribution lies in the cross-cultural dimension, drawing on insights from the

United Kingdom and Saudi Arabia. These contrasting healthcare systems provide different contexts of infrastructure, policy, and digital health maturity, enabling the study to generate findings that are both locally relevant and internationally transferable. As Irani et al. (2010) argue, design research must attend to local particularities while contributing knowledge that extends beyond single contexts. Similarly, comparative health research demonstrates that contrasting system-level factors can illuminate transferable lessons for technology adoption (Alwashmi et al., 2021; Greenhalgh et al., 2017). By grounding its analysis in design research rather than clinical trials, this study makes both a practical and theoretical contribution. Practically, it offers design-informed recommendations for developing IoT-based rehabilitation solutions that reflect real-world needs and challenges. Theoretically, it advances understanding of how design methods can be applied to healthcare innovation, ensuring that IoT solutions are user-centred, adaptable, and inclusive.

1.10 Structure of the Thesis

This thesis follows a structured approach to explore the integration of IoT technologies in post-stroke rehabilitation, guiding the reader through the research objectives, methodology, findings, and implications.

Chapter 1: Introduction – This chapter introduces the study, outlining key concepts and motivations. It provides an overview of the potential role of IoT technologies in healthcare, particularly in stroke rehabilitation, and presents the research questions and objectives that guide the study.

Chapter 2: Literature Review – The literature review examines the existing body of knowledge on post-stroke rehabilitation and IoT applications in healthcare, while also engaging with design research literature relevant to health technologies. It critically analyses previous studies, identifies gaps in the literature, and highlights the need for further research into the practical integration of IoT in rehabilitation. In particular, it emphasises that while IoT's technical potential has been widely discussed, there is limited exploration of how design approaches—such as user-centred, participatory, and speculative design—can inform the development of IoT for stroke rehabilitation. The review is divided into thematic sections covering the benefits and challenges of IoT, barriers to implementation (e.g., cost, digital literacy, data privacy), and cross-national healthcare perspectives, with a focus on Saudi Arabia and the UK. By incorporating both healthcare and design perspectives, the chapter establishes the interdisciplinary foundation of this thesis and positions its contribution within design research applied to digital health.

Chapter 3: Methodology – explains the mixed-methods design and four research phases: (1) international survey with healthcare professionals, (2) two workshops with stroke survivors in Saudi Arabia, (3) validation study with healthcare professionals, and (4) in-depth interviews with design experts in the UK. It also addresses ethical considerations and analysis methods.

Chapter 4: Online Survey – This chapter presents the findings from the online survey with healthcare professionals, exploring their experiences with and perspectives on IoT technologies in rehabilitation. The survey results establish a baseline understanding of the opportunities and challenges associated with IoT in stroke rehabilitation. It also presents cross-tabulations between variables such as years of clinical experience, geographic region, and familiarity with digital tools to contextualize attitudes toward IoT.

Chapter 5: Workshop 1 – This chapter details the first workshop, where stroke survivors were introduced to IoT devices and provided feedback on usability and effectiveness. It focuses on participants' initial perceptions of IoT for rehabilitation and explores how these technologies can support recovery activities. The chapter is written in the form of a research narrative, including reflections on facilitation, participant engagement, and observed challenges during the session.

Chapter 6: Workshop 2 – Building on insights from Workshop 1, this chapter focuses on the potential for personalizing IoT devices to meet the individual needs of stroke survivors. It analyses how tailored IoT applications can provide personalized feedback and enhance support for recovery. The narrative highlights changes made to the structure of the second workshop based on earlier feedback and explores themes related to customization, independence, and motivation.

Chapter 7: Validation of IoT-Based Recommendations – This chapter validates the IoT-based recommendations developed from the survey and workshop data. The validation process involved consultations with healthcare professionals, including physiotherapists and stroke rehabilitation specialists, who assessed the feasibility, usability, and potential impact of these recommendations on rehabilitation practices. Feedback from these professionals was essential for determining the recommendations' applicability in clinical settings. The chapter also compares responses from professionals in different national contexts, highlighting how health system characteristics shape attitudes toward innovation adoption.

Chapter 8: Design Expert Perspectives – reports findings from interviews with UK-based design experts. This chapter highlights how the recommendations were critiqued and extended within a design research framework, reinforcing the thesis's disciplinary contribution.

Chapter 9: Discussion and Conclusion – integrates insights across all phases, reflects critically on contributions to both healthcare and design, and discusses implications, limitations, and directions for future research.

Chapter 2: Literature Review

2.1 Introduction

Stroke rehabilitation has evolved significantly in recent decades, driven by advances in healthcare and digital technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Virtual Reality (VR). Stroke remains a major global health challenge, contributing to high rates of mortality and long-term disability (WHO, 2023). Survivors often face persistent physical, cognitive, and emotional difficulties that impact independence and quality of life. Traditional rehabilitation methods, while effective in some areas, can be burdensome due to limited access, high costs, and lack of continuous, personalized support. While emerging technologies offer new possibilities, the literature remains dominated by technical and clinical efficacy studies. A critical gap exists in understanding how these technologies are conceived, designed, and experienced by users, reflecting a broader need for a design-led perspective in digital rehabilitation. This chapter therefore adopts a design-informed framework to critically review the literature at the intersection of rehabilitation and digital health, with a particular focus on IoT. The aim is not only to describe technological capabilities but also to critique the prevailing techno-centric narratives and evaluate the integration of design principles—such as usability, accessibility, and inclusivity—within the research. By drawing on both healthcare and, crucially, design research literature, the review establishes an interdisciplinary foundation for this thesis. A cross-cultural lens is also applied, comparing the United Kingdom and Saudi Arabia to highlight how infrastructural, cultural, and policy contexts influence the design requirements and adoption pathways for technology adoption.

2.1.1 Objectives of the Literature Review

The objectives of this literature review are to:

- Critically examine existing research on stroke rehabilitation and the integration of emerging technologies, particularly the Internet of Things (IoT).
- Identify how far current literature addresses issues of usability, accessibility, and user experience from a design perspective.
- Explore how restorative and compensatory rehabilitation strategies are discussed in relation to digital technologies.

- Review the extent to which design methodologies (e.g., user-centred, participatory, speculative approaches) have been applied in developing rehabilitation tools.
- Compare adoption challenges and opportunities across different healthcare systems, with a focus on the United Kingdom and Saudi Arabia.
- Identify research gaps, especially regarding stakeholder involvement (stroke survivors, healthcare professionals, and designers) in the co-design of IoT solutions.

2.1.2 Methodology of the Review

To ensure transparency and rigour, this literature review was guided by a structured search strategy designed to capture both healthcare and design perspectives on stroke rehabilitation and emerging technologies. The approach was informed by guidelines for conducting systematic and integrative reviews but adapted to suit the interdisciplinary nature of the study.

- Databases searched: PubMed, Scopus, IEEE Xplore, ACM Digital Library, and Google Scholar were selected to provide coverage across healthcare, rehabilitation sciences, engineering, and design research.
- Search terms: combinations of keywords such as “stroke rehabilitation,” “Internet of Things (IoT),” “digital health,” “assistive technologies,” “AI in rehabilitation,” “VR rehabilitation,” “user-centred design,” “participatory design,” and “co-design in healthcare” were used. Boolean operators (AND, OR) were applied to refine results.
- Timeframe: 2010–2024 was chosen to reflect recent developments in digital health technologies while also capturing foundational studies in design and rehabilitation.
- Inclusion criteria: peer-reviewed articles, book chapters, and conference proceedings that (a) focused on IoT, AI, VR, or related digital technologies in healthcare or rehabilitation; and/or (b) engaged with design methodologies (usability, user-centred design, participatory approaches).
- Exclusion criteria: purely technical or engineering studies without a clear application to rehabilitation or without consideration of user experience, as well as articles lacking peer review.

- Screening process: abstracts were initially screened to remove irrelevant results. Full texts were then reviewed to evaluate relevance to the study's aims. Reference lists of key articles were also checked to identify additional sources.

This process ensured that the review was not limited to medical or technical accounts of IoT but also incorporated design literature that addresses usability, accessibility, and user experience. By explicitly including participatory and co-design perspectives, the review reflects the interdisciplinary foundation of this thesis and establishes a bridge between healthcare and design research.

2.2 Current State of Stroke Rehabilitation

Stroke rehabilitation is a complex, multidisciplinary process designed to help survivors recover lost physical, cognitive, and emotional functions. The primary objective of rehabilitation is to enhance quality of life by improving functional independence and minimising long-term disabilities (Langhorne et al., 2011; World Stroke Organization, 2023). Stroke frequently results in impairments affecting mobility, communication, cognition, and emotional well-being, requiring a coordinated approach involving various therapeutic interventions (Teasell et al., 2020). Effective rehabilitation typically combines physical, occupational, speech, and psychological therapies tailored to each patient's needs (Veerbeek et al., 2014). Recent clinical guidelines emphasise early intervention and task-specific training as essential components for functional recovery, recommending intensive, repetitive, and goal-oriented therapies during the critical early phases of post-stroke care (NICE, 2023; Winstein et al., 2016). These therapies aim to restore motor skills, enhance cognitive abilities, improve communication, and support emotional recovery, making rehabilitation a highly individualised and patient-centred process.

Despite these advancements, continuity of care after hospital discharge remains a major challenge. Research shows that many patients experience a sharp reduction in therapy intensity once they leave clinical settings, which often leads to plateauing or decline in recovery outcomes (Coupar et al., 2012; Chen et al., 2020). This problem is particularly evident in underserved and rural areas, where access to specialised rehabilitation is limited (Krishnamurthi et al., 2018). Survivors also face barriers such as high costs, limited availability of services, and the need for sustained, personalised support (Winstein et al., 2016; WHO, 2023). Traditional rehabilitation models often lack mechanisms for real-time monitoring, adaptive feedback, and home-based continuation of therapy (Chen et al., 2020). These limitations highlight a gap that emerging digital health technologies, including IoT-enabled systems, are poised to address by providing remote monitoring, timely feedback, and continuity of care (Patel et al., 2012; Bietz et al., 2019). However, the mere existence of these technologies does not guarantee their success. This context reinforces that the primary challenge is not just technical but socio-technical, demanding solutions that are not only clinically efficacious but also fundamentally usable, accessible, and acceptable from a user-centred design perspective. The repeated failure of technologically advanced but poorly designed health interventions (Greenhalgh et al., 2017) underscores that design quality is a critical determinant of real-world impact.

2.3 Traditional Rehabilitation Approaches

Traditional stroke rehabilitation has primarily focussed on restoring motor and cognitive function through Physical Therapy (PT), Occupational Therapy (OT), and Speech and Language Therapy (SLT) (Langhorne, Bernhardt and Kwakkel, 2011). These methods aim to help stroke survivors regain independence in daily activities, but they face significant limitations in accessibility, cost, continuity, and personalisation, which hinder their ability to meet the evolving needs of patients (Veerbeek et al., 2014; Winstein et al., 2016).

Physical Therapy (PT) emphasises improving mobility, muscle strength, coordination, and balance. Techniques such as Constraint-Induced Movement Therapy (CIMT), which promotes the use of affected limbs, have shown effectiveness in enhancing motor recovery by leveraging neuroplasticity (Taub et al., 2013). Similarly, Functional Electrical Stimulation (FES) and gait training are widely used to improve walking abilities and reduce fall risks (Howlett et al., 2015). However, PT often requires specialised equipment, trained professionals, and frequent visits to healthcare facilities, making it less accessible for patients in remote or underserved areas (Teasell et al., 2020). Occupational Therapy (OT) focusses on relearning essential activities of daily living (ADLs), such as dressing, eating, and grooming. It also incorporates adaptive devices and environmental modifications to help patients overcome physical limitations, promoting independence and quality of life (Radomski and Latham, 2014). While beneficial, OT programmes often require intensive, in-person sessions and resources that are challenging to access for many stroke survivors, particularly in resource-limited settings (Coupar et al., 2012). Speech and Language Therapy (SLT) addresses communication disorders such as aphasia and dysarthria, which significantly impact social interactions and quality of life. Therapists focus on restoring speech clarity, comprehension, and swallowing function to prevent complications such as aspiration pneumonia (Gresham et al., 1997; Brady et al., 2016). Despite its importance, SLT remains underutilised due to shortages of specialists, resource constraints, and high costs (WHO, 2023).

Although these traditional approaches are valuable and evidence-based, they often fail to provide the continuous, adaptive, and personalised care required for long-term recovery. A lack of real-time feedback, difficulties with home-based adherence, and restricted access after hospital discharge highlight the urgent need for innovative, technology-driven solutions such as IoT-enabled systems to complement traditional models of care (Patel et al., 2012; Bietz et al., 2019). However, for IoT to successfully fill these gaps, its development must be guided by a deep understanding of the very limitations it seeks to overcome. This necessitates a shift from a technology-push model to a design-pull approach, where user needs, context, and lived experience dictate the technological solution.

Table 1.2.1: Comparative Analysis of Traditional and IoT-Enabled Stroke Rehabilitation Approaches

Criteria	Traditional Rehabilitation	IoT-Enabled Rehabilitation
Patient Monitoring	Periodic clinical visits for assessment	Continuous, real-time monitoring through wearables and sensors
Personalization	Generic treatment plans	Personalized based on real-time data and patient feedback
Access to Services	Limited to in-person sessions	Tele-rehabilitation enables access from remote locations
Cost	High costs due to in-person care	Potentially lower costs through remote monitoring and telemedicine
Engagement	Lower engagement due to lack of interactive tools	Higher engagement with interactive tools like VR and gamification
Data Collection	Manual documentation	Automated data collection from connected devices

2.3.1 Importance of Early and Continuous Rehabilitation

Early and continuous rehabilitation are critical for maximising recovery and functional outcomes after a stroke. Initiating therapy within days of the event helps to prevent secondary complications such as muscle atrophy, joint contractures, and spasticity, while also promoting neuroplasticity—the brain's capacity to reorganise and recover lost functions (Langhorne, Bernhardt and Kwakkel, 2011; Winstein et al., 2016). Evidence suggests that early intervention is strongly associated with better motor outcomes, reduced disability, and improved quality of life (Pollock et al., 2014). It also contributes to greater patient confidence, motivation, and engagement in recovery, reinforcing adherence to therapy programmes (McKevitt et al., 2011). While early rehabilitation addresses immediate needs, long-term therapy ensures that progress is sustained over months and years. Lohse, Lang and Boyd (2014) found that patients who continued therapy for at least six months demonstrated significantly better motor function and independence compared to those who discontinued earlier. Similarly, Veerbeek et al. (2014) emphasised the importance of task-specific and intensive training throughout recovery, showing that extended rehabilitation can prevent regression and maintain functionality. However, traditional rehabilitation programmes face significant challenges in delivering continuous, long-term care. Resource-intensive in-person therapies are often inaccessible to patients in rural or underserved regions, where specialist professionals and equipment are scarce (Kaur, English and Hillier, 2012). Even in well-resourced settings, the high financial costs of long-term rehabilitation frequently lead to early discontinuation (Han, Wang and Xu, 2015). These limitations underscore the need for accessible, scalable, and sustainable rehabilitation models.

Emerging technologies, such as tele-rehabilitation and IoT-enabled devices, offer the potential to provide continuous, personalised care regardless of geographic or financial constraints (Chen et al., 2020; Johansson and Wild, 2011). By leveraging remote monitoring, real-time feedback, and adaptive algorithms, these technologies can extend the reach of rehabilitation programmes and reduce dependence on in-person sessions. Importantly, continuous digital rehabilitation has the potential to empower stroke survivors to play a more active role in their recovery. For example, research suggests that with user-friendly mobile applications and wearable sensors, patients can perform tailored exercises at home, track their progress, and receive timely feedback, thereby promoting autonomy, motivation, and long-term adherence (Cramer et al., 2019; Laver et al., 2020). Integrating these technologies into mainstream care pathways could significantly reduce hospital readmissions, improve cost-effectiveness, and enhance long-term outcomes for stroke survivors (Smith et al., 2021; Chen et al., 2020). This evidence highlights why exploring IoT adoption in stroke rehabilitation is central to this research: it addresses gaps left by traditional methods precisely because its core functionalities (connectivity, data, adaptability) align with the principles of user-centred, design-informed healthcare innovation. The critical task, therefore, is to ensure this potential is realised through rigorous design processes.

2.4 Emerging Technologies in Stroke Rehabilitation: A Design-Informed Critique

The documented limitations of traditional stroke rehabilitation—concerning accessibility, personalisation, and long-term continuity—have catalysed the integration of advanced digital technologies. While these emerging tools offer compelling solutions to bridge these gaps, the literature often prioritises technical capability over the design and implementation challenges that ultimately determine their real-world efficacy. This section moves beyond a descriptive account of technological functions to provide a critical, design-informed review of the Internet of Things (IoT), Artificial Intelligence (AI), and Virtual Reality (VR). It evaluates their potential not merely in terms of clinical output, but through the essential lenses of usability, accessibility, and socio-technical integration, thereby establishing a foundational rationale for this thesis's design-led approach.

2.4.1 The Internet of Things (IoT): Enabling Continuity and Creating New Design Hurdles

The Internet of Things (IoT) presents a paradigm shift for stroke rehabilitation by enabling continuous, data-driven care that extends beyond clinical settings into the home environment. Its core promise lies in using interconnected devices—wearable sensors, smart home adaptations, and tele-rehabilitation platforms—to collect real-time patient data, facilitate remote monitoring, and allow for dynamic personalisation of therapy plans (Chen et al., 2020; Smith et al., 2023).

Applications and Potential

Wearable sensors, embedded in devices like wristbands or smart clothing, can continuously monitor movement, gait, and physiological parameters, providing objective data to clinicians and feedback to patients (Cramer et al., 2019). This enables therapy plans to be adjusted remotely based on quantifiable progress. Furthermore, IoT-enabled smart home adaptations, such as voice-activated assistants and motion sensors, can enhance independence and safety for stroke survivors, reducing physical effort in daily tasks and alerting caregivers to emergencies (Patel et al., 2024). When integrated with tele-rehabilitation, IoT creates a comprehensive ecosystem for remote care, which studies have shown can achieve outcomes comparable to, or even superior than, traditional in-person sessions (Hübner et al., 2021).

A Design-Led Critique of Implementation Challenges

Despite its significant potential, the successful adoption of IoT is contingent upon overcoming profound design challenges that are often understated in techno-centric literature:

- **The Accessibility Paradox:** Many IoT devices are designed for a technologically adept user, creating a fundamental mismatch with the needs of a stroke population. Patients may experience hemiplegia, reduced dexterity, cognitive deficits, or limited digital literacy (Liu et al., 2021). Designing devices that are physically easy to don and doff, with simplified, intuitive interfaces, is not an optional extra but a core requirement. This challenge demands the application of inclusive and universal design principles to ensure solutions are usable by the widest range of abilities.

- **The Data Dilemma:** The continuous data collection that powers IoT also creates a critical "design for trust" problem. The storage, transmission, and use of sensitive health data raise significant privacy and security concerns (Kumar & Lee, 2022). Building trust requires that data handling is not only compliant with regulations like GDPR but is also transparent and communicated clearly to users. Security and ethical data practices must be designed into the system from the outset, not added as an afterthought.

- **The Interoperability Challenge:** The frequent use of proprietary systems by different device manufacturers creates a fragmented care experience. The inability of devices and platforms to seamlessly share data with each other and with Electronic Health Records (EHRs) is a failure of system and service design. This lack of standardisation hinders the creation of coherent, personalised rehabilitation programmes and reduces clinical efficiency, undermining the very personalisation IoT promises.

2.4.2 Complementary Technologies: VR and AI through a Design Lens

While IoT provides the connective tissue for continuous care, technologies like VR and AI offer specific intervention modalities whose value is equally dependent on thoughtful design.

Virtual Reality (VR)

VR creates immersive, simulated environments for practising motor and cognitive tasks, significantly enhancing patient engagement and motivation through gamified exercises (Laver et al., 2017). From a design standpoint, however, VR's potential is moderated by critical usability considerations. Interfaces must be intuitive and avoid sensory overload, which can be particularly disorienting for individuals with cognitive impairments. Furthermore, the high cost of equipment and the need for specialist training present significant barriers to accessibility, making VR a less equitable solution in low-resource or rural settings (Smith et al., 2020). Its success, therefore, is as much a question of accessible user experience (UX) design and sustainable implementation models as of technical immersion.

Artificial Intelligence (AI)

AI offers powerful capabilities for personalising rehabilitation by analysing data from IoT devices and EHRs to predict recovery trajectories, recommend interventions, and provide real-time feedback on exercise form (Lee et al., 2020). However, its clinical utility is entirely dependent on design choices. AI systems often function as "black boxes," whose decision-making processes are opaque to clinicians and patients. This lack of transparency can erode trust and limit adoption (Greenhalgh et al., 2017). For AI to be effectively integrated into clinical workflows, it must be explainable, and its interfaces must be designed to present insights in an actionable, understandable way for healthcare professionals, not just data scientists. Moreover, the risk of algorithmic bias necessitates a design ethos that prioritises fairness and equity to prevent the exacerbation of existing health disparities.

2.4.3 Synthesis: IoT as the Integrative Platform for Design-Informed Care

While VR and AI provide targeted therapeutic benefits, the unique role of IoT in this ecosystem is to serve as the integrative platform. It provides the continuous, real-world data from a patient's home environment that can fuel AI algorithms and contextualise VR-based therapy outcomes. This positions IoT as the backbone for a holistic, continuous rehabilitation model. However, this reinforces that IoT must be conceived not as a collection of discrete devices, but as a complex socio-technical system whose design must account for user interactions, data flows, and clinical integration simultaneously.

2.4.4 Conclusion: The Imperative for a Co-Design Approach

The literature reveals a consistent pattern: the significant technological potential of IoT, AI, and VR is consistently hampered by a lack of early and meaningful integration of design thinking. The challenges of accessibility, data trust, interoperability, and clinical usability are not minor obstacles but fundamental design problems that have often been overlooked in favour of technical development. This critical gap justifies the central methodology of this research: the application of participatory and co-design approaches. Engaging stroke survivors, caregivers, and healthcare professionals directly in the design process is not merely beneficial but essential to ensure that IoT-enabled rehabilitation solutions are not only technologically sophisticated but also usable, accessible, trustworthy, and ultimately, effective in the complexity of real-world recovery.

Table 2.2.2: Emerging Technologies and Their Benefits

Technology	Specific Contributions to Stroke Rehabilitation
IoT	Enables real-time monitoring of physical activity, gait, and progress via wearable devices; provides remote, personalized feedback.
VR	Creates immersive environments for motor and cognitive exercises, enhancing engagement and simulating real-world tasks safely.
AI	Analyzes patient data to predict outcomes, personalize treatment, and provide adaptive feedback in real-time for tailored therapy.
BCI	Facilitates motor function recovery by enabling direct control of assistive devices or robotic limbs using brain signals.

The literature synthesis indicates that the benefits of IoT in stroke rehabilitation are predominantly concentrated within three overlapping domains: continuous remote monitoring, personalised bio-feedback, and the enhancement of stakeholder communication. Existing research suggests that rather than acting in isolation, these domains form a connected ecosystem where data from monitoring informs the personalisation of recovery protocols, which is then mediated through communication channels between clinicians and survivors (Chen et al., 2020; Mountain et al., 2020). By identifying these thematic intersections, the research establishes the theoretical baseline required to investigate how design-led principles can bridge current gaps in implementation, moving beyond technical performance toward a more integrated, human-centred model of care.

Table 3.2.3: IoT in Rehabilitation Key Components and Benefits

IoT Component	Data Collected	Key Benefits
Wearables	Movement, physiological data	Real-time progress monitoring, therapy adjustments, early complication detection
Smart Home Devices	Environmental and motion data	Enhanced safety, improved autonomy, caregiver relief
Tele-Rehabilitation	Exercise adherence, performance metrics	Increased therapy adherence, reduced travel costs, remote accessibility
Cloud Database	Aggregated device data	Comprehensive insights, personalized therapy, secure and sharable data storage

2.5 A Design-Led Framework for Digital Rehabilitation

The preceding critique of emerging technologies reveals a consistent pattern: a predominance of techno-centric development that overlooks the fundamental socio-technical challenges of implementation. This gap underscores the necessity of a robust design framework. Moving beyond a view of design as mere aesthetics or usability testing, this section establishes the theoretical foundations that underpin this thesis. It articulates how core design philosophies—from user-centred to participatory and inclusive approaches—provide the essential lens for understanding and shaping IoT-enabled rehabilitation, transforming it from a technical proposition into a dignified, effective, and equitable human experience.

2.5.1 From User-Centred to Participatory and Co-Design: Shifting Agency in Healthcare

A foundational starting point is User-Centred Design (UCD), which positions user needs, preferences, and limitations as the primary driver of development (Norman, 2013). In healthcare, UCD is a vital corrective to purely engineering-led approaches, ensuring that technologies are usable and relevant to the daily routines of stroke survivors and clinicians. However, UCD can sometimes operate at a surface level, consulting users about pre-conceived ideas rather than involving them in the fundamental conception of solutions.

This limitation is addressed by the more transformative practices of participatory design and co-design. These approaches actively reposition users from subjects of research to active partners and co-creators in the design process (Sanders & Stappers, 2008). In the context of stroke rehabilitation, this means engaging survivors, caregivers, and clinicians not just in testing prototypes, but in defining the problems and shaping the very vision of what an IoT system should be and do. This shift is critical for building trust, ensuring cultural relevance, and creating a sense of shared ownership, which significantly enhances the adoption and long-term sustainability of digital health tools (Bødker et al., 2020). The persistent technology-driven development in IoT rehabilitation, which this thesis critiques, highlights a stark absence of this participatory ethos, a gap this research directly aims to fill.

2.5.2 The Imperatives of Inclusive and Universal Design

The diverse and often profound impairments resulting from a stroke—including hemiplegia (partial paralysis affecting one side of the body), aphasia (difficulty with language and communication), and cognitive deficits affecting memory and executive function—mean that rehabilitation technologies cannot rely on a one-size-fits-all approach. These varied and co-existing impairments directly impact a person's ability to interact with devices, making the principles of inclusive and universal design non-negotiable (Clarkson et al., 2013; Story, 1998). While UCD and co-design focus on process, inclusive and universal design provide critical outcome-oriented principles, demanding that products and environments be usable by the widest possible range of people without the need for adaptation or specialised design (Story, 1998; Clarkson et al., 2013). This directly challenges the design of many existing IoT devices, which often presume a level of dexterity, vision, or digital literacy that many stroke survivors do not have. Applying this lens necessitates adaptable interfaces, multi-modal feedback (e.g., combining visual, auditory, and haptic cues), and voice-first interactions from the outset. It moves accessibility from a compliance issue to a core design value, ensuring that the benefits of IoT are not reserved only for those with milder impairments.

2.5.3 Designing for Holistic Health and Wellbeing

Finally, the emerging field of design for health and wellbeing provides the overarching imperative that binds these approaches together. It argues that technology in a care context should aim not only to restore physical function but to enhance overall quality of life, dignity, and autonomy (Sanders, 2014; Pihlainen et al., 2020). This frames the evaluation of an IoT system not solely by clinical metrics but by its capacity to support psychosocial well-being, rebuild confidence, and foster meaningful engagement in life. This holistic view is a direct counter to a narrow biomedical model. It demands that we ask not just "Does the sensor accurately track arm movement?" but also "Does using this system make the patient feel empowered or monitored? Does it support their sense of self?" This aligns with the need to address the emotional barriers to recovery, ensuring technology is a supportive partner in the rehabilitation journey.

2.5.4 Synthesis: Implications for a Design-Informed Research Methodology

The absence of this integrated design perspective is the central gap this thesis identifies. The critiques of IoT's accessibility paradox, data dilemma, and lack of clinical trust are, at their core, failures of design philosophy and process. Therefore, this research is grounded in the conviction that a techno-centric approach is insufficient.

By adopting a design-led methodology that synthesises participatory co-design with the principles of inclusivity and wellbeing, this study moves beyond generating a list of technical features. It seeks to produce:

- Rich, nuanced insights into the lived experiences and values of stroke survivors and healthcare professionals across the UK and Saudi Arabia.
- Practical, design-informed recommendations that are culturally sensitive, inherently accessible, and focused on supporting holistic recovery.
- A critical demonstration of how integrating these design frameworks from the outset can lead to IoT solutions that are not only feasible and effective but also truly human-centred and equitable.

This firmly situates the contribution of this work within design research traditions, ensuring that design functions as the central, critical lens through which the problem is defined, investigated, and resolved.

2.6 Operationalising Design for IoT in Stroke Rehabilitation: From Principle to Practice

The established design philosophies provide a vital foundation, but they require translation into tangible design priorities for the specific context of IoT-enabled stroke rehabilitation. The literature reveals a gap between high-level principle and practical application. This section synthesises the theoretical framework to identify the key design dimensions that this research will investigate—dimensions that are critical for moving from technologically possible solutions to those that are genuinely usable, effective, and empowering for stroke survivors.

2.6.1 Key Design Dimensions for Investigation

Based on the synthesis of healthcare needs and design theory, this thesis will focus on the following interconnected design dimensions, which are chronically underexplored in the techno-centric literature:

- **1. Adaptability and Configurability:** A core design challenge is creating systems that can accommodate the vast heterogeneity of stroke impairment. This goes beyond simple personalisation. It involves designing for one-handed use as a default, creating interfaces that are cognitively scalable (from simple, step-by-step prompts to more complex goal-setting), and ensuring physical hardware can be donned, doffed, and operated with hemiparesis. The design question is not if a system can be personalised, but how easily and by whom (clinician, caregiver, or patient) this configurability is achieved.
- **2. Designing for Trust and Data Transparency:** The continuous monitoring inherent to IoT creates a unique design problem around perceived surveillance versus supportive care. This dimension investigates how to design for informed consent and data agency in a population that may have cognitive challenges. How are data collection and its purposes communicated clearly? How can interfaces provide patients with a sense of ownership and benefit from their own data, transforming it from a clinical metric into a tool for self-efficacy and motivation?
- **3. Contextual Integration and Emotional Engagement:** Rehabilitation does not occur in a vacuum. A critical design dimension is how IoT systems integrate into the domestic and social fabric of a survivor's life. This involves designing for environmental robustness (different lighting, noise levels) and minimising

disruption to daily routines. Furthermore, it requires moving beyond gamification clichés to design for genuine emotional support. This includes strategies for motivation during plateaus, mitigating frustration, and providing feedback that builds confidence rather than simply measuring performance.

2.6.2 The Centrality of Co-Design in Eliciting Design Requirements

While the dimensions above outline the *what*, this research posits that co-design is the essential methodology for uncovering the *how*. The complex, lived experience of stroke means that predefined design checklists are insufficient. Therefore, this study employs co-design not as a generic value, but as a necessary method to:

- Elicit nuanced, first-hand knowledge about the practicalities of the design dimensions listed above.
- Collaboratively generate ideas for features that are both clinically valuable and personally meaningful.
- Identify and reconcile potential tensions between patient desires (e.g., for simplicity) and clinical requirements (e.g., for detailed data).

2.6.3 Conclusion: Framing the Empirical Study

This design-led framework moves the research questions from "Can IoT work?" to "How must IoT be designed to work effectively and compassionately in the context of stroke recovery?" The following empirical chapters are structured to investigate these specific design dimensions. Through surveys and co-design workshops with stakeholders in the UK and Saudi Arabia, this research will generate grounded, evidence-based insights into these critical areas. The outcome will not be a general endorsement of patient-centricity, but a set of contextually-sensitive, practical design guidelines for creating IoT rehabilitation systems that are truly aligned with the needs, abilities, and lives of stroke survivors.

2.7 Barriers to Implementing IoT in Stroke Rehabilitation: A Socio-Technical Critique

Despite the potential of IoT, its transition from prototype to mainstream care is hampered by complex, interconnected barriers. These are not merely technical hurdles but deeply rooted socio-technical challenges that involve users, infrastructure, economics, and policy. This section critiques four fundamental barriers, framing them as issues that require integrated design and policy solutions, not just engineering fixes.

Table 4.2.4: Barriers to Implementing IoT in Stroke Rehabilitation

Barrier	Description	Impact on Rehabilitation
Data Privacy and Security	Ensuring the protection of sensitive patient data collected by IoT devices	May limit patient adoption if security concerns are not addressed
Cost of Devices and Infrastructure	High upfront costs for devices and the need for reliable internet connectivity	Limits access in low- and middle-income regions
Technological Literacy	Patients and healthcare providers may lack the skills to effectively use IoT devices	Reduces the effectiveness and widespread adoption of IoT technology
Interoperability	Lack of standardization across devices and systems	Prevents integration into healthcare systems and efficient data exchange

2.7.1 Data Privacy and Security: A Design-for-Trust Imperative

Safeguarding the sensitive data generated by IoT systems is a foremost challenge, but the issue extends beyond technical security. The continuous, intimate nature of the data collected—from movement patterns to daily habits—creates a crisis of patient trust if not managed transparently. While technical measures like multi-layered encryption and secure protocols are essential (Biswas et al., 2020), they are insufficient alone. The interconnected nature of IoT systems expands the attack surface, making them vulnerable to breaches. Therefore, the critical challenge is one of design: how to build systems that are not only secure but also *perceived as trustworthy* by vulnerable users. This involves designing intuitive consent mechanisms, clear data usage explanations, and interfaces that give patients a sense of agency over their information. Explorations into decentralised approaches like blockchain highlight the search for technical frameworks and system designs that can underpin trust (Biswas et al., 2020). Ultimately, compliance with regulations like GDPR must be the baseline; building genuine confidence requires embedding privacy and transparency as core design principles from the outset.

2.7.2 Interoperability, Cost, and the Accessibility Divide

This barrier cluster highlights a fundamental tension between innovation and standardisation. The lack of interoperability, driven by proprietary systems and a absence of universal standards, fragments care and cripples clinical efficiency (Raj et al., 2021). This is not just a technical failure but a failure of ecosystem design, preventing the seamless data flow required for truly personalised rehabilitation.

Compounding this is the significant cost of devices and the infrastructure needed to support them (Alwashmi et al., 2021). This creates a stark accessibility divide, where IoT's benefits are disproportionately available to wealthier, urban populations, thereby exacerbating existing health inequalities. This makes the development of low-cost, scalable devices and robust infrastructure in underserved areas a critical design and policy goal.

2.7.2.1 Economic Sustainability and Value Proposition

Rather than a formal cost-benefit analysis—which requires specific, localised data beyond this review's scope—this section considers the economic argument for IoT. The high initial investment in devices, infrastructure, and training must be weighed against the potential for long-term value. Evidence suggests that costs may be offset by reducing hospital readmissions, enabling earlier complication detection, and increasing patient independence, which reduces long-term care costs (Chen et al., 2020; Patel et al., 2022). The economic case, therefore, hinges on reframing IoT not as an expense but as a sustainable investment in a new, more efficient and home-based rehabilitation model. This value proposition is crucial for persuading healthcare systems, insurers, and policymakers to fund adoption.

2.7.3 Limited Technological Literacy: A Core Design Challenge

A final, critical barrier is the digital literacy gap among both patients and healthcare providers. For older stroke survivors, age-related cognitive decline, physical impairments, and technological unfamiliarity create profound usability challenges (Liu et al., 2021). Simultaneously, clinicians may lack the training to interpret IoT data effectively, limiting its clinical utility. This is not a user deficit but a design failure. Addressing it requires a two-pronged approach grounded in inclusive design:

1. **For Patients:** Interfaces must be simplified, leveraging voice commands, adaptive features, and intuitive feedback systems that accommodate a wide spectrum of abilities.

2. **For Professionals:** Data must be presented through clinician-friendly dashboards that translate raw data into actionable, clinical insights.

Overcoming this barrier is essential, as designing for accessibility and providing adequate training directly strengthens patient confidence and motivation, which are foundational to successful rehabilitation outcomes.

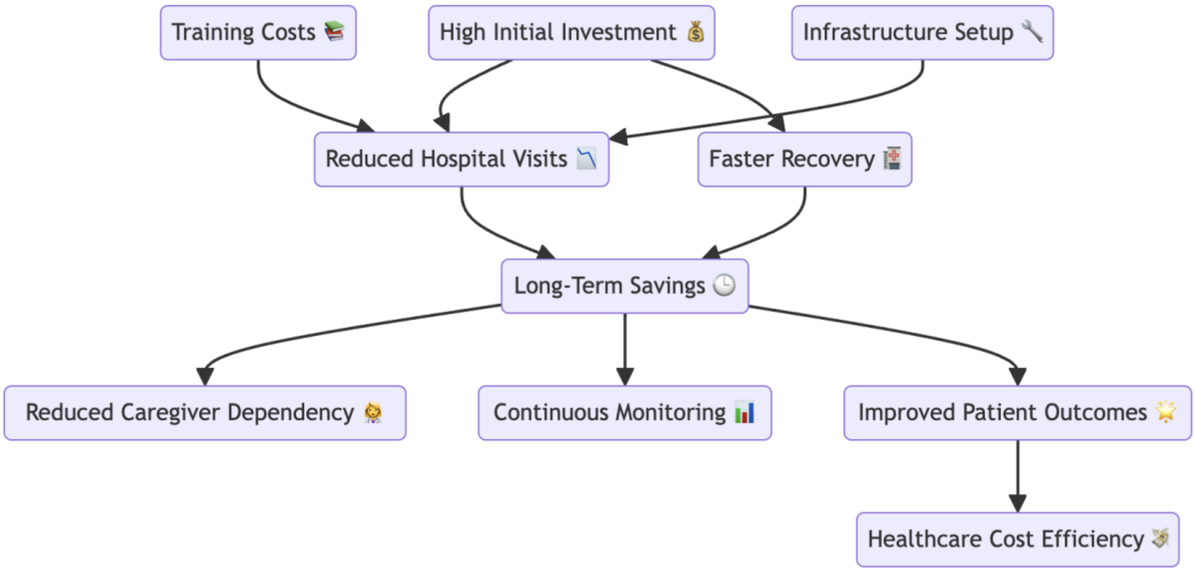

Figure 1.2.2: Cost-Benefit Analysis: Short-Term vs. Long-Term outcomes of IoT-enabled systems

2.8 Global Adoption and Access: Context as a Design Driver in IoT Rehabilitation

The global adoption of IoT in stroke rehabilitation is not a uniform process but a phenomenon shaped by profound contextual disparities. A techno-centric approach that ignores this context is destined to fail. This section critiques the variable feasibility of implementation across different settings, using the comparative contexts of this study—the United Kingdom (UK) and Saudi Arabia (KSA)—to illustrate how infrastructure, economics, and culture fundamentally dictate design requirements. This comparative lens is essential for developing IoT solutions that are not only technically sound but also contextually viable and equitable.

2.8.1 Divergent Contexts: A Tale of Two Systems

The implementation landscape for IoT varies dramatically between well-established and developing healthcare systems.

- **High-Income Contexts (e.g., the United Kingdom):** In settings like the UK's National Health Service (NHS), the pathway for IoT integration is supported by relatively robust infrastructure, digital health strategies, and funded pilot programmes (NHS, 2019). The primary design challenges here often revolve around interoperability with existing systems like EHRs, demonstrating cost-effectiveness to commissioners, and ensuring data governance compliance within a complex public healthcare structure. The design focus is on refinement and integration into a mature, though often bureaucratic, ecosystem.

- **Middle-Income and Developing Contexts (e.g., Saudi Arabia):** In contrast, countries like Saudi Arabia, while investing heavily in healthcare modernisation (Vision 2030), may face simultaneous challenges of infrastructure variability, a rapidly evolving digital health policy, and disparities in internet access between urban and rural populations. Here, the design challenges are more fundamental. They include creating low-cost, low-bandwidth devices that can function with intermittent connectivity, designing for scalability across diverse infrastructural conditions, and ensuring cultural and linguistic appropriateness of interfaces and content (Alwashmi et al., 2021). The absence of a single, monolithic system like the NHS necessitates more flexible and adaptable design solutions.

2.8.2 Structural Barriers as Design Constraints

The divergent contexts above create a set of non-negotiable design constraints:

- **The Economic and Infrastructural Divide:** The high cost of devices and the reliance on stable electricity and internet are not just financial problems but fundamental design parameters for global solutions. This is why the concept of frugal innovation has been incorporated into this review. Frugal innovation – creating maximum value with minimal resource use – directly addresses the resource constraints identified in both the Saudi context and in global discussions of equitable healthcare technology (Zeschky et al., 2014; Bhatti et al., 2018). It offers a design philosophy that prioritises affordability and robustness without compromising core functionality. Related to this is the principle of graceful degradation, where systems remain partially functional offline rather than failing completely, ensuring that infrastructural limitations do not render the technology useless.

- **The Human Capital and Literacy Gap:** The shortage of trained professionals and the limited digital literacy among some patient populations are, at their core, usability and training design challenges. This demands an emphasis on intuitive, minimally-invasive interfaces that reduce cognitive load, and the design of comprehensive training ecosystems for both clinicians and patients.

Furthermore, it highlights the need to design for collaborative use, where family members or community health workers can easily assist the patient.

2.8.3 Design-Led Strategies for Equitable Adoption

Addressing these disparities requires a shift from technology transfer to context-sensitive design. Promising strategies include:

- **Designing for Scale and Affordability:** Focusing on modular, platform-based designs that can be scaled up or down based on resources, rather than monolithic, expensive systems.
- **Leveraging Mobile-First and SMS-Based Solutions:** In regions with high mobile phone penetration but limited broadband, mHealth platforms (Nouwen et al., 2021) that operate on basic smartphones or even via SMS can bridge the accessibility gap, serving as a vital link for tele-rehabilitation and reminders.
- **Co-Design for Cultural and Contextual Fit:** This is perhaps the most critical strategy. Participatory design methodologies are essential to ensure that technologies are not simply imported but are co-created to align with local cultural norms, languages, and social structures. This is a central justification for this thesis's comparative approach, aiming to generate design insights that are sensitive to the specific contexts of both the UK and Saudi Arabia.

In conclusion, global access is not a secondary concern but a primary driver of design innovation. Understanding the contrasting realities of healthcare systems like the UK and KSA is not merely an academic exercise; it is a fundamental step in designing IoT rehabilitation tools that are truly global, equitable, and effective. This reinforces the core argument of this thesis: that without deep, design-led engagement with context, the promise of IoT will remain limited to the world's most privileged patients.

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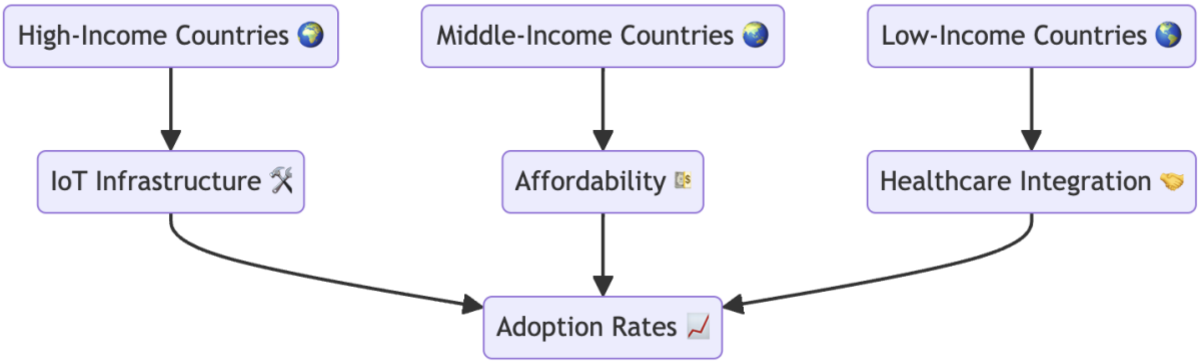

Figure 2.2.3: Global IoT Adoption Challenges

2.9 The Long-Term Engagement Challenge: Sustaining Rehabilitation Beyond the Short-Term

While evidence for the short-term efficacy of IoT in stroke rehabilitation is growing, a critical and under-examined question remains: how to sustain patient engagement and therapeutic benefit over months and years. The literature reveals a presumption that initial adoption will naturally translate into long-term use, but this overlooks the reality of device fatigue, evolving patient needs, and the psychological journey of long-term recovery. This section critiques this gap, framing long-term success not just as a clinical outcome, but as a complex design problem centred on sustained user engagement.

2.9.1 The Gap Between Short-Term Adoption and Long-Term Use

Studies demonstrate that IoT devices can improve motor function and engagement in the initial phases of rehabilitation (Patel et al., 2022). However, the field lacks robust investigation into whether these systems can adapt to the non-linear nature of stroke recovery, where patients often experience plateaus and require evolving motivation strategies. The crucial, unanswered question is not merely *if* benefits are sustained, but what design features enable IoT systems to remain relevant, useful, and engaging throughout the entire recovery continuum. This shifts the focus from clinical durability to the durability of the human-technology relationship.

2.9.2 Key Design Challenges for Long-Term Engagement

The literature points to several interconnected challenges that must be framed as design priorities:

- **Adapting to Evolving Abilities and Goals:** A system designed for acute recovery may become irrelevant or even demotivating for a patient in the chronic phase. Long-term engagement requires designs that are inherently adaptable, capable of shifting from focused motor retraining to supporting community reintegration and lifelong fitness without requiring a completely new device or platform.

- **Combating Device Fatigue and Maintaining Motivation:** The novelty of new technology inevitably wears off. Relying on simplistic gamification is insufficient. Future systems need sophisticated, personalised motivational strategies, potentially driven by AI, that can recognise frustration, celebrate subtle progress, and vary therapy activities to prevent monotony.

- **The Critical Role of Caregivers and Support Systems:** Long-term use is often mediated by informal caregivers. The current literature largely ignores the design of collaborative interfaces that involve caregivers in a supportive, non-burdensome way. Co-designing with both survivors and caregivers is essential to create ecosystems of support that endure.

2.9.3 Ethical and Economic Considerations for Sustained Use

The vision of lifelong rehabilitation tools also raises profound questions:

- **Data Privacy and Patient Autonomy:** Continuous long-term monitoring intensifies ethical concerns. Building lasting trust requires designs that offer clear consent models, data agency, and transparent purposes for data use, avoiding any perception of perpetual surveillance.

- **Economic Sustainability:** The long-term cost of device maintenance, updates, and data plans presents a significant barrier, particularly for low-income users (Smith & Thompson, 2020). Designing for long-term impact necessitates business models and frugal design strategies that ensure solutions are not only effective but also economically sustainable for healthcare systems and individuals.

2.9.4 Conclusion: Framing the Research Imperative

The gap in long-term evidence is, therefore, not just a call for more longitudinal clinical trials. It is a call for a design-led research agenda that investigates how to create IoT systems that are *by design* capable of sustaining engagement. This thesis contributes to this agenda by not asking "Are IoT systems effective in the long term?" but by investigating the prior, and more fundamental, question: "What do stroke survivors and clinicians perceive as the key design requirements for an IoT system they would want to use, and trust, over the long term?" By capturing these evidence-based user perspectives, this research provides the foundational design insights necessary to create the next generation of sustainable, long-term rehabilitation tools.

2.10 Synthesised Research Gaps and the Contribution of this Thesis

The preceding critique reveals that the field of IoT in stroke rehabilitation is constrained by a predominantly techno-centric paradigm. While technical feasibility and clinical efficacy are often documented, this review has identified a consistent undervaluing of the design and socio-technical factors that determine real-world success. The promise of IoT will remain unrealised unless research directly addresses the following synthesised gaps, which this thesis is designed to investigate:

Gap 1: The Lack of Deep, Co-Designed User Insights to Inform Fundamental Design Dimensions.

While user needs are sometimes acknowledged, the literature shows a stark absence of research that uses participatory and co-design methodologies to deeply understand the lived experience of rehabilitation. This has left critical design dimensions—such as how to build trust through transparent data handling, how to achieve true accessibility and adaptability for diverse impairments, and how to design for long-term emotional engagement beyond initial novelty—defined by assumptions rather than evidence. This thesis addresses this by employing co-design workshops with stroke survivors and healthcare professionals to generate rich, empirical data on these specific design priorities, moving from presumed needs to validated user perspectives.

Gap 2: The Underexplored Influence of Cultural and Healthcare Context on Design Requirements.

The development of IoT solutions has been largely confined to Western, high-income healthcare contexts. There is a critical lack of understanding of how cultural norms, infrastructural realities, and healthcare system structures—such as those in the UK versus Saudi Arabia—fundamentally shape what constitutes an acceptable, effective, and adoptable design. This thesis directly addresses this by conducting a cross-cultural, comparative study to investigate how context influences design requirements, ensuring that the resulting insights are not ethnocentric but are sensitive to different realities and constraints.

Gap 3: The Disconnect Between Ethical Acknowledgment and Design Integration.

Concerns about data privacy, security, and ethical implementation are widely acknowledged in the literature but are consistently treated as a compliance or regulatory issue separate from the design process. This creates a gap between ethical principle and design practice. This thesis bridges this gap by investigating how ethical concerns, particularly around trust and data agency, directly translate into concrete design features and communication strategies within IoT systems, making ethics a core driver of the user experience rather than a peripheral consideration.

In summary, this thesis does not seek to prove the technical viability of IoT, but to answer the more foundational, design-led question: What are the user-centred, culturally-sensitive, and ethically-grounded design principles for IoT in stroke rehabilitation, and how can they be implemented? By foregrounding the perspectives of stakeholders across two distinct contexts and employing rigorous design research methods, this study will generate the design-informed insights necessary to bridge the gap between technological potential and meaningful, real-world impact.

2.11 Conclusion: Charting a Design-Led Path Forward

This literature review has argued that the field of IoT in stroke rehabilitation is at a critical juncture. The considerable technical potential of these technologies is consistently undermined by a persistent techno-centric development paradigm that overlooks the fundamental socio-technical and design challenges of implementation. The gaps identified are not minor oversights but foundational flaws in the current approach: a lack of deep, co-designed user insights, an insensitivity to cultural and contextual diversity, and a disconnect between ethical principles and design practice. The future advancement of the field, therefore, depends on a deliberate shift towards a design-led research agenda. This requires:

1. Prioritising participatory and co-design methodologies to ensure solutions are grounded in the lived realities and values of stroke survivors and clinicians.

2. Embedding principles of inclusive and adaptive design from the outset to create systems that are accessible to the wide spectrum of abilities post-stroke.

3. Conducting rigorous cross-cultural and contextual studies to generate design knowledge that is globally relevant and locally applicable.

4. Integrating ethical considerations of trust and data agency as core drivers of the user experience, not as afterthoughts.

This thesis is positioned as a direct response to this imperative. It moves beyond asking *if* IoT can work, to investigating *how* it must be designed to succeed in the complex reality of stroke recovery. By employing a design-informed, mixed-methods approach to capture and analyse stakeholder perspectives across the UK and Saudi Arabia, this research will generate practical, evidence-based design recommendations. The ultimate aim is to bridge the persistent gap between the theoretical potential of IoT and its effective, equitable, and dignified real-world implementation, thereby contributing a critical design perspective to the future of stroke rehabilitation.

Chapter 3: Methodology

3.1 Overview of Methodological Approach

This chapter outlines the philosophical foundation, methodological rationale, and structured research design adopted in this study. It begins by introducing the pragmatist paradigm and the mixed-methods approach, explaining how they align with the design-led and exploratory nature of the research. It then presents a concise overview of the five sequential phases of data collection and analysis, each phase designed to explore a distinct yet interrelated perspective on the potential of Internet of Things (IoT) technologies in post-stroke rehabilitation. This revised chapter focuses exclusively on the research design and methodological decisions, removing all references to results or findings. Each phase is therefore described in terms of its purpose, participant recruitment, sampling criteria, and procedural design, rather than its outcomes. The chapter concludes with a detailed discussion of ethical considerations, reliability and validity, and the impact of COVID-19 on recruitment and data collection. The overarching aim is to provide a coherent account of how the research systematically integrated both quantitative and qualitative insights to develop empirically grounded and design-informed recommendations for IoT use in stroke rehabilitation. The study followed five interconnected and iterative phases, allowing findings from earlier stages to inform later ones in a process of continual refinement.

The Five Phases of the Study

- **Phase 1 – Online Survey with Healthcare Professionals:** Quantitative phase conducted in Saudi Arabia and the UK to identify professionals' familiarity with IoT, perceived benefits, and barriers to use in rehabilitation.
- **Phase 2 – Workshop 1 with Stroke Survivors:** Qualitative phase exploring user reactions to basic IoT functionalities and their potential support for early rehabilitation activities.
- **Phase 3 – Workshop 2 with Stroke Survivors:** Qualitative phase investigating advanced IoT features such as personalization and integration into daily living routines.
- **Phase 4 – Validation Survey with Healthcare Professionals:** Mixed phase evaluating the clarity, feasibility, and clinical relevance of the proposed IoT-based recommendations.

- **Phase 5 – Semi-Structured Interviews with Design Experts:** Qualitative phase validating the recommendations from a usability and human-centred design perspective.

Together, these phases form a sequential mixed-methods design that integrates quantitative breadth with qualitative depth. Insights from each stage were used to refine subsequent phases, reflecting a pragmatist, design-led orientation that emphasises applied problem-solving, iteration, and the generation of actionable knowledge. This revised methodology chapter consolidates all design, recruitment, sampling, and analysis decisions that were previously dispersed across earlier drafts, thereby presenting a coherent and comprehensive account of the research process. The study adopts a cross-contextual exploratory orientation—rather than a formal two-country comparative design—focusing analytically on the UK and Saudi Arabia while drawing on wider responses only for descriptive breadth. This approach recognises that, while the inclusion of other regions provided global insight into professional perspectives, the main comparative reflection remains limited to these two healthcare contexts, in alignment with the study's scope and ethical approvals.

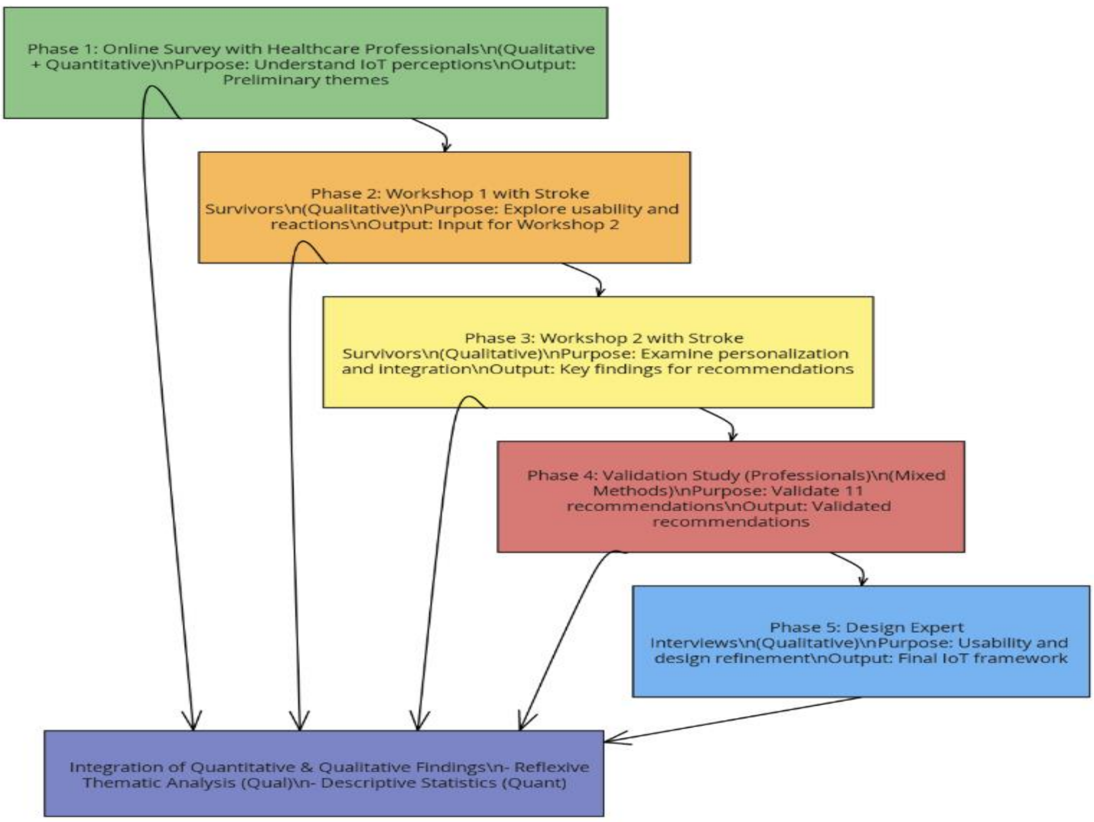

Figure 3.3.1: Study Methodology Workflow – each phase contributed distinct insights: Phase 1 established professional perspectives; Phases 2–3 captured survivor experiences; Phase 4 validated clinical feasibility; Phase 5 refined design principles.

3.1.1 Mixed-Methods Approach

This research employed a sequential mixed-methods approach, grounded in the pragmatist paradigm and shaped by the principles of design research. Pragmatism allows researchers to combine diverse methods to address complex, real-world challenges (Creswell & Plano Clark, 2018; Morgan, 2014). This section has been expanded to clarify why a mixed-methods design was chosen and how it strengthens the credibility and depth of the findings. The integration of quantitative surveys and qualitative workshops/interviews offered complementary insights—quantitative data revealed measurable patterns and professional attitudes, while qualitative data captured experiential nuances, emotional perspectives, and contextual barriers to IoT adoption. This dual structure facilitated triangulation, enabling the validation of emerging themes through multiple forms of evidence (Fetters, 2019; Mays & Pope, 2000). Rather than privileging one type of data over another, the mixed-methods strategy emphasized complementarity, using each dataset to elaborate and clarify the other. This alignment supports the research goal of developing clinically relevant and user-informed design recommendations for IoT-based rehabilitation. In summary, the mixed-methods approach allowed for:

- Integration of quantitative generalizability with qualitative contextual understanding.
- Iterative learning between phases, where each dataset informed the next.
- Cross-validation to enhance methodological rigour and interpretive reliability.

This methodological pluralism ensures that the final recommendations are evidence-based, user-oriented, and adaptable to real-world rehabilitation settings.

3.1.2 The Pragmatist Paradigm

The study is situated within the pragmatist paradigm, which prioritizes practical problem-solving, methodological flexibility, and knowledge derived from real-world experience (Creswell & Plano Clark, 2018). Pragmatism is particularly suited to design-led health research, where diverse stakeholder perspectives must be combined to produce meaningful solutions. This section clarifies the theoretical rationale for choosing pragmatism and how it shaped the design and execution of each research phase. Pragmatism aligns with the study's aim to explore how IoT technologies can be meaningfully integrated into rehabilitation contexts rather than to test a single hypothesis. The paradigm encourages interdisciplinary collaboration, integrating input from healthcare professionals, stroke survivors, and design experts. This ensured the study remained solution-oriented and responsive to participant feedback—core attributes of design research. The flexibility of pragmatism also allowed for methodological adaptation throughout data collection—particularly during the COVID-19 pandemic—without compromising ethical or analytical integrity. This responsiveness mirrors the design thinking process, emphasizing iteration, user engagement, and continual refinement.

3.1.3 Distinguishing Between Stakeholder Perspectives

To achieve a comprehensive understanding of IoT in post-stroke rehabilitation, this study engaged three key stakeholder groups—healthcare professionals, stroke survivors, and design experts—each contributing a unique perspective. This section has been refined to clarify how these perspectives informed different phases of the research, establishing a clear and explicit linkage between each stakeholder group and the methodological structure of the study.

- **Healthcare professionals** contributed insights into clinical practicality, workflow integration, and ethical considerations surrounding IoT use.
- **Stroke survivors** provided first-hand accounts of usability challenges, emotional engagement, and day-to-day barriers affecting rehabilitation adherence.
- **Design experts** evaluated the emerging recommendations for usability, inclusivity, and human-centred design principles.

The distinction between these perspectives ensures that the recommendations are balanced across clinical, experiential, and design domains, bridging the gap between technological feasibility and human need. This triangulation of viewpoints also embodies pragmatic pluralism, strengthening the study's validity through real-world diversity of input.

3.1.4 Pandemic Impact on Research Methodology

The COVID-19 pandemic significantly affected the research's implementation, particularly in recruitment, data collection, and participant diversity. This section has been rewritten to provide a clear account of the methodological adaptations made during this period, focusing on the procedural changes themselves rather than presenting results.

- **Participant Recruitment and Representation**

Due to travel restrictions and institutional safety protocols implemented during the pandemic, the host rehabilitation centre in Saudi Arabia adopted strict scheduling policies to minimise group sizes and manage infection risk. As part of these measures, the centre segregated rehabilitation services by gender, offering sessions for male patients on specific days. Consequently, when Workshop 1 was scheduled, only male stroke survivors were present at the centre and available to participate. This resulted in an all-male participant group for the first workshop. Although this contextual constraint limited gender diversity, it is transparently acknowledged here, and the data have been interpreted with this limitation in mind.

- **Methodological Adaptations During the Pandemic**

To ensure continuity during the pandemic, online recruitment was expanded internationally for healthcare professionals in Saudi Arabia and the UK. The validation study with healthcare professionals (Phase 4) was conducted during this period, using remote methods to gather critical feedback on the emerging recommendations. Remote tools (e.g., video conferencing, shared documents) also supported data collection where in-person contact was not possible. These adjustments preserved the integrity of data triangulation and allowed the study to maintain its cross-cultural scope despite disruptions.

- **Post-Pandemic Additions**

The design expert interviews (Phase 5) were conducted in 2025, following the main data collection period. This phase is not framed as a direct adaptation to the pandemic, but rather as a considered addition made possible by the extended research timeline that resulted from pandemic-related delays. The additional time created an opportunity to incorporate a further layer of disciplinary critique, addressing gaps that had emerged from earlier phases and significantly strengthening the study's contribution to design research. This addition was therefore a consequence of the revised project schedule, not a methodological shift required by the pandemic itself.

- **Reflections on Research Resilience**

This experience highlighted the strength of the pragmatist, mixed-methods framework, whose inherent flexibility allowed the research to remain methodologically robust under real-world constraints. The adaptations also reflected the study’s central theme—the value of IoT and digital tools in maintaining connectivity and continuity of care during disruptions.

3.2 Phase 1: Online Survey with Healthcare Professionals

3.2.1 Rationale and Survey Objectives

The online survey served as the foundational, quantitative phase of this sequential mixed-methods study. Its primary purpose was to collect empirical baseline data from healthcare professionals regarding their understanding, perceptions, and experiences with Internet of Things (IoT) technologies in stroke rehabilitation. The utilization of survey research forms a central component of this study's mixed-methods design, aimed at elucidating the perspectives and experiences of healthcare professionals involved in post-stroke rehabilitation (Creswell & Hirose, 2019). This phase explored how IoT technologies are perceived, adopted, and evaluated within clinical contexts, particularly regarding their role in supporting Activities of Daily Living (ADL).

The survey was guided by four core objectives:

1. **To assess IoT familiarity and knowledge:** Evaluate participants' baseline knowledge and experience with IoT to identify gaps requiring additional training, with a specific focus on the differing healthcare contexts of Saudi Arabia and the UK (Creswell & Plano Clark, 2018).
2. **To identify key rehabilitation challenges:** Understand the difficulties stroke survivors face in ADLs, such as mobility and independence, and explore how IoT might address these challenges (Morgan, 2014).
3. **To explore barriers and facilitators:** Investigate perceived barriers (e.g., data security, usability, cost) and facilitators to IoT adoption in clinical practice.
4. **To inform subsequent qualitative phases:** Identify themes and priorities to shape the design and focus of the subsequent workshops and validation studies, ensuring the research progression was empirically informed (Fetters, 2019).

This approach privileged contextual validity and user-centred iteration over statistical generalisability, aligning with the design-research principles of this thesis.

3.2.2 Survey Design and Instrument Development

The survey was designed to capture healthcare professionals' perspectives by combining quantitative and qualitative methods within a single instrument, following a concurrent mixed-methods approach. This design allowed for the simultaneous collection of quantitative data and qualitative insights, providing a comprehensive overview of practitioners' experiences and perceptions (Creswell & Hirose, 2019).

The instrument comprised 26 questions, organized into two sections:

- **Section 1: Demographics.** This section collected variables such as age, gender, professional role, years of experience, and geographic location to characterize the sample.
- **Section 2: IoT Perceptions and Experiences.** This section contained 23 questions using a five-point Likert scale to quantitatively assess attitudes towards technology usage, familiarity with IoT, perceived benefits, and adoption barriers. Additionally, three qualitative, open-ended questions encouraged detailed feedback on personal experiences, challenges, and innovative ideas related to IoT integration.

The survey design was informed by established technology acceptance frameworks, specifically the Technology Acceptance Model (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003), and adapted for rehabilitation contexts (Brooks et al., 2020). To enhance methodological rigour and face validity, the instrument underwent pilot consultations with physiotherapists and rehabilitation specialists to refine questions for clarity and relevance (Fetters, 2019). The survey instrument is included in Appendix A.

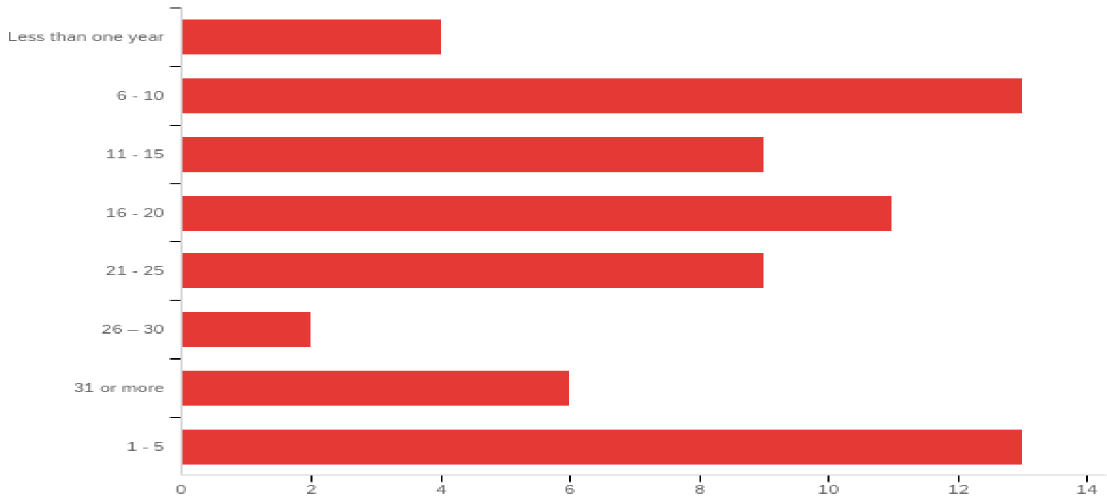

Figure 4.3.2: The Participants' Experience (Distribution of participant experience levels, ordered from least to most experienced)

3.2.3 Participant Recruitment and Sampling Strategy

A purposive sampling strategy, supplemented by snowball sampling, was employed to recruit healthcare professionals actively engaged in stroke rehabilitation in Saudi

Arabia and the United Kingdom. This enabled a meaningful cross-contextual exploration between two distinct healthcare systems (Creswell & Plano Clark, 2018).

Inclusion Criteria: Participants were required to be healthcare professionals over the age of eighteen who specialized in post-stroke rehabilitation, with a minimum of two years of professional experience to ensure informed perspectives.

Recruitment Channels: Recruitment was conducted through professional associations, academic networks, and rehabilitation centres. Key channels included the Association of Chartered Physiotherapists in Neurology (ACPIN) and the Association of Paediatric Chartered Physiotherapists (APCP), alongside specialised LinkedIn groups and professional forums. The target population was occupational therapists and physiotherapists from the UK and Saudi Arabia. These organizations were selected for their close links to the research focus. To increase participation, the survey was also shared on social media platforms, leveraging professional networks.

Sample Description: Data collection over a six-week period yielded 67 valid responses. The final sample comprised 42 physiotherapists and 25 occupational therapists. Geographically, 25 participants were from Saudi Arabia, 17 from the UK, and 16 (approximately 24%) from other countries (including Ireland, Romania, Malaysia, the United States, and Australia). To preserve the UK-Saudi cross-contextual focus, responses from outside these two regions were retained in overall descriptive summaries but were excluded from direct cross-country comparative analysis. This a priori methodological decision protected the internal validity of the primary contextual analysis while acknowledging broader international perspectives. The sample was 72% female and 28% male, which is representative of the gender distribution common in the physiotherapy and occupational therapy professions.

Table 5.3.1: Demographic Profile of Online Survey Participants (n=67)

Characteristic	Category	Number (n)	Percentage (%)
Profession	Physiotherapist	42	62.7%
	Occupational Therapist	25	37.3%
Country	Saudi Arabia	25	37.3%
	United Kingdom	17	25.4%
	Other	16	23.9%
Gender	Female	48	71.6%
	Male	19	28.4%

Note: *"Other" countries contribute to overall descriptives only; UK–Saudi comparisons are restricted to the two focal countries.*

Table 6.3.2: The Educational Achievement of The Participants

#	Answer	%	Count
1	Diploma	5.97%	4
2	Bachelor's degree	46.27%	31
3	DPT degree	1.49%	1
4	Postgraduate diploma	4.48%	3
5	Master's degree	32.84%	22
6	PhD degree	5.97%	4
7	Other (please specify)	2.99%	2
	Total	100%	67

3.2.4 Data Collection and Ethical Considerations

The survey was administered online using the Jisc Online Surveys platform to accommodate geographical distance and pandemic-related restrictions. All respondents received a digital information sheet and consent form outlining the study's objectives, voluntary nature, and data confidentiality procedures. Submission of the survey implied informed consent. No personally identifiable information was collected. This phase received ethical approval from the Lancaster University Faculty of Health and Medicine Research Ethics Committee. All participants provided informed consent, and data were handled in accordance with UK GDPR and university protocols. For a comprehensive discussion of ethical considerations, see Section 3.8.

3.2.5 Data Analysis Strategy

Consistent with the study's exploratory aims and the modest, uneven country sample sizes, the quantitative analysis focused on descriptive statistics. Data from closed-ended items were analysed using frequencies and percentages to summarise participants' familiarity with IoT, perceived benefits, and barriers (Creswell & Plano Clark, 2018). Cross-tabulations were employed to explore variations across key variables such as profession and country (UK vs. Saudi Arabia). Qualitative data from the open-ended responses were analysed using inductive thematic analysis, following the six-step framework outlined by Braun and Clarke (2006). This involved familiarisation with the data, generating initial codes, searching for themes, reviewing potential themes, defining and naming themes, and producing the report. Coding was conducted manually to identify recurrent patterns related to usability, institutional support, and ethical concerns. The quantitative and qualitative findings were then integrated using a "connecting and merging" strategy (Fetters, Curry, & Creswell, 2013). This allowed one data strand to inform and enrich the interpretation of the other, ensuring a nuanced understanding and providing a robust conceptual foundation for designing the subsequent participatory workshops.

3.2.6 Reflexivity and Positionality

As a researcher with a background in physiotherapy, I acknowledge that my clinical perspective may have influenced question framing, potentially biasing emphasis toward functional over interactional design concerns. To mitigate this, the survey instrument was reviewed by supervisors from both design and healthcare disciplines, and iterative pilot testing was used to balance perspectives and enhance validity.

3.3 Phase 2: Workshop 1 with Stroke Survivors

3.3.1 Rationale and Objectives

Workshop 1 represented the first qualitative phase of this research, designed to explore stroke survivors’ perceptions, experiences, and expectations regarding the use of Internet of Things (IoT) technologies in post-stroke rehabilitation. The workshop followed the online survey with healthcare professionals and built directly on its findings, which highlighted concerns about patient readiness and accessibility. This participatory and design-informed approach was consistent with the study’s pragmatist mixed-methods framework, allowing participants to act as co-creators rather than passive recipients (Creswell & Plano Clark, 2018). The primary aim was to gather experiential and reflective feedback on how IoT might help address specific challenges in stroke recovery, focusing on perceived usability, adaptability, and engagement. The workshop was designed to evaluate the perceived potential of IoT rather than its clinical effectiveness, ensuring the phase remained exploratory and user-centred (Morgan, 2014).

Specific objectives were:

1. To assess stroke survivors' initial reactions to IoT technologies and their ease of interaction.
2. To identify contextual barriers to adoption (e.g., language, dexterity, cognitive load, comfort).

3. To capture participants' rehabilitation goals and the perceived usefulness of digital aids.
4. To generate qualitative insights to inform the design and refinement of Workshop 2.

3.3.2 Participant Recruitment and Sampling

A purposive sampling strategy was employed to recruit participants from the Abdul Latif Rehabilitation Centre in Jeddah, Saudi Arabia, in collaboration with the centre's physiotherapy team. The centre's clinical staff identified and pre-screened potential participants based on the study's inclusion and exclusion criteria. Eligible individuals were then provided with study information by the research team, and a final verbal confirmation of understanding and consent was obtained immediately prior to the workshop session. Recruitment and the workshop were conducted over a two-week period. This strategy ensured the inclusion of individuals with varied recovery experiences, functional levels, and rehabilitation settings.

Inclusion Criteria:

- Confirmed diagnosis of stroke within the past five years.
- Medically stable adult currently receiving outpatient or community-based rehabilitation.
- Sufficient cognitive, linguistic, and physical stability to participate in interactive activities for at least one hour.
- Ability to provide informed consent.

Exclusion Criteria:

- Severe cognitive or language impairments that would prevent comprehension or voluntary participation.

A total of twelve (*n* = 12) participants were recruited, all of whom consented and completed the session. All participants were male. This gender limitation was a contextual constraint resulting from COVID-19 restrictions and the gender-based scheduling policies at the rehabilitation centre, a common structure in Saudi healthcare facilities. This is recorded transparently as a factor shaping the sample demographics.

Ethical Approval: This phase received ethical approval from the Lancaster University Faculty of Health and Medicine Research Ethics Committee. All participants provided informed consent, and data were handled in accordance with UK GDPR and university protocols. For a comprehensive discussion of ethical considerations, see Section 3.8.

Table 7.3.3: Workshop 1 Participant Overview

Characteristic	Details
Workshop	Workshop 1
Location	Abdul Latif Rehabilitation Centre, Saudi Arabia
Participants (n)	12
Gender	All Male
Languages Used	Arabic & English
Inclusion Criteria	Adult stroke survivors (diagnosis <5 yrs), medically stable, sufficient cognitive/communication ability.
Notable Features	Conducted during COVID-19; male-only sample due to institutional scheduling policies.

3.3.3 Workshop Design and Procedure

The workshop was a structured, participatory session lasting approximately two hours, designed to be accessible and inclusive. It comprised three main stages:

Part 1: Educational Introduction (30 minutes)

An introductory session built a foundational understanding of IoT using minimal technical jargon. A curated video presentation and live demonstrations in Arabic and English covered:

- An overview of IoT as interconnected devices.
- The relevance of IoT to healthcare and stroke rehabilitation.
- Specific benefits for independence, safety, and home-based exercise. Visual aids and relatable examples were used to illustrate concepts and reduce apprehension.

Part 2: Hands-On Interaction (60 minutes)

This central component provided participants with direct, experiential engagement with a curated set of IoT devices, chosen for their relevance to post-stroke mobility and self-management. Devices included:

1. **Wearable Sensors for Movement Tracking:** Used to monitor physical therapy exercises, providing real-time feedback on range of motion and accuracy.

2. **Smart Home Devices for Independence:** Voice-activated assistants and automated lighting systems were demonstrated to show control of the environment with minimal physical effort.

Participants experimented with the devices under guided supervision. The researcher and a bilingual assistant provided support, ensuring participants felt confident. Observational notes documented verbal feedback, non-verbal cues, usability difficulties, and engagement levels.

Part 3: Guided Feedback and Reflection (30 minutes)

A facilitated group discussion using semi-structured prompts gathered structured qualitative feedback. Key areas of reflection included:

- Ease of Use (interface accessibility, navigation).
- Perceived Usefulness (alignment with rehabilitation goals).
- Comfort and Accessibility (physical comfort, challenges).
- Suggestions for Improvement.

Sessions were audio-recorded, transcribed verbatim, and translated into English for analysis.

3.3.4 Data Collection and Analysis

A dual-phase data collection strategy was employed to capture evolving perceptions:

- **Pre- and Post-workshop Questionnaires:** These gathered baseline data on knowledge, attitudes, and expectations, and later evaluated shifts in awareness and acceptance. Questionnaire data were summarised descriptively to identify trends.
- **Group Discussions and Observational Notes:** These provided rich qualitative data on experiences and viewpoints.

Data Analysis:

Qualitative data from transcripts and field notes were analysed using inductive thematic analysis following Braun and Clarke's (2006) six-phase framework. Codes were generated from participants' statements and grouped into overarching themes reflecting shared perceptions and concerns. To enhance credibility, initial coding was reviewed with academic supervisors. Reflexivity was maintained through journaling to acknowledge the researcher's background as a physiotherapist and its potential influence on interpretation.

3.3.5 Relationship to Workshop 2

Workshop 1 served as the foundational phase for the iterative workshop design. Participants from Workshop 1 were invited to participate in Workshop 2 to allow for continuity and longitudinal comparison. However, the inclusion of new participants who met the same criteria was also permitted to avoid sampling bias and introduce fresh perspectives. Therefore, Workshop 2 was designed to build upon—but not depend exclusively on—the experiences of Workshop 1, aligning with the iterative, exploratory nature of the research design (Creswell, 2014). The insights on usability barriers and personalization needs gathered in Workshop 1 directly informed the refined structure and advanced focus of Workshop 2.

Table 8.3.4: Commentary Summary

Feedback Area	Action Implemented
Lack of detail on recruitment & inclusion criteria	Added rationale for recruitment through physiotherapists and COVID restrictions; included sample size and ethical reference.
Unclear connection between survey and workshop design	Linked Workshop 1 directly to survey themes (technology familiarity, usability).
Method vs results distinction	Rephrased all evaluative statements as *exploratory aims* rather than findings.
Ethical transparency	Specified approval reference, consent procedure, anonymisation method.
Integration with later phases	Clarified that insights from Workshop 1 informed Workshop 2 design.

3.4 Phase 3: Workshop 2 with Stroke Survivors

While Workshop 1 focused on foundational usability and initial reactions to IoT technologies, Workshop 2 advanced the investigation by exploring personalisation features and integration into daily routines. The key differences were: (1) Workshop 2 employed co-design activities rather than hands-on device trials; (2) the focus shifted from 'what works' to 'how it could be personalised'; and (3) participants engaged with hypothetical scenarios rather than demonstrations.

3.4.1 Rationale and Objectives

Workshop 2 advanced the exploration of Internet of Things (IoT) technologies through a more personalized, design-focused approach, building directly upon the insights and participant feedback from Workshop 1. The session was exploratory, aiming to understand how stroke survivors perceive, interpret, and imagine the use of more advanced IoT features in their rehabilitation journey, rather than to test clinical effectiveness (Creswell & Plano Clark, 2018). The workshop emphasized the co-exploration of design possibilities, personalization options, and usability factors that could enhance comfort and independence in daily living (Morgan, 2014).

Specific objectives were:

1. To explore how advanced IoT features (e.g., remote monitoring, adaptive feedback) could be tailored to participants' individual rehabilitation goals.
2. To identify participant preferences for personalization and interface types (e.g., visual, auditory, tactile feedback).
3. To investigate the emotional and social dimensions of IoT adoption, including its influence on confidence, empowerment, and trust.
4. To gather critical reflections on data privacy, ethical considerations, and the meaningful integration of IoT into daily routines.
5. To refine the criteria and focus for the subsequent validation study (Phase 4).

Together, these objectives ensured that Workshop 2 contributed specifically to the integration dimension of the study by exploring how IoT might be woven into the fabric of daily life, rather than merely demonstrating isolated device functions.

3.4.2 Participant Recruitment and Sampling

Recruitment for Workshop 2 was conducted through the same rehabilitation centre as Workshop 1 (Abdul Latif Rehabilitation Centre, Saudi Arabia) to ensure continuity and a supportive environment. The centre's staff again assisted in identifying and pre-screening potential participants against the same inclusion/exclusion criteria used in Workshop 1. The research team provided information sheets to eligible individuals and obtained written informed consent. Recruitment for this second workshop was conducted over a one-week period, following the completion of Workshop 1. The same ethical protocol and inclusion/exclusion criteria from Workshop 1 were applied.

Participant Flow: Of the twelve participants from Workshop 1, five returned for Workshop 2. To maintain a robust sample size and introduce fresh perspectives, seven new participants were recruited, resulting in a total of twelve (*n* = 12) participants for Workshop 2. All participants were male, consistent with the gender-based scheduling policies of the host institution. This mixed group ensured both continuity for longitudinal reflection and diversity of new viewpoints.

Table 9.3.5: Workshop 2 Participant Overview

Characteristic	**Details**
Workshop	Workshop 2
Location	Abdul Latif Rehabilitation Centre, Saudi Arabia
Participants (n)	12 (5 returning, 7 new)
Gender	All Male
Languages Used	Arabic & English
Inclusion Criteria	Adult stroke survivors (diagnosis <5 yrs), medically stable, sufficient cognitive/communication ability.
Notable Features	Iterative design; focused on personalization and advanced features based on Workshop 1 feedback.

3.4.3 Workshop Design, Adjustments, and Procedure

Building on feedback from Workshop 1—which highlighted a need for clearer guidance and simplified interaction—the design of Workshop 2 was refined to be more conceptual and discussion-based. The primary aim was to explore perceptions and preferences through guided exploration rather than structured device trials.

The 2-hour session was structured into three core phases:

Part 1: Conceptual Overview and Advanced Technical Scenarios (30 minutes)

An educational discussion replaced technical demonstrations. Using simplified visual models and real-life scenarios, the session introduced advanced IoT concepts relevant to post-stroke recovery, such as:

- Remote monitoring and data analytics for personalized care plans.
- Adaptive feedback systems that adjust to user ability.
- The potential for reduced clinic visits and enhanced therapy adjustments. This approach encouraged participants to reflect on how such technologies could support independence, safety, and motivation in their own contexts.

Part 2: Interactive Scenarios and Personalized Co-creation (60 minutes)

This segment moved from hands-on device interaction to a participatory design activity. Participants worked in small groups with hypothetical device cards and illustrations depicting use-cases like:

- Home-based exercise reminders and progress tracking.
- Fall-detection sensors and safety alerts.
- Adaptive lighting and environmental control systems. Participants were prompted to describe desirable design features, discuss personalization options, and identify potential concerns related to complexity, cultural fit, and accessibility. Facilitators used open questions to ensure accessibility for all ability levels.

Part 3: Structured Reflection and Feedback (30 minutes)

A semi-structured discussion guided participants through reflection on four key areas derived from the study's objectives: perceived usefulness, personalization, accessibility, and data privacy/ethical considerations. Sessions were audio-recorded and transcribed verbatim for qualitative analysis.

Key Adjustments from Workshop 1:

- **Simplified Materials:** Used visual aids and conceptual cards to reduce cognitive load.
- **Inclusive Communication:** Enhanced bilingual (Arabic/English) facilitation.
- **Focus on Personalization:** Discussions were explicitly guided by prompts about adapting technology to individual needs and abilities.
- **Collaborative Format:** Shifted from demonstration to co-creation, fostering a collaborative dialogue.

3.4.4 Data Collection and Analysis

A consistent two-phase data collection strategy was employed, mirroring the approach in Workshop 1:

- **Pre- and Post-workshop Questionnaires:** These captured baseline knowledge and attitudes, and later evaluated shifts in perceptions, confidence, and acceptance after the workshop. Data were analysed descriptively to identify trends.
- **Audio Recordings and Observational Notes:** Recordings of group discussions were transcribed and translated. Observational notes captured

non-verbal cues, engagement levels, and expressions of confidence or hesitation.

Data Analysis:

Qualitative data were analysed using the same inductive thematic analysis framework (Braun & Clarke, 2006) applied in Workshop 1. This ensured methodological consistency and allowed for the triangulation of themes across both workshops. The analysis focused on generating design-relevant insights into accessibility, personalization, and emotional engagement.

3.4.5 Ethical Considerations

This phase was covered under the same Lancaster University Faculty of Health and Medicine Research Ethics Committee protocol as Workshop 1. All participants provided informed consent, and data were handled in accordance with UK GDPR and university protocols. For a comprehensive discussion of ethical considerations, see Section 3.8. To reduce participant fatigue, the workshop was held in a separate week and included frequent breaks. All participants were reminded of their right to withdraw at any point.

Table 10.3.6: Commentary Summary

Feedback Theme	**Revision Action Implemented**
Clarify that workshops explored *potential*, not *effectiveness*	Re-framed purpose as exploratory, aligned with ethics approval
Explicit participant link between workshops	Added participant numbers and continuity details
Expand data-collection explanation	Described transcription, field notes, and qualitative coding
Align with pragmatist mixed-methods structure	Highlighted iterative and design-informed progression
Strengthen ethical transparency	Specified consent process, data protection, and schedule adjustments

3.5 Phase 4: Validation of IoT-Based Recommendations

3.5.1 Rationale and Objectives

This phase served as a confirmatory stage in the broader mixed-methods design, aiming to validate the set of 11 IoT-based design recommendations generated from the integration of all prior phases (the online survey, Workshops 1 & 2, and the design-expert interviews). The primary purpose was to confirm the professional feasibility, ethical integrity, and contextual relevance of the recommendations within real-world clinical practice, rather than to test their empirical effectiveness (Creswell & Plano Clark, 2018). This expert-driven validation process strengthened the credibility and applicability of the final output, ensuring the recommendations were grounded in professional experience and aligned with established clinical standards and patient-centred care principles (Fetters, 2019).

The specific objectives were:

1. To assess the clarity, practicality, and clinical applicability of the draft IoT-based recommendations.
2. To evaluate the perceived feasibility and scalability of the recommendations across different healthcare environments, specifically in the UK and Saudi Arabia.
3. To identify potential ethical, operational, and implementation barriers (e.g., cost, training, data security, staff workload).
4. To refine and finalize the recommendations based on expert feedback, ensuring they are actionable, sustainable, and contextually adaptable.

3.5.2 Participant Recruitment and Sampling

A purposive sampling strategy was employed to recruit healthcare professionals with direct clinical experience in stroke rehabilitation. Recruitment built upon professional contacts established during Phase 1 (the online survey), ensuring participants had some prior familiarity with the study's context.

Inclusion Criteria:

- A minimum of two years of clinical experience in stroke rehabilitation.
- Currently practicing as a physiotherapist, occupational therapist, or rehabilitation consultant.
- Some familiarity with digital health tools or technology-assisted rehabilitation.
- Fluency in English.

Exclusion Criteria:

- Lack of direct experience with stroke care or rehabilitation technology.

Invitations were distributed via rehabilitation centres, professional associations (including ACPIN and APCP), academic networks, and institutional mailing lists. A total of eighteen healthcare professionals participated, with 10 from Saudi Arabia and 8 from the UK. This diverse sample represented various care settings (acute hospitals, rehabilitation units, community care) and strengthened the cross-contextual validity of the findings.

Table 11.3.7: Validation Phase Participant Overview

Characteristic	Details
Phase	Validation Survey
Participant Type	Healthcare Professionals
Total Participants (n)	18
Geographic Distribution	Saudi Arabia (n=10), United Kingdom (n=8)
Professions	Physiotherapists, Occupational Therapists, Rehabilitation Consultants
Inclusion Criteria	>2 years experience in stroke rehab, familiarity with digital health tools.

3.5.3 Validation Design and Procedure

The validation employed a qualitative expert consultation approach, structured as an online survey. The instrument featured the 11 IoT-based recommendations, each accompanied by short explanatory notes. The design intentionally used open-ended prompts instead of numeric scales (e.g., Likert) to encourage rich, narrative responses, prioritising depth of insight over quantitative precision (Morgan, 2014).

Participants were asked to review each recommendation and provide feedback on:

- **Clarity:** How understandable was the recommendation?
- **Feasibility:** How practical is it to implement in your clinical context?
- **Clinical Applicability:** How well does it align with real-world rehabilitation processes and patient needs?
- **Ethical Soundness:** Are there any ethical concerns (e.g., regarding data privacy or patient autonomy)? Participants were also prompted to identify strengths, weaknesses, and key contextual considerations, such as infrastructure readiness, patient literacy, and staff training requirements.

3.5.4 Data Analysis

Data from the open-ended responses were analysed using thematic analysis (Braun & Clarke, 2006). The coding process was both inductive, allowing new themes to emerge from the data, and deductive, guided by the study's prior findings and theoretical frameworks.

The analysis identified recurrent themes related to the implementation of the recommendations. Overarching themes included:

1. **Feasibility and Scalability:** Concerns and enablers related to cost, interoperability, and adaptability to existing healthcare systems.
2. **Ethical and Privacy Considerations:** Focus on data security, patient consent, and transparency.
3. **Clinical Integration and Training:** The importance of staff readiness, ongoing support, and the integration of IoT into therapeutic workflows.

Triangulation was applied by comparing these validation themes with findings from prior phases to assess consistency and further refine the recommendations (Fetters, 2019). This iterative process ensured the final recommendations were robust and comprehensively vetted.

3.5.5 Ethical Considerations

This phase received ethical approval under the same Lancaster University Faculty of Health and Medicine Research Ethics Committee protocol (Appendix E3). All participants provided informed consent, and data were handled in accordance with UK GDPR and university protocols. For a comprehensive discussion of ethical considerations, see Section 3.8. As this phase involved professional consultation without direct patient interaction or clinical testing, it posed minimal ethical risk.

3.6 Phase 5: Design Expert Interviews

3.6.1 Rationale and Objectives

This phase was conducted to ensure the research outputs were robustly informed by design principles, engaging expert designers and design researchers to critique and refine the IoT-based recommendations from a disciplinary perspective. While earlier stages provided insights from healthcare professionals and stroke survivors, this phase interrogated the draft IoT-based recommendations through a specialist design lens. The objective was to ensure the recommendations were not only clinically feasible but also robustly aligned with core design principles, thereby transitioning the research outputs from being clinically-informed to being design-informed. The involvement of design experts aligns with established frameworks in design research, particularly human-centred design (HCD), co-design, and inclusive design principles (Norman, 2013; Sanders & Stappers, 2008; Clarkson et al., 2013). This interdisciplinary approach bridged the gap between technological innovation and human experience, ensuring the final recommendations prioritised usability, inclusivity, and real-world scalability.

The specific objectives were:

1. To gather expert feedback on the 11 IoT-based recommendations from a design perspective.
2. To assess the feasibility, usability, and inclusivity of the recommendations for implementation.
3. To explore design-specific considerations such as interface simplicity, cultural sensitivity, interoperability, and data ethics.
4. To refine the recommendations into more implementable, user-centred, and ethically robust guidelines.

3.6.2 Participant Recruitment and Sampling

A purposive sampling strategy was employed to recruit design experts from the United Kingdom. The aim was to select individuals with specific, advanced expertise in domains critical to the study: digital health, human-computer interaction (HCI), and participatory/service design.

Inclusion Criteria: Participants were required to have prior professional experience in the design and evaluation of healthcare technologies.

Recruitment was challenging, with a low response rate; however, four experts agreed to participate, providing a depth of specialised knowledge. All participants were approached via email, provided with a participant information sheet, and gave written consent before taking part. Ethical approval for this phase was covered under the broader study approval from Lancaster University's Faculty Research Ethics Committee. For a comprehensive discussion of ethical considerations, see Section 3.8.

Table 12.3.8: Design Expert Participant Profiles

ID	Role/Expertise	Years of Experience	Sector
D1	Lecturer in HCI and Digital Health	12	University
D2	Senior UX Designer, Healthcare Systems	15	Industry
D3	Research Fellow, IoT and Accessibility	10	University
D4	Consultant in Service Design for Health	18	Consultancy

3.6.3 Justification for Sample Size and Reflexive Positioning

The design-expert phase was conducted with a small sample of four participants. While limited in number, this sample was purposefully chosen to prioritise depth of engagement over breadth. In qualitative research, particularly within specialised design contexts, smaller samples are appropriate where the aim is rich, contextualised understanding rather than statistical generalisability (Mason, 2010; Braun & Clarke, 2019). The high level of expertise among participants ensured the insights generated were highly relevant and informed.

From a reflexive perspective, I acknowledge that the sample size was influenced by practical constraints, including the limited availability of design experts. My positionality as a researcher with a professional background in rehabilitation but not formal design training significantly shaped this phase. I entered the interviews with a firm understanding of the clinical problem but an openness to being guided on design solutions. To mitigate potential bias from my enthusiasm for IoT, I actively "bracketed" my assumptions during interviews, explicitly inviting criticism and alternative viewpoints. This stance was fruitful; the experts consistently challenged my clinical perspective, fundamentally strengthening the design contribution of this thesis.

3.6.4 Data Collection Procedure

Semi-structured online interviews were conducted using Microsoft Teams, Lancaster University's approved platform for research, with participants offered the choice of platform based on preference. Each interview lasted 45–60 minutes and was audio-recorded with consent. Prior to the interview, participants were provided with the draft set of 11 IoT-based recommendations derived from prior phases, allowing them to review the material and prepare reflections.

The interview schedule was designed to elicit detailed, critical feedback on:

1. The overall clarity and ambition of the recommendations.
2. Their feasibility from a design and implementation perspective.
3. Considerations for usability, accessibility, and inclusivity.
4. Ethical implications, particularly regarding data privacy and patient autonomy.
5. Specific suggestions for refinement and strengthening.

All interviews were transcribed verbatim, anonymised, and securely stored in accordance with Lancaster University's data management policies and GDPR.

3.6.5 Data Analysis

The interview transcripts were analysed using Reflexive Thematic Analysis (RTA) following Braun and Clarke's (2019) six-phase process: 1) familiarisation with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing potential themes, 5) defining and naming themes, and 6) producing the report.

The coding process was inductive, allowing themes to emerge from the data, but was also sensitised by the structure of the 11 recommendations. This approach ensured the analysis remained grounded in the experts' critiques while staying focused on the study's core outputs. The analytical process prioritised depth of interpretation, transparency in decision-making, and coherence with the study's pragmatist and design-focused orientation.

3.6.6 Rigour and Trustworthiness

- **Thematic Saturation:** While the sample was small, strong thematic convergence was observed across the four interviews, particularly regarding system integration, interoperability, and ethical design, indicating that key issues had been identified.
- **Triangulation:** This phase served as a form of expert validation, triangulating the earlier findings from patients and healthcare professionals with specialised design knowledge.
- **Transparency:** All stages of sampling, consent, data handling, and analysis were carefully documented to ensure auditability.
- **Reflexivity:** As noted in 3.6.3, a reflexive journal was maintained to acknowledge and mitigate the researcher's influence on the data collection and interpretation process.

3.7 Integration of the Mixed-Methods Design

This section explains how the mixed-methods strategy was practically integrated and operationalised across all research phases, ensuring continuity between data sources and maintaining alignment with the study's pragmatist foundation. Rather than presenting each method in isolation, the study adopted a sequential exploratory mixed-methods framework (Creswell & Plano Clark, 2018), where each phase informed and refined the next through an iterative process of design, reflection, and validation. As illustrated in Figure 4, quantitative findings from the online survey shaped the structure and content of Workshop 1, which in turn guided Workshop 2's exploration of personalisation and advanced IoT features. Insights from both workshops then informed the validation survey and design-expert interviews, culminating in the development of the final 11 IoT-based recommendations. This layered integration reflects a “building and merging” typology (Fetters, Curry & Creswell, 2013), ensuring that each phase was conceptually interdependent and contributed progressively to a coherent methodological framework.

At the design level, the initial online survey with healthcare professionals provided the quantitative foundation for subsequent qualitative exploration. The survey identified priority areas such as usability, motivation, safety, and data security, which directly influenced the design of Workshop 1 tasks with stroke survivors. This strategic linkage ensured that the workshops were clinically grounded, addressing real-world rehabilitation challenges identified by professionals while maintaining sensitivity to participants’ lived experiences. Workshop 1 offered experiential insights into everyday usability and participants’ initial impressions of IoT technologies, while Workshop 2 built upon these insights to explore advanced functionalities, personalisation, and integration into daily routines. The two workshops therefore formed a progressive, interconnected sequence rather than separate activities, collectively deepening understanding of how IoT could support stroke rehabilitation in practical and inclusive ways.

At the analytical level, quantitative and qualitative data were integrated iteratively through a “connecting and merging” strategy (Fetters, Curry & Creswell, 2013). Themes that emerged from the reflexive thematic analysis of workshop discussions—such as accessibility, motivation, engagement, and perceived usefulness—were compared with quantitative patterns from the survey. For the survey data, this comparative analysis was conducted on two levels: a primary, focused analysis comparing the UK and Saudi Arabia sub-samples to address the core cross-contextual research focus, and a secondary, descriptive analysis of the full dataset (including the ~24% of participants from other countries) to provide broader international context. This included comparing workshop themes with quantitative patterns from the survey on practitioner confidence and reported barriers to IoT adoption. This dual-level comparative process allowed data strands to interact dynamically, enabling one dataset to inform, refine, and extend the interpretation of another rather than treating them as isolated or confirmatory. Through this iterative linkage, insights about usability challenges, personalisation needs, and engagement strategies were triangulated across professional and survivor perspectives, ensuring that the emerging recommendations were grounded in both clinical evidence and lived experience.

At the interpretive level, findings from all five phases—the online survey, Workshops 1 and 2, the validation survey, and the design-expert interviews—were synthesised to generate the final 11 IoT-based recommendations. This additional layer of disciplinary critique, introduced to strengthen the design contribution of the research, ensured that the final outputs were rigorously vetted from a design perspective. Integration at this stage followed an interpretive and design-informed logic rather than confirmatory triangulation, consistent with the principles of reflexive thematic analysis (Braun and Clarke, 2019) and the pragmatist orientation of the study. The aim was to combine clinical, experiential, and design perspectives into an evidence-informed framework that was both credible and practically applicable. This interpretive synthesis prioritised complementarity over convergence, recognising that the inclusion of multiple perspectives enhances understanding and broadens the transferability of findings.

This multi-stage integration strategy ensured methodological coherence across all phases, transforming potentially fragmented datasets into a connected and cumulative evidence base. Quantitative data contributed breadth by mapping professional attitudes and systemic trends, while qualitative findings provided depth through first-hand accounts and experiential reflection. Together, these complementary strands produced an iterative cycle of design and refinement, aligning with the pragmatist commitment to actionable knowledge (Biesta, 2010) and the design-research ethos of co-creation. Rather than relying solely on simple triangulation, the study's integration process emphasised iterative interaction between datasets, allowing each phase to inform and enrich the next. Together, the five sequential phases transformed discrete methodological activities into a cumulative evidence base, ensuring that design choices, participant insights, and expert validation were cohesively aligned within a pragmatist, design-informed framework. This integration established a clear methodological thread connecting survey findings, workshop experiences, and the final validation stage, thereby strengthening both internal coherence and analytical depth.

3.8 Ethical Considerations

Maintaining ethical integrity was a central guiding principle throughout this research. Because the study involved vulnerable populations—including stroke survivors, many of whom faced physical, cognitive, and emotional challenges—alongside healthcare professionals and design experts, it was conducted under strict ethical oversight to ensure participant safety and dignity. The research adhered to the ethical frameworks and guidance of Lancaster University's Faculty Research Ethics Committee, the British Psychological Society (BPS, 2021), and the General Data Protection Regulation (GDPR, 2018). Ethical considerations were integrated at every stage of the research process rather than treated as an isolated procedural requirement. This approach reflected the pragmatist and design-informed ethos of the study, where respect for participants' autonomy, lived experience, and vulnerability actively shaped methodological choices. Prior to any data collection, full ethical approval was obtained from Lancaster University's Faculty of Health and Medicine (FHM) Research Ethics Committee, covering all participant groups, materials, and data-handling protocols. Subsequent minor amendments, such as the inclusion of the design-expert interviews, were formally reviewed and approved under the same ethics application. To ensure comprehensive protection of participants, ethical safeguards were structured across five interrelated domains:

1. **Informed consent** — ensuring participants fully understood the study aims, procedures, and their rights before taking part.
2. **Privacy and confidentiality** — maintaining anonymity and secure handling of all personal information.
3. **Data protection** — adhering to GDPR principles for secure storage, restricted access, and responsible disposal of research data.
4. **Voluntary participation** — emphasising participants' right to withdraw at any stage without consequence.
5. **Respect for vulnerability** — ensuring that the participation of stroke survivors, in particular, was facilitated sensitively, with accommodations for physical or cognitive limitations.

Together, these domains ensured that ethical practice was not merely procedural but embedded as a core methodological principle that upheld respect, transparency, and accountability throughout the research. All phases of this study were approved by the Lancaster University Faculty of Health and Medicine Research Ethics Committee, with full documentation provided in Appendices E1–E4, including participant information sheets, consent forms, and approval letters.

3.8.1 Informed Consent

Informed consent was treated as an ongoing, dialogic process, not a one-off signature (Orb, Eisenhauer & Wynaden 2001). Every participant—healthcare professional, stroke survivor, or design expert—was provided with a plain-language information sheet and consent form, describing the study's aims, data use, and the right to withdraw without consequence. For the online surveys (Phase 1 and the Validation Survey in Phase 4), consent was obtained electronically; submission of the survey constituted informed consent, consistent with Lancaster University policy, and no personally identifiable data were collected. For workshops with stroke survivors, consent was revisited verbally and visually before and during each session to accommodate potential fatigue or communication difficulties. Simplified language and visual aids were used to support comprehension. Participants were encouraged to reconfirm consent throughout the session, reinforcing autonomy and agency. For design-expert interviews, written information and consent were provided via email before the meeting, and participants reconfirmed consent verbally prior to recording. All participants were informed that their anonymised input might be used in academic publications. This iterative approach to consent upheld transparency, autonomy, and respect, ensuring full alignment with institutional and professional standards (BERA 2018; Bryman 2016).

3.8.2 Privacy and Confidentiality

Privacy was protected through anonymisation, confidentiality protocols, and secure data management across all research phases. Surveys were anonymous by design and administered via secure online platforms (Jisc Online Surveys for Phase 1), while workshop and interview datasets were treated as confidential. Transcripts were de-identified through pseudonyms (e.g., StrokeSurvivor-SA-02, Physiotherapist-UK-03). Indirect identifiers such as clinic names or job titles were generalised to minimise deductive disclosure risks in small samples (BPS 2021). All digital files—including transcripts, survey exports, and consent records—were stored on encrypted, password-protected university servers, accessible only to the researcher and supervisors. A separate encrypted keyfile linking pseudonyms to contact details was maintained and destroyed after transcription verification. No photographs or video data were collected. Field notes were coded consistently using pseudonyms. Data retention followed Lancaster University's data management policy (2023): de-identified data retained for audit purposes, identifiable data destroyed post-verification. Participants could request data withdrawal until the point of anonymisation.

3.8.3 Data Security and IoT Transparency

Although IoT devices were demonstrated during workshops, no live physiological or motion data were collected. Participants engaged with the devices for experiential and educational purposes only. This distinction was clearly communicated during recruitment and reiterated in consent forms. Devices were preconfigured using standard encryption protocols (AES-256, SSL) to simulate secure data handling and educate participants about potential privacy features. By highlighting transparency and data security during demonstrations, the study modelled ethical IoT usage, aligning with digital ethics best practice (ICO 2021). Participants were assured that their engagement was fully illustrative and that no data capture or monitoring occurred. This transparency enhanced trust and participation.

3.8.4 Voluntary Participation and Right to Withdraw

Participation was entirely voluntary. Stroke survivors, in particular, were reminded that withdrawal could occur at any point without explanation or consequence. This reassurance was crucial for participants recruited through healthcare centres, mitigating perceived power imbalances between researcher and clinician. To ensure inclusion, participants experiencing fatigue or cognitive strain could pause or leave sessions at any time. By foregrounding voluntariness, the research safeguarded participants' psychological well-being and autonomy, ensuring that engagement remained ethically sound and mutually respectful.

3.8.5 Ethical Reflexivity

Ethical practice was reflexively reviewed throughout the project via regular supervisory consultations and ethics audits. This reflexive process ensured that ethical awareness evolved alongside methodological adaptation, reflecting the pragmatist orientation of the study. Researcher positionality—balancing the dual roles of technologist and rehabilitation researcher—was explicitly acknowledged to prevent bias and overinterpretation of participants' experiences. Overall, embedding ethics within every stage of the research design and implementation enhanced both credibility and participant trust, allowing for authentic and respectful co-production of knowledge.

3.9 Reliability and Validity

In any research study, ensuring reliability and validity is about maintaining trustworthiness, reflexivity, and methodological coherence rather than simple replication of results. In this mixed-methods, design-informed research, reliability refers to the consistency and dependability of interpretations, while validity emphasises the credibility, authenticity, and real-world applicability of findings (Mays & Pope, 2000; Lincoln & Guba, 1985). Given the exploratory and participatory nature of this study on Internet of Things (IoT) technologies in post-stroke rehabilitation, both concepts were adapted to suit a pragmatist paradigm, in which knowledge is valued for its practical use and real-world consequences (Creswell & Plano Clark, 2018; Morgan, 2014). To enhance reliability and validity, I applied data triangulation to integrate insights from multiple sources: (1) quantitative data from healthcare professionals' online surveys, (2) qualitative feedback from stroke survivors during Workshops 1 and 2, and (3) professional reflections gathered during the validation phase. This combination ensured that findings were cross-validated conceptually and sensitive to both technical and experiential perspectives, strengthening the interpretive credibility of the study (Fetters, Curry & Creswell, 2013). For instance, if participants identified usability challenges in the survey, I observed whether similar concerns appeared during workshop discussions or validation feedback. Through this iterative comparison, I strengthened the coherence and interpretive reliability of the findings across phases.

3.9.1 Ensuring Reliability

Reliability in this study referred to the dependability and consistency of interpretations across participant groups, rather than the mechanical replication of results. Within the pragmatist paradigm, reliability is not about identical outcomes but about the stability of insights that are contextually grounded and meaningful for practical application (Morgan, 2014; Teddlie & Tashakkori, 2009). Pragmatism prioritises the value of knowledge through its usefulness in guiding decision-making and design. To ensure procedural reliability, core elements of the workshop design were standardised—including instructions, timing, and structure—while still allowing flexibility for natural discussion and creative feedback. This balance preserved the authenticity of qualitative input while preventing procedural inconsistencies. Pilot testing of the online survey also enhanced reliability by identifying ambiguous items and refining question wording. Similarly, supervisory reviews and peer debriefings helped verify that the survey and workshop instruments measured the intended constructs and produced stable insights. I also maintained an audit trail throughout data collection and analysis, documenting key methodological decisions, coding iterations, and reflective notes. This record of decision-making supported the dependability and confirmability of the research (Lincoln & Guba, 1985). Reflexive journaling, maintained from the early design stages through final analysis, allowed me to recognise how my dual role—as researcher and practitioner—might influence interpretation, thereby enhancing reflexive reliability (Berger, 2015). Survey reliability was strengthened by combining closed-ended Likert-scale items (for measurable comparisons) with open-ended prompts (for contextual elaboration). In workshops, all participants received identical introductory briefings about IoT devices to ensure comparable understanding before providing feedback. This consistency allowed for fair comparison of responses while maintaining the participant-centred and design-oriented spirit of the study (Biesta, 2010; Morgan, 2014).

3.9.2 Ensuring Validity

Validity addressed whether the research truly captured participants' perceptions, experiences, and needs in relation to IoT applications in stroke rehabilitation. Within the mixed-methods framework, validity was understood as a layered concept encompassing construct, content, face, ecological, and transferability dimensions.

- **Construct validity** was achieved by ensuring that all survey and workshop instruments aligned directly with the core constructs of the study—rehabilitation progress, usability, motivation, and independence. For example, survey questions on usability addressed clarity of feedback, ease of navigation, and satisfaction with device interaction, ensuring that the measures reflected the theoretical framework underpinning IoT engagement.
- **Content validity** was strengthened through the inclusion of both professional and survivor perspectives, capturing the intersection between clinical feasibility and user experience. This comprehensive coverage would not have been achieved if only one group had been included.
- **Face validity** was maintained by using accessible, non-technical language and clear visual materials during workshops, ensuring that all participants—

regardless of cognitive or linguistic limitations—could meaningfully engage and respond.

- **Ecological validity** was enhanced by structuring workshop activities to mirror real-world rehabilitation routines. Participants interacted with IoT demonstrations and discussed scenarios such as home-based balance monitoring or motivation through feedback apps, thereby ensuring that insights were grounded in realistic practice (Braun & Clarke, 2019).
- **Transferability (External Validity)** was approached through rich contextual documentation, acknowledging the geographic and cultural boundaries of the study—Saudi stroke survivors and healthcare professionals from both Saudi Arabia and the UK. While not statistically generalisable, these comparative insights reveal transferable lessons for similar rehabilitation systems integrating IoT technologies.

Additionally, the validation survey reinforced internal validity, confirming that the 11 IoT-based recommendations derived from earlier phases were perceived as feasible, clear, and contextually relevant by practising professionals. This iterative verification reflects the pragmatic aim of credibility through application, ensuring that validity was tied to usefulness and real-world impact.

3.9.3 Limitations to Reliability and Validity

Despite rigorous efforts to ensure methodological integrity, certain contextual factors influenced interpretation. Variations in participants' technological literacy and physical ability affected the way individuals interacted with IoT demonstrations and the level of depth in their feedback. However, these variations were not treated as methodological weaknesses but as valuable reflections of real-world diversity, highlighting the inclusivity challenges inherent in designing for heterogeneous user groups (Sanders & Stappers, 2014). While external validity was bounded by the specific participant populations—Saudi stroke survivors and healthcare professionals from Saudi Arabia and the UK—this cultural and professional diversity enriched the data by exposing contextual nuances and systemic contrasts between healthcare models. Consequently, while the findings are not statistically generalisable, they are transferable to comparable rehabilitation settings where IoT adoption is emerging. Finally, recognising the limitations of small-sample qualitative phases, I mitigated bias through triangulation, supervisory peer debriefing, and detailed contextual reporting.

By documenting decision trails, reflexive notes, and participant demographics, the study meets Lincoln and Guba's (1985) four trustworthiness criteria—credibility, transferability, dependability, and confirmability. In sum, the methodological approach prioritised trustworthiness, reflexivity, and contextual sensitivity, ensuring that the findings are not only theoretically sound but also practically relevant. The diversity of participant perspectives across settings and disciplines strengthens the thesis's contribution to developing inclusive, design-informed IoT solutions for post-stroke rehabilitation, grounded in both empirical evidence and human experience.

3.10 Potential Biases and Mitigation Strategies

Recognising and mitigating bias was central to maintaining the credibility and transparency of this mixed-methods, design-informed research. Bias may arise from multiple sources — the researcher, participants, sampling choices, or analytic procedures — and can affect how data are interpreted. Anticipating these risks allowed me to incorporate strategies that enhanced trustworthiness and reflexivity, ensuring that findings reflected participants' authentic perspectives rather than researcher assumptions. The following subsections discuss key sources of potential bias and the corresponding mitigation strategies applied throughout the study.

3.10.1 Researcher Bias

Because I designed the study, facilitated workshops, and analysed data, there was a possibility that my background as a physiotherapy researcher and my enthusiasm for IoT could influence interactions or interpretations. To counter this, I adopted a reflexive and transparent approach throughout the research process (Finlay, 2002; Berger, 2015). I maintained a reflexive journal documenting assumptions, expectations, and emotional responses during data collection and analysis. This helped me consciously recognise where my professional perspective might colour interpretation. Through bracketing (Tufford & Newman, 2010), I set aside pre-existing beliefs about IoT's promise to remain open to participants' lived experiences. Investigator triangulation further strengthened rigour. My supervisors regularly reviewed the thematic coding, providing alternative readings and challenging emerging assumptions. Feedback from health-care professionals and design experts was also sought during analysis, ensuring that interpretations were grounded in diverse expertise. These practices align with Lincoln and Guba's (1985) trustworthiness criteria of dependability and confirmability and are consistent with design-oriented reflexive inquiry (Nowell et al., 2017).

3.10.2 Selection and Sampling Bias

Selection bias can occur when participants are not representative of the broader population. Given the voluntary recruitment approach, there was a risk that stroke survivors who participated were more technologically confident or motivated than average, and that professionals who joined the online survey were those already engaged with digital health. To mitigate this, I used purposive sampling to achieve variation in age, rehabilitation needs, gender, and technological literacy among stroke survivors, and diversity of role and experience among healthcare professionals. This ensured a breadth of perspectives while accepting that the goal was transferability rather than statistical generalisability. It is important to clarify that this sampling approach does not undermine the purpose of exploring the design of IoT. The research was not intended to produce generalisable results but rather to generate rich, contextual insights into stakeholder perspectives – a goal for which purposive sampling is well-suited. I explicitly acknowledged these contextual boundaries in interpreting results, framing them as insights relevant to similar healthcare settings where IoT adoption is emerging – particularly in Saudi Arabia and the UK, which provided complementary systemic contrasts. This aligns with the pragmatist stance, valuing practical applicability and contextual understanding over universal generalisation (Creswell & Plano Clark, 2018; Morgan, 2014).

3.10.3 Confirmation Bias

Confirmation bias refers to a tendency to privilege data that support one's expectations. In this project, there was a risk of focusing on IoT's potential benefits while under-representing its limitations. To minimise this, I intentionally sought both positive and critical reflections from participants. During workshops, I prompted discussion not only of perceived advantages but also of frustrations, accessibility barriers, and ethical concerns. In data analysis, negative or contradictory cases were coded and discussed with supervisors to maintain interpretive balance. The validation survey further helped counter confirmation bias by asking independent professionals to appraise the clarity and feasibility of the 11 IoT-based recommendations, verifying that they represented realistic and balanced perspectives rather than selective enthusiasm.

3.10.4 Social Desirability Bias

Social desirability bias occurs when participants respond in ways they believe are expected. This risk was salient during group workshops, where participants might have felt pressure to appear cooperative or positive toward technology. To address this, I emphasised at the beginning of each session that there were no right or wrong answers, and that constructive criticism was equally valuable. Participants were encouraged to speak in their own language when possible, fostering comfort and authenticity. Feedback forms and surveys were anonymised to protect privacy and reduce perceived evaluation. I also employed indirect questioning, asking what challenges “stroke survivors in general” might face when using IoT, enabling participants to share critical perspectives without self-consciousness. These steps supported the study’s ethical commitments to autonomy and psychological safety, ensuring that the data reflected genuine rather than performative engagement.

3.10.5 Attrition and Engagement Bias

Although this research was not longitudinal, attrition bias was still considered. Stroke survivors sometimes experienced fatigue, cognitive strain, or scheduling difficulties that could limit workshop participation. To mitigate this, sessions were designed to be flexible and participant-centred, allowing rest breaks, optional task adjustments, and shorter engagement periods when needed. This inclusive structure not only minimised attrition risk but also yielded valuable insights into how fatigue, accessibility, and attention affect the practical adoption of IoT in rehabilitation. Observing variations in engagement became an analytical lens for understanding real-world usability and device design needs (Lincoln et al., 2000; Sanders & Stappers, 2014).

3.10.6 Integrating Bias Mitigation within the Mixed-Methods Design

Throughout the sequential phases, bias mitigation was embedded into the mixed-methods integration process. The pragmatist orientation required transparency in how data from different strands informed each other (Creswell & Plano Clark, 2018). During design integration, survey insights shaped workshop focus areas, preventing researcher preference from driving topic selection. During analysis, I compared qualitative themes with quantitative trends to identify convergent and divergent viewpoints. Finally, during interpretation, peer review and validation feedback ensured that resulting recommendations reflected multiple standpoints. Documenting this iterative process in an audit trail enhanced accountability and provided evidence of reflexive triangulation, reinforcing the study's credibility and methodological coherence with Section 3.9 on reliability and validity.

3.11 Methodological Limitations

A rigorous research study requires not only a robust methodology but also a transparent acknowledgment of its constraints. This section details the methodological limitations of this study, outlining their potential impact on the interpretation of the findings and the generalisability of the recommendations. By explicitly addressing these issues, this research upholds the principles of trustworthiness, credibility, and reflexive integrity (Lincoln & Guba, 1985).

3.11.1 Sampling and Representativeness

The sampling strategies across all phases, while appropriate for an exploratory, design-informed study, present limitations regarding statistical generalisability.

- **Modest Sample Sizes:** The sample sizes for both the survey (*n*=67) and the workshops (*n*=12 each) were modest. In healthcare research focusing on specialised populations, such sizes are not uncommon and can yield rich, meaningful data (Creswell & Hirose, 2019). However, they preclude broad statistical generalisation. The findings should be interpreted as providing in-depth, contextual insights and transferable lessons, rather than representing the entire populations of healthcare professionals or stroke survivors.
- **The UK/Saudi Arabia Contextual Focus:** The study was framed as a cross-contextual exploration between the UK and Saudi Arabia. A key limitation was the inclusion of respondents from other countries (approximately 24% of the survey sample). To protect the internal validity of the UK/SA analysis, these responses were excluded from direct comparative analysis, but their presence introduces a complexity in neatly characterising the study as a strict two-country comparison. The findings are therefore most relevant to healthcare contexts similar to those of the UK and Saudi Arabia, with the international responses providing supplementary, global perspective.
- **Gender Imbalance in Workshops:** Due to COVID-19 restrictions and the gender-based scheduling policies of the host rehabilitation centre in Saudi Arabia, both workshops were conducted with all-male participants. This was a significant contextual constraint that limits the transferability of the workshop findings regarding gender-specific perspectives on IoT adoption. The insights

are deeply valuable for understanding male stroke survivors' experiences but cannot speak to the potential perceptions, barriers, or preferences of female stroke survivors in the same context.

- **Design Expert Sample Size:** The sample of four design experts, while providing a depth of specialised knowledge, is small. However, given the high level of expertise and the observed thematic saturation on key issues like integration and ethics, the feedback was sufficiently rich to meet the phase's objective of providing deep, design-focused critique (Mason, 2010).

3.11.2 Methodological Design and Implementation

The chosen methodologies, though well-justified, inherent certain constraints.

- **Self-Reported Data and Social Desirability Bias:** The survey and workshop data relied on self-reported perceptions, attitudes, and intentions. Participants, particularly in a group setting, may have been influenced by social desirability bias, providing responses they believed were expected or favourable. While mitigation strategies were employed (e.g., anonymity in surveys, emphasising the value of critical feedback in workshops), this potential bias must be acknowledged.
- **The Demonstrative Nature of IoT Engagement:** A fundamental limitation is that the workshops were designed to explore *perceived potential*, not to measure clinical efficacy. Participants interacted with IoT devices in a controlled, demonstrative setting over a short period. Their positive feedback reflects a reaction to the *idea* and initial experience of the technology, not evidence of its long-term therapeutic effectiveness, adherence rates, or sustained usability in a home environment. This distinction is critical and was a deliberate parameter of the ethical approval and research design.
- **Researcher Positionality:** As a researcher with a clinical background in physiotherapy, my perspective inherently shaped the study, from the framing of survey questions to the facilitation of workshops and the interpretation of data. While reflexivity and supervisory reviews were used to mitigate this, a potential bias towards functional rehabilitation outcomes over purely interactional or aesthetic design considerations may persist.

3.11.3 Scope and Generalisability

The scope of the study defines the boundaries of its conclusions.

- **Exploratory versus Confirmatory:** This research was explicitly exploratory and design-led. It successfully identified key themes, barriers, and facilitators, and generated a set of evidence-informed recommendations. However, it does not *test* these recommendations through controlled implementation. The validation and design expert phases assessed *perceived* feasibility and design soundness, not empirical outcomes.
- **Contextual Specificity:** The workshop findings are deeply rooted in the specific cultural and institutional context of a single rehabilitation centre in Saudi Arabia. The survey incorporated perspectives from the UK and other countries, but the rich, experiential data from survivors is context-specific. This limits the direct transferability of findings to other cultural or healthcare settings without adaptation.
- **Focus on Specific Stakeholder Groups:** The study engaged three key stakeholder groups: healthcare professionals, stroke survivors, and design experts. It did not include other potential stakeholders, such as hospital administrators, policymakers, or technology developers, whose perspectives on cost, scalability, and implementation would be crucial for moving the recommendations into practice.

In conclusion, these limitations do not undermine the value of the study's findings but rather define the parameters within which they should be understood. They highlight that the contributions of this research lie in its conceptual and practical groundwork—generating foundational insights, a robust set of design-informed recommendations, and a clear agenda for future research involving longitudinal studies, broader sampling, and the empirical testing of IoT interventions in real-world rehabilitation contexts.

Chapter 4: Online Survey

4.1 Introduction

This chapter presents the results of the online survey conducted with healthcare professionals to explore their perspectives on the use of Internet of Things (IoT) technologies in post-stroke rehabilitation. As detailed in Chapter 3, the survey employed a mixed-methods design, recruiting healthcare professionals from the UK and Saudi Arabia. The purpose was to capture their familiarity with connected devices, perceived benefits and challenges, and views on how these technologies could enhance patient care and clinical practice. The findings provide an empirical foundation for the subsequent qualitative phases of the research, establishing a clear baseline understanding of professional attitudes that shaped the design and focus of the following workshops.

4.2 Survey Findings: Technology Awareness and Perceptions

This section presents the key findings from the online survey of 67 healthcare professionals—primarily physiotherapists and occupational therapists—from the United Kingdom (UK) and Saudi Arabia, with additional responses from Ireland, Malaysia, Australia, Romania, and the United States. International responses are included in descriptive summaries; comparative interpretation focuses on the UK and Saudi Arabia, in line with the study's cross-country design.

4.2.1 Awareness and Familiarity with IoT Devices

Respondents showed moderate awareness of connected technologies in healthcare. While 62.7% viewed IoT as an innovative addition to rehabilitation practice, fewer than half reported direct awareness of medical-grade IoT systems (e.g., continuous medication monitors, insulin delivery systems, wearable motion sensors). Awareness was higher for consumer devices (smartphones, smartwatches, activity apps) than for clinical systems. Only 17.9% had ever used connected devices in professional practice—and where use occurred, it typically involved general digital tools (fitness trackers, tablets, voice-activated assistants) rather than specialist clinical devices. This awareness–use gap indicates that IoT integration in rehabilitation is at an early stage and that structured professional education is needed to translate curiosity into confident clinical use.

Table 13.4.1: The Modes of Delivery for Advanced Treatments

#	Answer	%	Count
1	Individual face-to-face appointments	14.93%	10
2	Home-based programme only/self-management	7.46%	5
3	Combination of face-to-face and home-based programme	64.18%	43
4	Group class	5.97%	4
5	Other (please specify)	7.46%	5
	Total	100%	67

Table 14.4.2: The Effectiveness of Connected Devices on Patient Recovery Time

#	Answer	%	Count
1	Yes, within 3 months	11.94%	8
2	Yes, within 6 months	11.94%	8
3	Yes, within 12 months	7.46%	5
4	Yes, greater than 12 months	7.46%	5
5	No	37.31%	25
6	Further comments:	23.88%	16
	Total	100%	67

4.2.2 Perceived Benefits of IoT in Rehabilitation

Despite limited hands-on experience, respondents articulated clear potential benefits for stroke rehabilitation, including:

- **Remote monitoring** to track progress beyond clinical environments.
- **Real-time feedback** to improve adherence to home programmes.
- **Personalisation** through data-driven tailoring of exercise intensity/frequency.
- **Improved communication** and continuity via secure data sharing among clinicians, patients, and caregivers.

Open-ended comments emphasised IoT's role in extending access in rural or resource-limited areas (a theme especially noted by Saudi respondents). UK participants frequently highlighted efficiency gains and better integration with existing digital pathways within the NHS. Overall, professionals favoured hybrid care, combining in-clinic supervision with home-based continuity.

4.2.3 Barriers and Challenges to Implementation

Enthusiasm was tempered by practical constraints. The most frequently cited barriers were:

- **Limited training and institutional support: ~74%** reported insufficient education/guidance on IoT use in rehabilitation.
- **Data privacy and ethical concerns: ~68%** mentioned confidentiality/security risk, particularly for cloud-based systems.
- **Cost and infrastructure:** device purchase/maintenance and lack of IT support constrained adoption, especially outside large centres.
- **Patient readiness and cognitive load:** some stroke survivors struggle with digital literacy, interface complexity, or memory/attention demands.
- **Lack of clinical guidelines:** respondents sought clearer, evidence-based frameworks for IoT deployment in rehabilitation.

Together, these constraints indicate that technological readiness requires aligned investment in infrastructure, training, governance, and patient/caregiver education.

4.2.4 Overall Attitudes toward IoT Adoption

Most respondents (77.6%) agreed that connected devices have a legitimate role in post-stroke rehabilitation. Future-use intentions were cautiously positive:

- **53.7%** “somewhat likely” to adopt;
- **37.3%** “very” or “extremely likely”;
- **1.5%** rejected use outright.

Professionals preferred hybrid models that maintain therapeutic relationships while leveraging digital monitoring. In short, conceptual acceptance is high, but implementation confidence depends on support for training, workflow fit, and regulatory compliance.

4.3 Comparative Analysis: Perspectives from the United Kingdom and Saudi Arabia

This section presents a focused comparison of survey responses from healthcare professionals in the United Kingdom (UK, *n*=17) and Saudi Arabia (KSA, *n*=25). The analysis illustrates how differences in healthcare system maturity, infrastructure, and cultural context shape professional attitudes towards IoT adoption in stroke rehabilitation. While both groups recognised the potential of IoT, their readiness, primary concerns, and implementation priorities diverged significantly, providing critical context for the design-led framework developed in this thesis.

4.3.1 Readiness and Perception: Enthusiasm vs. Cautious Integration

A quantitative comparison of core attitudes reveals distinct patterns of technological readiness between the two cohorts, as summarised in Table 4.3.

Table 15.4.3: Comparative Readiness and Perceptions (UK vs. Saudi Arabia)

Dimension	United Kingdom (n=17)	Saudi Arabia (n=25)	Significance & Context
View of IoT as Innovative	**~58.8%** (Very/Extremely Innovative)	**~72.0%** (Very/Extremely Innovative)	Saudi practitioners showed higher stated enthusiasm, aligning with national digital transformation goals (e.g., Vision 2030).
Perception of IoT as Essential	**~29.4%** (Definitely/Probably Essential)	**~44.0%** (Definitely/Probably Essential)	Saudi respondents were more likely to perceive IoT as central to future practice, likely viewing it as a tool to bridge service gaps.
Likelihood of Future Use	**~47.0%** (Very/Extremely Likely)	**~56.0%** (Very/Extremely Likely)	Both groups showed strong potential for adoption, with a slightly stronger inclination

			among Saudi practitioners.
Preferred Care Model	**~70.6%** favoured a Hybrid Model	**~68.0%** favoured a Hybrid Model	A strong, shared preference for a hybrid approach underscores that IoT is seen as an augmentative tool, not a replacement for human interaction.

The data indicates that while conceptual acceptance is high in both contexts, practitioners in Saudi Arabia express a notably stronger conviction in IoT's essential and innovative role. This aligns with the region's strategic focus on technology as a lever for rapid healthcare expansion. In contrast, UK responses reflect a more cautious optimism within a mature, regulated system like the NHS, where interest centres on efficiency and continuity of care. Crucially, the overwhelming and shared preference for a hybrid care model across both countries validates a core premise of this research: technology must augment, not replace, the therapeutic relationship.

4.3.2 Barriers and Design Implications: Diverging Challenges, Converging Principles

Qualitative analysis of implementation barriers revealed a clear divergence in primary concerns, which directly informed the context-sensitive design mandates of this study, as detailed in Table 4.4.

Table 16.4.4: Comparative Barriers and Design Priorities

Barrier Theme	United Kingdom (UK) Focus	Saudi Arabia (KSA) Focus	Implication for Design Framework
Data Privacy & Governance	**Dominant Concern.** Explicitly cited GDPR compliance, ethical	**Moderate Concern.** Focus was less on specific regulation and more on	**Mandate for Configurable Data Transparency:** Systems must foreground security,

	oversight, and secure institutional approvals.	general data security and trust in cloud infrastructure.	provide clear data ownership models, and be designed for regulatory compliance.
Cost & Infrastructure	**Secondary Concern.** Cited as a barrier to device procurement and dedicated staff training time.	**Primary Obstacle.** Frequently cited high device costs, lack of technical support, and the need for foundational infrastructure development.	**Mandate for Frugal Innovation & Adaptive Simplicity:** Solutions must be cost-effective, low-bandwidth, and designed for environments with limited technical support.
System Integration	**High Concern.** Focused on interoperability with existing systems (e.g., EHRs) and avoiding increased administrative burden.	**Moderate Concern.** Emphasised the need for system-level staff training rather than integration with legacy digital systems.	**Mandate for Interoperability by Design:** Clinical value is contingent on seamless integration into existing workflows without creating extra work.
Cultural Context	Strong emphasis on **Patient Autonomy** and individual oversight.	Strong emphasis on **Family Involvement** in monitoring and a shared responsibility for care.	**Mandate for a Human-in-the-Loop Service Model:** Design must enable configurable access to accommodate familial involvement while protecting patient privacy.

The contrasting barriers illustrate that successful IoT implementation cannot follow a one-size-fits-all approach. In the UK's established system, the primary hurdles are integration into stringent ethical and workflow frameworks. Conversely, the KSA context is constrained more by economic and infrastructural capacity, necessitating solutions that prioritise affordability and robustness. Practitioner narratives encapsulate this divide: a UK physiotherapist stressed, “Technology is an excellent supplement, but rehabilitation must remain personal,” while a Saudi occupational therapist highlighted IoT’s potential for access, noting, “IoT can help us reach patients in villages where rehabilitation centres do not exist.”

4.3.3 Synthesis and Forward Link

This comparative analysis confirms that the perceived value and feasibility of IoT are deeply contextual. These insights were instrumental in shaping the subsequent phases of this research. The design of Workshop 1 and the development of the Four-Principle Framework (Chapter 8) were directly informed by these distinct national priorities, ensuring that the exploration of IoT solutions was grounded in the practical realities and cultural norms identified by healthcare professionals in both the UK and Saudi Arabia.

4.4 Integration of Findings and Design of Workshop 1

The survey findings played a crucial role in shaping the design, structure, and focus of Workshop 1, ensuring that it directly addressed the realities, perceptions, and challenges expressed by healthcare professionals. Insights from both the quantitative and qualitative data provided a strong foundation for developing participant activities, the technology demonstrations, and the discussion themes used during the workshop phase.

4.4.1 From Professional Perspectives to Survivor Engagement

The online survey revealed that while healthcare professionals generally viewed IoT technologies positively, they highlighted practical barriers such as limited training and patient readiness issues. These findings directly informed the design of Workshop 1, shifting the focus from professional feasibility to user-centred inquiry. The workshop was therefore designed to explore stroke survivors' perceptions using real-world examples of connected devices that mirrored the rehabilitation scenarios discussed by survey participants, creating a coherent link between the professional perspective on feasibility and the user perspective on usability and lived experience.

4.4.2 Addressing Knowledge Gaps and Real-World Context

Professionals’ feedback on the importance of education and accessibility guided the creation of explanatory materials and visual aids for Workshop 1. The video presentation introduced IoT in simple, practical terms—covering wearables, sensors, and home-based monitoring systems—to ensure participants could engage regardless of prior technical familiarity. These materials were designed to demystify

IoT while maintaining a focus on its relevance to everyday post-stroke challenges such as mobility, exercise adherence, and communication with therapists. In line with the survey's findings that most clinicians supported hybrid models of care, Workshop 1 incorporated discussion prompts around how technology might supplement—rather than replace—traditional rehabilitation. This balance reflected the participants' concerns about maintaining human interaction and ethical oversight while adopting digital solutions.

4.4.3 Building on Cross-Country Insights

The comparative analysis between UK and Saudi Arabia respondents informed the cultural and contextual framing of Workshop 1 activities. Saudi professionals' emphasis on family involvement and infrastructure limitations inspired the inclusion of examples showing how IoT could operate in home-based, family-supported settings. Meanwhile, the UK participants' focus on data privacy and integration into clinical pathways influenced the inclusion of prompts about safety, regulation, and clinician–patient communication. This ensured that Workshop 1 reflected not only international perspectives but also the unique cultural considerations relevant to stroke rehabilitation in Saudi Arabia—the primary site of the workshop implementation.

4.4.4 Linking Quantitative and Qualitative Insights to Design

By combining the statistical evidence (e.g., 62.7% of professionals viewing IoT as innovative but only 17.9% having used connected devices) with thematic patterns from open-ended responses, the research identified five design priorities that informed Workshop 1:

1. **Ease of use and accessibility** – devices must be simple enough for daily use by patients with cognitive or motor impairments.
2. **Personalisation and adaptability** – technologies should allow individualised progress tracking.
3. **Patient motivation and engagement** – systems should encourage active participation and feedback.
4. **Ethical assurance and privacy** – concerns about data handling should be addressed clearly.
5. **Integration with current care models** – IoT should complement, not replace, human interaction.

These priorities were transformed into interactive discussions and design-thinking exercises in Workshop 1, where stroke survivors reflected on similar issues from their own experiences.

In summary, the online survey functioned as a formative phase, grounding the qualitative exploration in authentic professional insight. The survey data established clear themes—enthusiasm tempered by caution, potential limited by awareness—that directly shaped how IoT concepts were introduced to survivors in Workshop 1. This integration of findings exemplifies the pragmatist mixed-methods design of the study, where each phase built upon the previous one to refine understanding, ensuring coherence between the survey's professional insights and the workshops' experiential exploration.

4.5 Discussion of Findings, Themes, and Implications

The online survey provided critical insights into how healthcare professionals perceive the potential, challenges, and contextual dynamics surrounding the integration of Internet of Things (IoT) technologies into post-stroke rehabilitation. The findings align with global trends in digital health adoption while revealing country-specific factors that shape readiness and attitudes in the United Kingdom (UK) and Saudi Arabia. This section synthesises the results, discusses emerging themes, and explores their implications for clinical practice, technology design, and subsequent phases of this research.

4.5.1 Professional Readiness and Conceptual Acceptance

The survey revealed a high conceptual acceptance of IoT among healthcare professionals, reflecting growing optimism about its potential to enhance rehabilitation through remote monitoring, personalised feedback, and data-driven care. Participants largely agreed that IoT could help sustain patient motivation and improve the continuity of post-discharge therapy—findings consistent with existing literature emphasising digital tools as enablers of engagement and self-management (Panch et al., 2019; Cottrell et al., 2020). However, the data also highlighted a significant gap between awareness and practical adoption. While most respondents were aware of IoT's potential, only a small proportion had hands-on experience using such devices in clinical contexts. This indicates that current familiarity is predominantly theoretical, reflecting an early stage of adoption where enthusiasm outpaces implementation.

Similar trends have been reported across allied health fields, where interest in digital health innovation often exceeds operational readiness (Krick et al., 2021; WHO, 2022).

4.5.2 Systemic and Contextual Barriers

Respondents identified several barriers that hinder the routine integration of IoT technologies in post-stroke rehabilitation. These include deficits in professional training, lack of institutional infrastructure, cost limitations, and ethical concerns regarding data security. In the UK, participants highlighted data protection, interoperability, and system integration challenges within the highly regulated NHS framework. Concerns centred around maintaining patient confidentiality, aligning with national policies on digital governance and clinical accountability.

Conversely, Saudi respondents emphasised infrastructure readiness and access equity, aligning with the country's Vision 2030 goals to expand healthcare digitisation. They pointed to the need for institutional investment, technical support, and widespread digital training as prerequisites for adoption. These differences underscore how institutional maturity and healthcare infrastructure shape perceptions of feasibility. Mature systems such as the NHS struggle with integration into existing frameworks, while emerging systems like Saudi Arabia's face foundational challenges of resource development and capacity building.

4.5.3 Central Themes: Technological Readiness and Patient Engagement

Two dominant themes emerged from the analysis—technological readiness and patient engagement—which together define the foundation for successful IoT implementation in rehabilitation practice. Technological readiness encompasses not only familiarity with IoT tools but also access to appropriate infrastructure, training, and technical support. Many professionals expressed a need for structured education and continuing professional development (CPD) to build competence and confidence in using connected devices. Patient engagement was equally prominent. Respondents emphasised that IoT can empower patients by enhancing self-awareness, motivation, and autonomy through real-time feedback and progress tracking. However, engagement is dependent on usability, accessibility, and inclusivity—devices must be simple, adaptable, and designed with patient diversity in mind. These themes collectively reinforce that technological innovation alone is insufficient; success depends on embedding IoT within a supportive ecosystem that integrates clinicians, patients, and caregivers.

4.5.4 Cross-Country Reflections

Comparative analysis revealed distinct but complementary perspectives between UK and Saudi healthcare professionals. UK practitioners tended to view IoT as an extension of existing clinical systems—something that should be carefully integrated within established workflows and regulatory structures. They prioritised data ethics, professional oversight, and evidence-based implementation. In contrast, Saudi participants saw IoT as an innovation frontier with transformative potential, driven by national digital-health ambitions. Their focus lay in infrastructure development, capacity building, and expanding rehabilitation access to underserved populations.

These perspectives reflect broader systemic differences: the UK's healthcare system values incremental, governance-driven adoption, while Saudi Arabia's evolving system promotes rapid innovation and expansion. Both approaches have merit, and together they highlight the necessity of context-sensitive design—a principle central to the design-led methodology of this research.

4.5.5 Implications for IoT Integration in Rehabilitation Practice

The findings suggest that IoT integration is most viable when supported by structured frameworks that address training, ethics, and policy alignment. Successful implementation requires:

- **Clinical guidelines and ethical governance** to ensure data protection and maintain patient trust.
- **Targeted professional training** to bridge knowledge gaps and promote confidence.
- **Interdisciplinary collaboration** between clinicians, technologists, and policymakers to ensure usability and scalability.

IoT technologies were perceived as particularly valuable for improving continuity of care in rural or resource-limited settings, where access to in-person therapy is limited. In both national contexts, participants saw IoT as a way to reduce rehabilitation disparities, thereby improving equity in healthcare delivery. These insights directly informed the design of Workshop 1, which sought to explore stroke survivors' perspectives on the usability, personal relevance, and acceptability of IoT technologies in real-life rehabilitation contexts.

4.5.6 Implications for Practice

Translating these findings into practice requires adaptive strategies tailored to each healthcare context:

- In the UK, where patient autonomy and clinical governance are highly emphasised, IoT applications can strengthen self-management and remote monitoring, giving patients more control over their rehabilitation while ensuring therapist oversight.
- In Saudi Arabia, where family involvement is integral to recovery, IoT systems should be designed to facilitate family–clinician communication and shared responsibility in rehabilitation.

Personalised rehabilitation plans that integrate IoT tools can thus be adapted to each patient's goals, environment, and cultural context. Ensuring such adaptability supports a human-centred approach that balances innovation with empathy.

4.5.7 Recommendations

To address the challenges identified and capitalise on IoT's potential, the following recommendations are proposed:

1. **Targeted Training and CPD:** Develop structured, region-specific training for rehabilitation professionals to enhance digital literacy and practical competence in IoT integration.
2. **Pilot Implementation Programmes:** Establish pilot studies in both the UK and Saudi Arabia to evaluate real-world applications of IoT in stroke rehabilitation and generate evidence-based best practices.
3. **Stakeholder Collaboration:** Engage patients, families, clinicians, and policymakers in co-design processes to ensure that IoT technologies meet clinical, ethical, and cultural requirements.
4. **Infrastructure Investment:** Expand digital infrastructure and technical support, particularly in emerging health systems, to facilitate sustainable technology integration.
5. **Policy and Governance Alignment:** Create national and institutional policies that incentivise innovation while safeguarding patient privacy and data ethics.
6. **Research and Evaluation:** Conduct longitudinal studies to examine the long-term impact of IoT on rehabilitation outcomes, patient satisfaction, and health equity.

7. **Family-Centred Technology Design:** In regions where family plays a major role in patient care, IoT solutions should enable caregivers to monitor progress, support adherence, and participate in decision-making.

Implementing these strategies ensures that IoT adoption moves beyond conceptual acceptance toward practical integration, achieving meaningful impact across diverse healthcare settings.

In summary, the survey findings depict a professional community that is enthusiastic yet cautious about IoT adoption. Practitioners in both the UK and Saudi Arabia share a vision of technology-enhanced rehabilitation but differ in readiness and infrastructural capacity. The insights reveal a need for training, ethical assurance, patient-centred design, and contextual adaptation. These conclusions served as the conceptual foundation for Workshop 1, which explored the same issues from the stroke survivors' perspective—bridging professional expectations with end-user experiences. This transition marked the shift from professional insight to patient engagement, advancing the study's mixed-methods exploration of IoT's role in post-stroke rehabilitation.

4.6 Summary of Survey Phase

The survey served as a foundational stage of this mixed-methods study, providing both quantitative and qualitative insights into healthcare professionals' awareness, perceptions, and readiness toward Internet of Things (IoT) technologies in post-stroke rehabilitation. Drawing responses primarily from practitioners in the United Kingdom and Saudi Arabia, the data revealed a strong conceptual acceptance of IoT's potential to improve rehabilitation outcomes—particularly in areas such as remote monitoring, personalised care, and enhanced communication between patients and clinicians. Despite this optimism, participants also identified critical barriers to adoption, including limited training, ethical and data-security concerns, and infrastructural constraints. These findings indicate that while professionals recognise the theoretical value of IoT, practical implementation remains hindered by technological readiness and contextual limitations within clinical environments. The cross-country comparison enriched this understanding. UK respondents, operating within an established NHS framework, prioritised data protection, ethical compliance, and evidence-based integration. In contrast, Saudi professionals expressed stronger enthusiasm, viewing IoT as a vehicle to bridge service gaps and extend access to rehabilitation services in alignment with

Vision 2030's digital-health agenda. Both groups agreed, however, that IoT should complement—not replace—human interaction in care delivery.

The survey outcomes directly informed the design of Workshop 1, highlighting several key themes for qualitative exploration:

- Balancing technological assistance with human-centred rehabilitation.
- The importance of structured education and professional training in facilitating IoT use.
- The need for personalised, user-friendly systems aligned with stroke survivors' cognitive and physical capabilities.
- Ensuring ethical integrity and data security in digital health practice.

By identifying these themes, the survey acted as a bridge between professional insight and user experience—shifting the research from healthcare providers' theoretical views to stroke survivors' lived perspectives. It also validated the study's pragmatist design philosophy, reinforcing that effective technology adoption requires integrating both experiential and empirical evidence.

Overall, the survey provided a robust empirical foundation that guided subsequent phases of the research. It underscored the promise of IoT technologies in improving rehabilitation outcomes while revealing practical, ethical, and contextual challenges that must be addressed for real-world adoption. The comparative analysis between the UK and Saudi Arabia demonstrated that successful IoT implementation requires region-specific strategies, informed by cultural norms, infrastructure readiness, and policy priorities. These findings not only shaped the next stage—Workshop 1—but also contributed to the formulation of the final IoT-based recommendations later validated in this study. The global outlook embedded in the survey results highlights that while IoT offers universal potential, its success in stroke rehabilitation depends on tailoring approaches to diverse healthcare contexts.

Table 17.4.5 Summary of Phase 1 – Online Survey

Component	**Description**
Phase Title	Phase 1 – Online Survey with Healthcare Professionals
Purpose	To explore rehabilitation professionals' familiarity with IoT technologies, their perceived benefits and barriers to implementation, and contextual differences between the UK and Saudi Arabia.
Research Type	Quantitative (online survey using mixed closed and open questions)

Target Participants	Healthcare professionals (physiotherapists, occupational therapists, rehabilitation nurses and technologists) with ≥ 2 years experience in post-stroke rehabilitation.
Recruitment & Sampling	Purposive and snowball sampling via professional networks (ACPIN, APCP, LinkedIn, rehabilitation centres). Conducted online due to COVID-19 restrictions.
Sample Size & Distribution	67 valid responses (UK = 41; Saudi Arabia = 16; Other countries = 10). 42 physiotherapists (63%), 25 occupational therapists (37%).
Data Collection Period	Six weeks (2023).
Instrument & Data Type	Structured questionnaire via Microsoft Forms with quantitative items and open-ended qualitative prompts.
Key Themes Identified	1. Awareness vs. Practical Use of IoT 2. Perceived Benefits – remote monitoring, motivation, personalisation 3. Barriers – training gaps, data security, cost 4. Ethical and policy concerns 5. Cross-country contrasts in infrastructure and readiness.
Analytical Approach	Descriptive statistics (quantitative) and reflexive thematic analysis for open responses (Braun & Clarke, 2019).
Key Findings	- High conceptual acceptance but low practical experience. - Training deficits and data-security concerns as dominant barriers. - UK focus on interoperability and ethical compliance; Saudi focus on access and infrastructure. - Shared interest in IoT’s role in enhancing continuity of care.
Contribution to Next Phase	Informed the design of Workshop 1 by identifying priority themes (usability, privacy, personalisation). Provided baseline quantitative evidence to guide subsequent qualitative exploration with stroke survivors.

Chapter 5: Workshop 1

5.1 Introduction

This chapter presents the findings from Workshop 1, which explored stroke survivors' lived experiences and perceptions of integrating Internet of Things (IoT) technologies within post-stroke rehabilitation. Building on insights from the professional survey (Chapter 4), this phase sought to understand how survivors themselves interpret the usefulness, accessibility, and emotional impact of such technologies when introduced through an interactive, design-informed workshop. Unlike the survey, which examined clinical readiness from a professional standpoint, this chapter focuses on the experiential dimension—how survivors make sense of technology in the context of their daily recovery. The discussion highlights themes that emerged from direct participant interaction and reflection rather than theoretical assumptions.

5.2 Workshop Context and Participant Demographics

Participants

Workshop 1 was conducted at the Abdul Latif Rehabilitation Centre in Jeddah, Saudi Arabia. A diverse group of twelve stroke survivors was recruited through the centre's clinical team. The inclusion criteria required participants to be at least three months post-stroke and to have the cognitive capacity to provide informed consent. It is important to note that the participant group consisted entirely of men, a reflection of contextual constraints stemming from the host institution's scheduling policies. As detailed in Table 5.1, the cohort was heterogeneous, encompassing a range of ages (from 50s to 70s), time since stroke (from 4 months to 4 years), stroke types (ischaemic and haemorrhagic), and impairment profiles (left and right hemiparesis). This demographic variation was crucial for capturing a wide range of perspectives on IoT adoption and ensures the subsequent thematic findings are interpreted within the context of the varied lived experiences that generated them.

Data were collected via pre- and post-workshop questionnaires and audio-recorded group reflections. The audio data were transcribed, translated from Arabic to English, and analysed using reflexive thematic analysis (Braun & Clarke, 2019). The questionnaires provided quantitative data on changes in awareness and confidence, while the qualitative analysis captured nuanced emotional, cognitive, and behavioural responses to IoT technologies. The workshop itself combined three core components, as detailed in Chapter 3: a short educational presentation introducing IoT-enabled rehabilitation tools (e.g., wearable motion sensors, smart-home assistants); a hands-on interaction phase with selected devices to prompt reflection on real-world applicability; and a guided group discussion on the usefulness, accessibility, and personal relevance of the technologies.

Table 18.5.1: Participant Demographics

Participant ID	Age	Diagnosis	Additional Conditions
PA	68	CVA left hemiplegia	Diabetes, Blood Pressure
PB	71	CVA left hemiplegia	Hypertension
PC	62	Right ischemic hemiplegia	None
PD	70	CVA left hemiplegia	None
PE	76	CVA left hemiplegia	None
PF	62	Right ischemic hemiplegia	None
PG	65	CVA left hemiplegia	Diabetes, Blood Pressure
PH	58	Left ischemic hemiplegia	None
PI	79	CVA right hemiplegia	None
PJ	51	CVA left hemiplegia	None
PK	88	CVA left hemiplegia	None
PL	73	CVA right hemiplegia	None

Note: *CVA (Cerebrovascular Accident) is the clinical term for a stroke. It is used here as it was the standard term in the participant recruitment and clinical records.*

5.3 Overarching Thematic Framework

Thematic analysis of the workshop data crystallized these initial reactions into four overarching themes that capture the core tensions in adopting IoT for stroke rehabilitation.

1. **The Paradox of Assistive Feedback:** The tension between the motivation from real-time feedback and the risk of dependency or frustration.
2. **The Human-in-the-Loop Imperative:** The strong preference for technology that augments, rather than replaces, the therapeutic relationship.
3. **Accessibility as a Socio-Technical Challenge:** The intersection of cost, technological literacy, and physical design as barriers to independent use.

4. **Configurable Trust as a Foundation:** The need for transparency and control over data privacy to build essential trust in connected systems.

Each theme is explored in depth in the following sections, supported by direct participant quotations. These survivor-informed perspectives provided the fundamental design constraints and opportunities that directly shaped the focus and structure of Workshop 2, moving the inquiry toward personalization and daily integration.

5.4 Summary of Quantitative Feedback

Prior to the detailed thematic analysis, quantitative data from post-workshop questionnaires provides a high-level overview of participant perceptions. Figure 5.1 illustrates the proportion of participants reporting specific challenges, revealing that 'Ease of Use' was the most prominent concern, followed by 'Cost' and 'Data Privacy'. Furthermore, Table 5.1 offers a consolidated view of the perceived challenges and benefits, clearly demonstrating that participants' optimism about IoT's potential for independence and motivation is consistently balanced by apprehensions regarding usability and accessibility. This quantitative data grounds the subsequent qualitative themes in the collective priorities of the participant group.

Table 19.5.2: Challenges and Benefits of IoT Devices

Task/Activity	Participant IDs	Challenges Reported	Perceived Benefits
Walking	A, B, C, D	Difficulty using devices while walking	Enhanced mobility support
Health Monitoring	E, F, G, H	Complex interfaces, need for assistance	Better blood pressure, glucose control
Rehabilitation Tasks	I, J, K, L	Complex setup, lack of guidance	Simplified rehab routine
Daily Living Activities	A, C, G, L	Need for additional training	Increased independence
Device Usability	D, F, I, K	Lack of technical skills	Simplified with post-workshop training

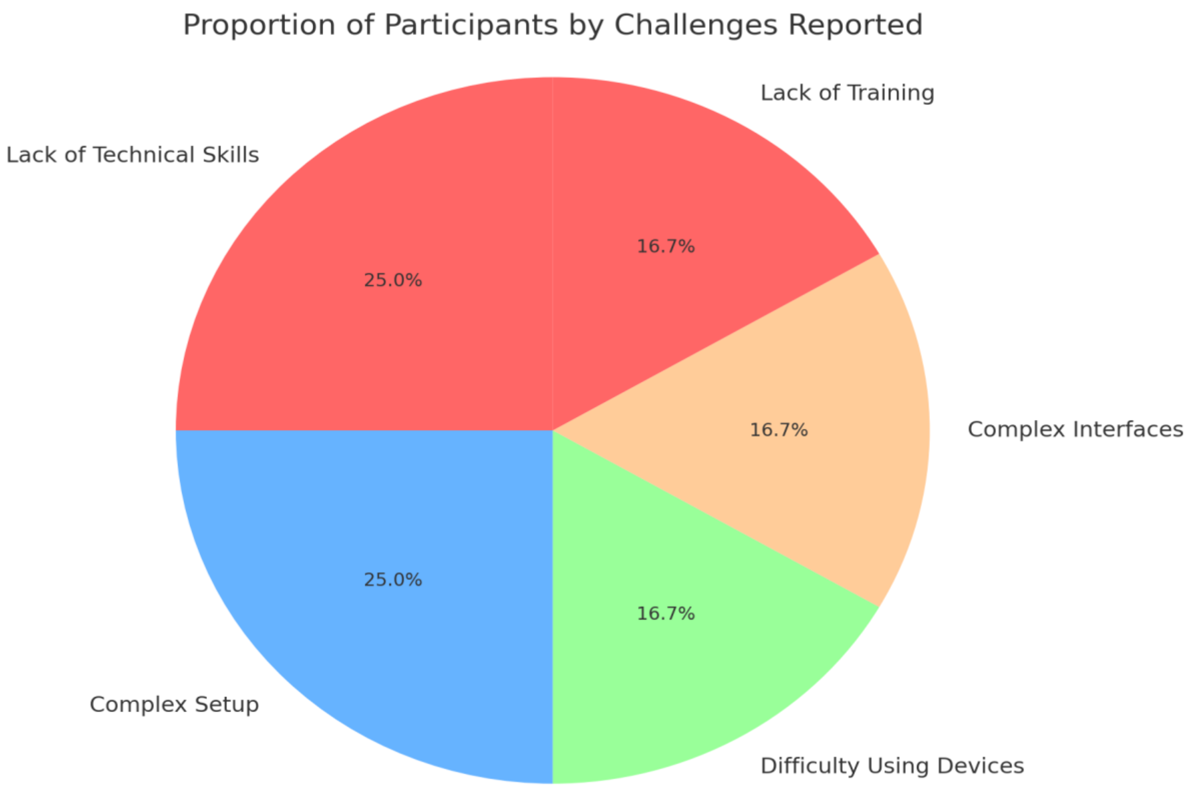

Figure 5.5.1: Proportion Of Participants By Challenges Reported

5.5 Thematic Analysis of Workshop 1 Findings

This section presents an integrated analysis of the data from Workshop 1, structured around four key themes that capture core participant perspectives on IoT adoption. The narrative charts the evolution of their perceptions, from initial expectations to post-session reflection. The analysis is supported by direct participant quotations and grounded in the quantitative data presented in the accompanying tables.

5.5.1 Theme 1: The Paradox of Assistive Feedback

This theme captures the central tension between the motivating potential of IoT feedback and the risk of frustration due to complexity. This shift in participant stance, from initial scepticism to increased confidence, is supported by quantitative data from pre- and post-workshop questionnaires (summarised in Table 5.2), which showed a clear positive trend in participants' self-rated perceptions of IoT's usefulness and their confidence in using it after the hands-on session. Prior to the workshop, the concept of automated progress tracking was a source of both hope and anxiety. Participants hoped for tools that would offer "independent mobility" and be "a way to track my progress at home". However, this optimism was immediately tempered by a fear of complexity, with one participant candidly admitting, "I need help to use it" (Participant A). The hands-on demonstration served as a critical turning point. For many, directly engaging with the devices demystified the technology. Participant A reflected on this shift, noting, "I realised the devices were easier to use than I expected and could help me perform daily tasks more efficiently." This experience fostered a sense of control, with Participant G stating, "The session gave me a sense of control over my rehabilitation." However, the theme's paradoxical nature was confirmed by persistent concerns. As detailed in the feedback summary (Table 5.3), usability remained a key area for improvement. Participant I highlighted that "the interfaces are not always user-friendly, especially for older users," indicating that for the positive potential to be fully realised, the design must achieve a seamless, intuitive interaction that minimises cognitive load.

Table 20.5.3: Summary of Shifts in Participant Perceptions Pre- and Post-Workshop

Participant ID	Pre-Workshop Perception	Post-Workshop Perception	Improvement
PA	"I need help to use it"	More comfortable with assistance	Positive
PB	"It's perfect"	More enthusiastic about usage	Positive
PC	"I like it but need help"	Able to perform tasks more independently	Positive
PD	Skeptical about technology	More confident using IoT for daily activities	Positive
PE	"I dream to be better"	Gained hope and optimism for rehabilitation	Positive
PF	Lacked confidence in technology	Found IoT useful for time management	Positive
PG	"It's complicated"	Gained confidence with additional training	Moderate
PH	Positive	Highly engaged and motivated post-workshop	Positive
PI	Lacked technical skills	Found IoT helpful with more guidance	Moderate
PJ	Initially hesitant	Found devices helpful for daily monitoring	Positive
PK	Initially optimistic	Remains optimistic, but seeks additional features	Neutral
PL	Concerned about complexity	Appreciates simplicity in tasks	Positive

5.5.2 Theme 2: The Human-in-the-Loop Imperative – Technology as a Bridge, Not a Replacement

A resounding and consistent finding was that technology must augment, never replace, human care. Participants universally valued the irreplaceable role of therapist empathy and guidance. Pre-workshop, participants aspired to "effective assistance," framing technology as a supportive tool. This sentiment solidified after the demonstrations. While they saw value in IoT for saving time and managing tasks, the emotional and interpretive role of the therapist was seen as non-negotiable. As one participant poignantly explained, "The device can show numbers, but it cannot tell me if I'm doing well like my therapist does" (Participant H). Another participant emphasised the importance of human encouragement, stating, "I need that human voice saying 'you can do it'—a machine can't give you that hope" (Participant D). Participants consistently envisioned a hybrid model of care. In this model, IoT devices provide data, reminders, and support between formal therapy sessions, but the therapist remains the central figure. As a third participant noted, "This could be my homework, and then I bring the results to my doctor for him to understand" (Participant J). This highlights that the value of IoT in rehabilitation lies not in automation, but in its capacity for enhanced intermediation—strengthening the connection between survivor and therapist rather than severing it.

5.5.3 Theme 3: Barriers to Access and Understanding – The Socio-Technical Hurdle

Participants framed accessibility in broad terms, encompassing cost, technological literacy, and physical design. These were not seen as separate issues, but as interconnected barriers that could preclude adoption entirely. Before the workshop, participants vividly described the challenges of their daily lives, from the "struggle to transition from bed to the bathroom" (Participant G) to the "emotional strain" of social isolation (Participant L). They hoped IoT could alleviate these burdens, with Participant C sharing the hope that it would "help me manage daily tasks without help." However, doubts about the technology's suitability were pervasive. Concerns about physical design were common, with one participant noting, "My fingers don’t work like they used to; I need big buttons, not a tiny touchscreen" (Participant I). Similarly, anxiety about complexity was clear: "If it has too many menus, I will get lost and give up," shared another (Participant J). The hands-on workshop served to demystify the technology, making it feel more approachable. As summarised in Table 5.3, this direct experience led to positive feedback on the core concept, yet it also crystallised the specific usability barriers that designers must overcome. Despite this increased comfort, significant concerns persisted. Participant F emphasised the need for "training to understand all the features," while the barrier of cost was starkly highlighted by Participant K, who stated, "This is good, but if it is not covered by insurance, I cannot afford another bill." This collective feedback positions accessibility not just as a usability issue, but as a socio-technical challenge requiring designs that are economically, physically, and cognitively accessible to a vulnerable population.

Table 21.5.4: Participant Feedback Summary

Participant ID	Key Feedback	Suggestions for Improvement
A	Needs assistance with technology, but sees value	Simplify device interfaces
B	Found devices highly useful for daily activities	No improvements suggested
C	Appreciated time-saving features but struggled initially	Add more instructional resources
D	Initially skeptical but found IoT beneficial post-workshop	More training sessions needed
E	Gained optimism, found IoT helpful for walking	Add more customization options
F	Useful for monitoring but found setup complex	Provide better user manuals
G	Appreciated health monitoring features	Simplify the use of smartwatches
H	Highly engaged with IoT, motivated to use devices	Provide mobile application integration
I	Benefited from task management but found devices complex	Improve device accessibility
J	Initially hesitant, later found IoT valuable for rehab	Add user-friendly features for seniors
K	Remains optimistic, but requires more support for complex tasks	Expand device functionality
L	Found devices beneficial but wants easier setup	Provide simplified user interfaces

5.5.4 Theme 4: Trust and Privacy in Connected Care – The Foundation for Adoption

Trust emerged as a foundational theme, cutting across all discussions and encompassing device reliability, data privacy, and the need for technical support. Initial apprehension about continuous monitoring was high. Pre-workshop, participants expressed unease about data sharing, with one stating, "I would use it only if I know who sees my data. I don't want my information going everywhere" (Participant A). This was a common concern, as another participant questioned, "How can I be sure my health data is safe on the internet?" (Participant C). These concerns were not fully alleviated by the demonstrations, indicating that trust requires more than technical functionality; it demands transparency and user control. Participants indicated that for trust to be established, systems must be demonstrably reliable and must provide clear, simple means for users to understand and control who has access to their personal health information. This is especially critical in the cultural context of the study, where family involvement is often expected. As one participant explained, "I would want my son to know if I fell, but not necessarily every detail about my exercise" (Participant L). Another added, "My wife should have access, but maybe not my brother" (Participant J). Therefore, the data suggest that data governance in this context cannot be based on a purely individualistic model but must be configurable to align with familial and cultural norms.

5.6 Discussion: Synthesising Participant-Centred Design Imperatives

This discussion synthesises the core findings from Workshop 1, interpreting their broader significance for designing IoT-based stroke rehabilitation systems. The workshop's value lies not in evaluating clinical outcomes, but in articulating the critical user-experience tensions and participant-defined priorities that must underpin any such technological development. It establishes a survivor-informed framework that moves beyond a mere list of features to define the essential conditions for adoption.

5.6.1 From Perceived Challenges to Foundational Design Constraints

The analysis demonstrates that the primary barriers to IoT adoption are not a lack of interest, but a coherent set of concerns regarding complexity, context, and trust. Participants' initial scepticism represented a pragmatic response to potential misalignments with the lived reality of recovery, aligning with models of technology acceptance that emphasise perceived ease of use as a critical determinant of adoption (Davis, 1989). A central conclusion is that for this user group, usability is not merely a feature—it is the fundamental prerequisite for any meaningful engagement, a principle central to inclusive design (Clarkson et al., 2013). The interrelated themes reveal a core design paradox: the very personalisation that can motivate must be delivered without imposing a cognitive or configuration burden. This finding challenges the assumption that greater user control inherently leads to better personalisation, particularly for users with cognitive or physical impairments (Sanders & Stappers, 2008). For stroke survivors, the evidence points to a need for intelligent adaptation, where the system learns and adjusts autonomously. Furthermore, the strong emphasis on the human element and trust necessitates a shift from a product-centric to a service-centric view of IoT. Participants consistently framed technology as a single node within a broader ecosystem of care, underscoring that a device’s success is contingent on its ability to strengthen, rather than replace, human relationships. This aligns with a socio-technical systems perspective, which argues that technological outcomes depend on the interaction between tools, people, and organisational structures (Clegg, 2000). Consequently, the design challenge extends beyond the device's hardware and software to encompass the entire service model and data governance structure in which it is embedded.

5.6.2 Positioning the Findings within the Design Research Process

The reflexive analysis of Workshop 1 was instrumental in transitioning the study from exploratory data gathering to a principled design investigation. Participants' expressed uncertainties were reframed from simple obstacles into a clear set of generative design requirements. The apprehension towards complexity—encapsulated by the statement, "I need help to use it"—crystallised the central question for Workshop 2: how to deliver personalised adaptation without resorting to complex user interfaces. Similarly, the pronounced desire for human connection, summarised by the insight that "The device can show numbers, but it cannot tell me if I'm doing well like my therapist does," established a non-negotiable boundary for all subsequent ideation: technology must function as a bridge to the therapist, never a substitute.

Consequently, Workshop 2 was designed to explore solutions that embodied these principles, specifically investigating how to achieve automated personalisation and integrate technology as a seamless partner within a human-centric recovery service. In this way, Workshop 1 served as a vital scoping and grounding mechanism. It ensured the research would not pursue technological sophistication for its own sake but would remain rigorously anchored in the socio-emotional and practical realities of stroke recovery. The findings provided the empirical foundation and the ethical compass for the co-design activities that followed.

5.6.3 Limitations and Forward Trajectory

A recognised limitation of this phase is its conceptual nature; the findings reflect short-term exposure and anticipated perceptions, rather than documented behaviours from sustained domestic use. This properly limits claims regarding long-term ‘seamless integration’ but is appropriate for a study informing the early-stage design process.

Several important demographic and contextual factors also shape the transferability of these findings.

- **Age and Gender:** The sample consisted entirely of male participants, predominantly in their 50s to 70s, with only one individual over 80. Consequently, the findings may not fully represent the perspectives of female stroke survivors or the specific needs of the oldest old, who may face greater technological or physical barriers.
- **Cognitive and Physical Capacity:** Recruitment required participants to have the cognitive capacity to understand and tolerate a one-hour workshop. This necessarily excluded individuals with more severe cognitive or communication impairments, whose interaction needs with IoT could be significantly different.
- **Geographical and Socioeconomic Context:** The workshop was conducted in a major urban centre (Jeddah). The perspectives gathered may not reflect those of stroke survivors in rural areas, where internet connectivity, access to technical support, and family caregiving structures could differ substantially.

These limitations do not undermine the value of the findings but, rather, define the specific context from which they emerged. The principal outcome of this chapter is therefore not a set of universally applicable solutions, but a critically grounded framework of user priorities derived from this specific cohort. These priorities—the paradox of assistive feedback, the human-in-the-loop imperative, accessibility as a socio-technical challenge, and configurable trust as a foundation—directly shaped the objectives of Workshop 2. The subsequent phase builds upon this foundation by exploring how these principles can be translated into tangible IoT features, thereby moving the research from understanding user perceptions towards co-creating potential solutions.

5.7 Conclusion: From Foundational Insights to Iterative Refinement

In summary, Workshop 1 provided essential, foundational insights into the perceptions of stroke survivors regarding IoT in rehabilitation. The findings reveal a landscape of cautious optimism, where the potential for empowerment and independence is carefully weighed against very real concerns over complexity, trust, and the preservation of human connection. The four key themes—The Paradox of Assistive Feedback, The Human-in-the-Loop Imperative, Barriers to Access and Understanding, and Trust and Privacy in Connected Care—collectively provide a critically grounded framework of user priorities. These insights were instrumental in shaping the research's iterative, co-design ethos. Participant feedback crystallised the core design challenges: managing complexity and ensuring seamless integration into therapeutic routines. Consequently, Workshop 1 successfully shifted the focus from a general exploration of technology to a targeted investigation for Workshop 2, which was designed to explore how to achieve personalisation without imposing a cognitive burden and how to design technology that acts as a seamless partner in a human-centric recovery journey. The primary outcome of this chapter is this user-defined agenda, which set a clear and actionable pathway for the co-creative work that follows.

Chapter 6: Workshop 2

6.1 Introduction: Advancing from Perception to Principle

This chapter presents the findings from Workshop 2, which explored stroke survivors' deeper perceptions of advanced Internet of Things (IoT) technologies following their initial exposure in Workshop 1. While the first workshop established a foundational landscape of user perceptions and tensions, this chapter moves the research forward by synthesising these insights to articulate a set of generative, stakeholder-validated design principles. The primary purpose was not to evaluate clinical effectiveness, but to act as a co-creation session, understanding how survivors imagined IoT could be embedded in their routines and defining *how* to achieve personalisation and integration without imposing a cognitive or emotional burden—the core challenge identified previously.

6.2 Workshop Context and Analytical Approach

Workshop 2 was conducted at the Abdul Latif Rehabilitation Centre in Jeddah, Saudi Arabia, with twelve stroke survivors. The cohort included both returning participants from Workshop 1 and newly recruited individuals, ensuring both continuity of reflection and the introduction of fresh perspectives. The session involved a bilingual presentation on advanced IoT concepts (e.g., wearable sensors, smart home systems), followed by facilitated co-design discussions. Data from these discussions were analysed using Reflexive Thematic Analysis (Braun & Clarke, 2019), as detailed in Chapter 3. As summarised in Table 6.1, the participant group was mixed-gender and represented a range of ages, time since stroke, and impairment levels, ensuring the findings were informed by diverse rehabilitation experiences. The evolution in participant confidence provides a critical foundation for the ensuing principles. The marked decrease in apprehension following the demonstration (captured in Figure 6.1) validates that usability challenges can be overcome through thoughtful design. The principles, therefore, emerged from translating this observed psychological shift towards acceptance into definitive design mandates; for instance, the principle of **Adaptive Simplicity** is the design response required to earn and maintain user confidence. Detailed qualitative feedback supporting these shifts is summarised in Table 6.2.

Table 22.6.1: Participant Demographics and Conditions

Encrypted ID	Diagnosis	Age	Gender
PA	ISCHEMIC CVA LEFT HEMIPLEGIA	74	Female
PB	CVA ISCHEMIC INFARCTION RIGHT HEMIPLEGIA	67	Female
PC	Right ischemic hemiplegia	62	Male
PD	CVA left hemiplegia	70	Male
PE	CVA left hemiplegia	76	Male
PF	Right ischemic hemiplegia	62	Male
PG	LEFT HEMIPLEGIA CVA ISCHEMIA	74	Male
PH	Left hemiplegia post recent ischemic stroke	82	Female
PI	CVA right hemiplegia	79	Male
PJ	Post Stroke Left Hemiplegia	59	Male
PK	CVA left hemiplegia	88	Male
PL	CVA right hemiplegia	73	Male

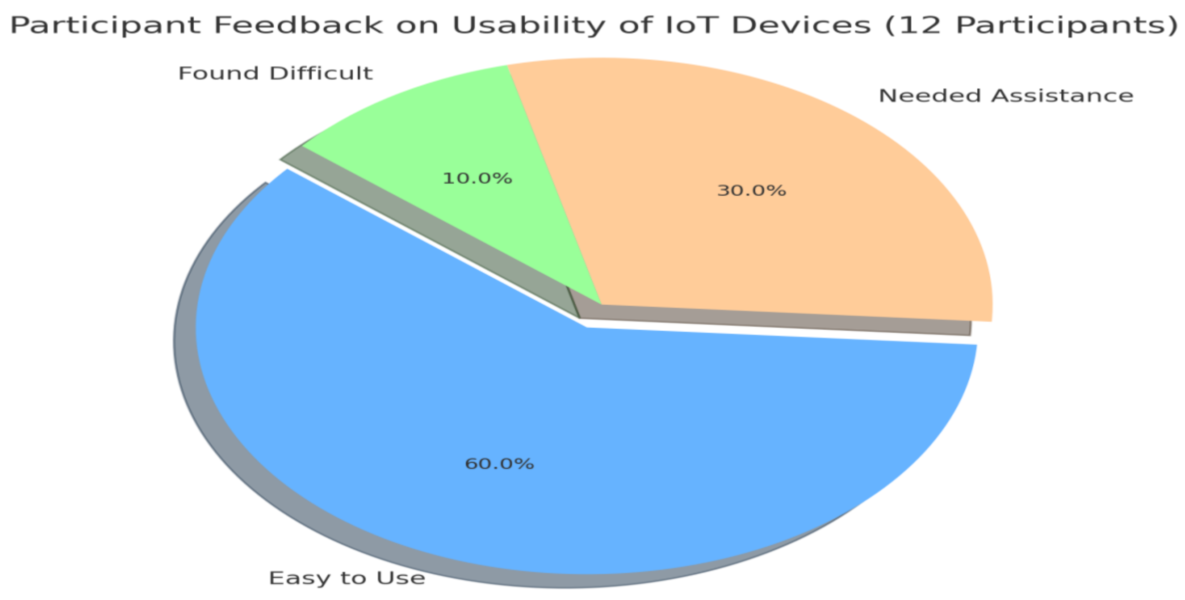

Figure 6.6.1: Participant Feedback on Usability

Table 23.6.2: Pre- and Post-Workshop Feedback

Participant	Pre-Workshop Feedback	Post-Workshop Feedback
PA	Limited understanding of IoT technology. Concerned about complexity.	Improved understanding, found devices easier to operate.
PB	Optimistic but apprehensive about using IoT alone. Concerned about device assistance.	Optimistic, highlighted ease of use and real-time feedback.
PC	Basic knowledge, curious about IoT's applicability to ADLs.	More confident, emphasized health tracking potential.
PD	Worried about technological complexity. Needed more explanation.	Less worried about complexity, found technology accessible.
PE	Unfamiliar with IoT, feared complexity.	Positive impression, appreciated practical exposure.
PF	Had some idea of health monitoring, but concerned about using devices independently.	Appreciated real-time feedback, felt empowered.
PG	Unaware of IoT applications in rehabilitation.	Better understanding, sees potential for ADL improvement.
PH	Expected real-time health monitoring but concerned about interface.	Impressed with simplicity, but still feels guidance needed.
PI	Hoped IoT would help with independence but uncertain about ease of use.	More confident in using IoT for independence, but still cautious.
PJ	Fear of technology use without assistance.	Optimistic about benefits but still cautious about technological challenges.
PK	Limited knowledge, expected IoT to simplify tasks.	Positive about simplicity, sees potential for managing tasks.
PL	Optimistic but feared technological barriers.	Optimistic about ease of use but still cautious about technology use.

6.3 Key Design Principles: A Synthesis of User Needs and Design Feasibility

The thematic analysis, building iteratively upon the findings from Workshop 1, solidified four governing principles for IoT systems in stroke rehabilitation. The following sections present the findings for each principle, first by detailing the new evidence from Workshop 2 and then by synthesising the design implications.

1. The Principle of Adaptive Simplicity

6.3.1 Workshop 2 Findings and Confirmation

This principle builds on the "Paradox of Assistive Feedback" from Workshop 1. In Workshop 2, the key new insight was that participants explicitly demanded automation as the solution to complexity. While the desire for personalisation remained strong, they rejected any interface that required them to navigate complex menus or make numerous configuration choices. Visual evidence from post-workshop feedback showed that 40.0% of participants still "Needed Assistance" or "Found it Difficult" to use the demonstrated devices, underscoring the pervasiveness of the usability challenge. Crucially, a new participant from Workshop 2 stated: “The customisable plan looks wonderful, but if I have to press more than two buttons to start, I will not use it. The system must just know how to simplify” (Participant C). This quote moves beyond Workshop 1's general apprehension ("I need help to use it") by specifying the required solution: intelligent, automated simplicity.

6.3.2 Adaptive Simplicity: Design Synthesis and Implications

These findings indicate that for this user group, personalisation and simplicity are not a trade-off but an integrated design requirement: the former must be delivered through the latter. This aligns with gerontechnology literature, where high configurability often creates a prohibitive cognitive burden, leading to technology abandonment (Czaja et al., 2019). The design implication is that personalisation must be delivered primarily through passive sensing and intelligent algorithms operating in the background, minimising active user configuration. This approach is a direct application of Universal Design principles (Story, 1998), ensuring usability is the foundational requirement for equitable access. The ultimate aim is cognitive offloading, making the system inherently error-tolerant. Therefore, the design mandate is to prioritise automated adaptation over user-controlled configuration.

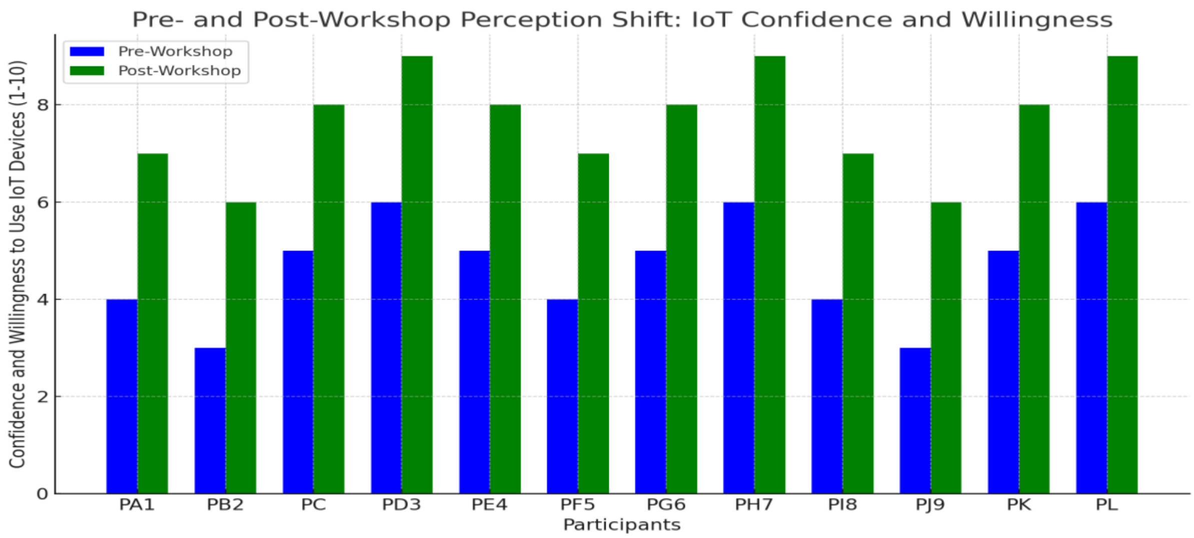

Figure 7.6.2: omparison of Pre- and Post-Workshop Measures of Participant Confidence and Willingness to Adopt IoT Devices

2. The Human-in-the-Loop Service Model

6.3.3 Workshop 2 Findings and Confirmation

This principle refines the "Human-in-the-Loop Imperative" from Workshop 1. The new insight from Workshop 2 was that as the concept of data-driven monitoring became more advanced, participants' emphasis on the therapist's interpretive and emotional role intensified, rather than diminished. One participant, reflecting on the potential for continuous data collection, explained: “The real-time tracking is good, but I still need my doctor to tell me what the numbers mean. A machine can't give me the trust I need or the hope” (Participant F). This reinforces the constraint identified in Workshop 1 but adds a crucial nuance: the value of the human expert increases with the complexity and volume of the data generated by the technology.

6.3.4 Human-in-the-Loop Service Model: Design Synthesis and Implications

This finding confirms that IoT's value lies in augmenting, not replacing, clinical judgement—a core tenet of effective tele-rehabilitation (Brewster et al., 2014). The design implication is a fundamental shift in priority from patient-facing gadgets to clinician-facing services. The core deliverable becomes a dashboard that translates raw, continuous patient data into synthesised, actionable clinical insights. This approach mitigates the risk of clinician data overload and "black-box" algorithmic decision-making, instead empowering therapists to tailor interventions remotely with greater efficiency and context. This model underscores the need for Service Design to structure accountability and collaborative control between the patient, the technology, and the clinician.

3. The Principle of Configurable Data Transparency

6.3.5 Workshop 2 Findings and Confirmation

This principle evolves from the "Trust and Privacy" theme in Workshop 1. Workshop 2 revealed a critical evolution from general apprehension about data sharing to a specific demand for granular, configurable control, heavily influenced by the cultural context of family involvement in care. Participants explicitly differentiated between data types and recipients. One participant stated: “I want my wife to see if I am safe, but I do not want the machine telling everyone my specific health problems. The device must let me choose who sees the private data” (Participant G). This new evidence moves beyond a desire for privacy to a requirement for a nuanced, user-controlled data-sharing model that accommodates familial relationships.

6.3.6 Configurable Data Transparency: Design Synthesis and Implications

These findings necessitate a shift from simple regulatory compliance to a proactive, user-centric model of data governance. This aligns with the 'Privacy by Design' framework (Cavoukian, 2009), which mandates embedding privacy directly into the fundamental structure and design of a system. The design implication is the creation of simple, intuitive privacy dashboards that allow users to manage data-sharing permissions easily. This is especially critical in cultural contexts, like that of Saudi Arabia, where shared responsibility for care is integral. The design mandate is to build trust through user agency and transparent data handling, providing configurable controls that reflect complex social and familial structures.

4. The Principle of Contextual Motivation

6.3.7 Workshop 2 Findings and Confirmation

This principle adds a new dimension to the engagement themes from Workshop 1. Workshop 2 confirmed that long-term motivation is intrinsically linked to social context, and that poorly designed gamification risks fostering isolation. Participants welcomed motivational features but were critical of those that felt solitary or infantilising. One participant suggested: “The scores should be shared with my support group so we can encourage each other, not just used by me alone. That makes me feel less isolated” (Participant J). This new data highlights that the social embeddedness of a motivational feature is as important as the feature itself.

6.3.8 Contextual Motivation: Design Synthesis and Implications

This finding confirms that digital motivation must be framed as a socio-technical solution, not just a software feature. It challenges the simplistic application of gamification in health apps, which can sometimes undermine adult autonomy and social connection (Tong et al., 2022). The design implication is that motivational strategies must explicitly foster genuine social connection and align with adult values. The design mandate is to create meaningful engagement through community-integrated features, such as shared goal-setting with peers or family, thereby using technology to strengthen existing support networks and promote holistic well-being.

6.4 Synthesis: From Principles to Actionable Requirements

The principles of Adaptive Simplicity, the Human-in-the-Loop Service Model, Configurable Data Transparency, and Contextual Motivation collectively form the user-validated design framework of this research. They underscore that technological sophistication is secondary to empathetic, ethical, and context-aware design. This synthesis is not a conclusion but a translation mechanism; it provides the direct empirical and theoretical foundation for the eleven specific design mandates developed in the next phase.

6.5 Discussion: Synthesising Co-Design Principles for IoT in Stroke Rehabilitation

This discussion synthesises the findings from Workshop 2, building upon the new evidence presented in Section 6.3, to articulate the core contribution of this chapter: a set of co-design principles for IoT in stroke rehabilitation. Moving beyond a functional analysis of device features, the chapter demonstrates that a design-led approach is essential for navigating the core tensions between technological capability and the lived experience of recovery. The findings establish that success is contingent not on technical sophistication, but on designing for adaptive simplicity, human-centred service integration, configurable trust, and contextual motivation.

6.5.1 The Central Role of Design: Navigating Key Tensions

The analysis reveals that integrating IoT into stroke rehabilitation is fundamentally a service design challenge, not merely a product design one. The findings consistently highlighted critical tensions that design must negotiate.

- **The Paradox of Personalisation:** Participants desired adaptive, personalised feedback but rejected the cognitive burden of complex configuration. This surfaces the core design challenge of delivering intelligence without complexity. The principle of Adaptive Simplicity addresses this paradox, challenging the assumption that more user controls lead to better personalisation and aligning with concepts of 'calm technology' (Weiser and Brown, 1997), where the user's primary task—rehabilitation—remains the focus.
- **The Human-in-the-Loop Imperative:** The irreplaceable value placed on human empathy and therapeutic relationships underscores that IoT must be framed as a tool for enhanced intermediation. This finding positions technology as a node within a broader therapeutic ecosystem that augments, rather than automates, human care, thereby challenging a purely product-centric view of IoT.

6.5.2 Ethical and Inclusive Design as a Foundational Requirement

The ethical concerns raised are not peripheral issues but central design constraints that emerged directly from the co-design process.

- **From Privacy to Configurable Trust:** Participant apprehension about data sharing, especially within the cultural context of family involvement in Saudi Arabia, necessitates a shift from simple compliance to designs that enable Configurable Data Transparency. This means creating intuitive interfaces that allow users to see and control who accesses their data, integrating ethical governance directly into the user experience.
- **Inclusivity Beyond Usability:** The varied adaptability of participants reinforces that Universal Design is non-negotiable. A design that only works for the "tech-savvy" fails ethically and practically. This requires a commitment to interfaces that minimise cognitive load and offer multiple, flexible interaction pathways (Clarkson et al., 2013).

6.5.3 Contribution to Knowledge and Position in the Field

This chapter's primary contribution is the articulation of these four principles derived directly from a co-creative process with end-users. While existing literature often focuses on the clinical efficacy and functional benefits of IoT, this research:

- Foregrounds the socio-emotional and relational dimensions of technology adoption, which are central concerns for human-centred design.
- Provides a critical, grounded framework that cautions against technological solutionism, emphasising that the most "advanced" feature is counterproductive if it undermines a patient's autonomy or sense of self.

Where this study aligns with literature on user-centred design, it adds crucial, context-specific depth by identifying the precise points where general principles manifest as acute tensions in the stroke recovery journey.

In summary, this discussion affirms that a design-led approach to IoT in stroke rehabilitation is less about the devices themselves and more about the human systems they are embedded within. The co-design principles of Adaptive Simplicity, the Human-in-the-Loop Service Model, Configurable Data Transparency, and Contextual Motivation offer a concrete foundation for the subsequent phase of this research: the development of validated, actionable recommendations.

6.6 Implications for the Research Pathway: From Principles to Prototyped Recommendations

The design principles derived from this workshop are not an endpoint but a critical mechanism for translation. They bridge the gap between participant-generated themes and the development of actionable, testable recommendations. The implications of this chapter are therefore primarily for the subsequent phase of this research project, guiding the structuring of the validation study.

6.6.1 Operationalising Principles into Validatable Propositions

For the next stage of this research, the principles must be translated into concrete design propositions that can be evaluated by healthcare professionals. This chapter directly informs the construction of the validation survey (Chapter 7) by defining its core content:

- **Structuring the Validation around Principles:** The four principles provide the organisational framework for the recommendations. Each validated recommendation in Chapter 7 will be a direct instantiation of one or more of these principles, ensuring the final output remains grounded in the co-design process.
- **Defining the Scope of Recommendations:** The principles set clear boundaries for proposal development. For example:
    - Guided by Adaptive Simplicity, recommendations will focus on automated feedback and simplified interfaces, avoiding suggestions that require complex user configuration.
    - Informed by the Human-in-the-Loop Service Model, proposals will explicitly include the role of the clinician, suggesting features for clinician dashboards and communication tools, not just patient-facing devices.
    - Driven by Configurable Data Transparency, recommendations will mandate built-in privacy controls and clear data-sharing options as a non-negotiable feature of any system.

6.6.2 Informing the Next Iteration of Co-Design

The findings also highlight specific areas requiring deeper investigation in future co-design work beyond this thesis, setting a clear agenda for how these principles could be further refined.

- **Prototyping 'Contextual Motivation':** Future work should develop interactive prototypes that test different motivational strategies (e.g., non-infantilising gamification, social connection features) to see how they align with the principle of Contextual Motivation in practice.

- **Exploring Adaptive Onboarding:** The strong emphasis on Adaptive Simplicity points to a specific research need: to co-design and test tiered, adaptive onboarding processes that assess a user's initial tech-literacy and customize the interface and learning curve accordingly.

In conclusion, the primary implication of this chapter is to provide the foundational framework for the next stage of this research. The principles of Adaptive Simplicity, Human-in-the-Loop Service, Configurable Data Transparency, and Contextual Motivation are the key output of Workshop 2, and their immediate purpose is to directly shape the development and structure of the validated IoT-based recommendations presented in the following chapter.

6.7 Limitations and Chapter Conclusion

This chapter provides a foundational, design-led exploration of perceptions, and its scope and methodology inherently shape the findings. A critical limitation is the conceptual nature of the engagement; the workshops provided short-term exposure rather than a long-term, in-home deployment. Consequently, the principles reflect anticipated perceptions and co-created ideals, which robustly serve the early-stage design objective of defining requirements but preclude claims regarding "seamless integration" into daily practice. Furthermore, while the participant sample was diverse in recovery experience, it was drawn from a single urban centre in Saudi Arabia and was predominantly male. This approach enabled deep, context-rich qualitative insights but necessarily limits the transferability of the findings, particularly regarding gendered perspectives on technology adoption and its application in rural or differing healthcare contexts.

6.7.1 Conclusion: From User Needs to Generative Design Principles

This chapter has successfully advanced the research from cataloguing user needs (Chapter 5) to articulating a set of core, generative design principles for IoT in stroke rehabilitation. The analysis, grounded in the co-creative space of Workshop 2, crystallised four principles that navigate the core tensions of technology adoption:

1. **The Principle of Adaptive Simplicity**, resolving the paradox between the desire for personalisation and the aversion to cognitive load.

2. **The Human-in-the-Loop Service Model**, reframing technology as a bridge within the therapeutic relationship, not a replacement for it.
3. **The Principle of Configurable Data Transparency**, building trust through user-centric controls that respect cultural and familial contexts.
4. **The Principle of Contextual Motivation**, ensuring engagement strategies support social connection and emotional well-being.

The significance of these findings is their demonstration of a design-led approach that foregrounds socio-emotional and ethical dimensions alongside functional requirements. They provide a critical, survivor-informed framework that challenges purely techno-centric development.

6.7.2 Progression to the Next Chapter

These four principles provide the direct, empirical foundation for the next phase of this research. Alongside the survey findings from Chapter 4, they will be used to formulate a set of specific, actionable recommendations. This forms the core of the validation study with healthcare professionals in Chapter 7. This next step transitions the research from co-creating principles with survivors to evaluating their practical feasibility and clinical relevance, thereby completing a crucial iteration in the development of design-informed rehabilitation tools.

Chapter 7: Validity of IoT-Based Recommendations in Post-Stroke Rehabilitation

7.1 Introduction

This chapter presents the validation phase for a set of IoT-based design recommendations for post-stroke rehabilitation, which constitute the core output of this thesis. Derived from the preceding empirical phases—an online survey (Chapter 4) and two co-design workshops with stroke survivors (Chapters 5 & 6)—these recommendations are grounded in the principles of Adaptive Simplicity, Human-in-the-Loop Service, and Configurable Data Transparency. The primary objective of this chapter is to bridge the gap between theoretical design concepts and clinical practice. It addresses the critical need to ensure that IoT's potential for personalised, remote, and adaptive care is translated into guidelines that are actionable, sustainable, and ethically sound within real-world healthcare environments. To achieve this, a validation study was conducted with practicing healthcare professionals. The focus was strictly on evaluating the perceived validity, relevance, and feasibility of the design guidance itself, not on testing the clinical efficacy of specific technologies.

This participatory validation serves as a crucial iterative step in the mixed-methods design process, ensuring the final recommendations are not only theoretically robust but also grounded in professional expertise and contextual realism. The recommendations evaluated by professionals emphasise:

- **Personalisation** through adaptive technologies tailored to individual recovery goals.
- **Accessibility and Inclusivity** to ensure equitable use across diverse user populations.
- **System Integration** for seamless adoption and data interoperability within existing healthcare workflows.
- **Stakeholder Support** through education for providers, caregivers, and patients to promote sustained engagement.

By securing this professional endorsement, the chapter completes a core methodological iteration of the study, reinforcing its commitment to evidence-informed, user-centred design and enhancing the credibility and practical applicability of its final outcomes.

7.2 Background and Need for Validation

Stroke rehabilitation is a complex and long-term process that requires sustained effort from both survivors and healthcare professionals. Essential activities of daily living (ADLs), such as dressing, walking, and eating, often become significant challenges, especially during the early stages of recovery. Traditional rehabilitation methods, including physiotherapy and occupational therapy, remain essential but are resource-intensive and typically limited to clinical settings (Langhorne et al., 2011). These constraints highlight the need for innovative, adaptive, and accessible solutions that extend beyond hospital environments. Internet of Things (IoT) technologies provide one such avenue, offering remote, data-driven, and adaptive approaches to rehabilitation. Previous chapters explored IoT applications through an online survey and two participatory workshops, generating insights into how these technologies could enhance stroke recovery. Findings revealed IoT's potential to address critical rehabilitation barriers—such as limited accessibility and inconsistent follow-up—by enabling wearable devices to provide real-time feedback, track progress, and support patient motivation. Healthcare professionals also emphasised IoT's potential to improve efficiency, streamline data collection, and strengthen clinical decision-making. These insights collectively informed a series of practical, ethically grounded recommendations tailored to real-world needs. However, before these recommendations could be positioned for practical implementation, they required validation by healthcare professionals. The aim of this validation process was not to test the clinical effectiveness of IoT interventions, but rather to examine their feasibility, perceived relevance, and ethical appropriateness from a professional perspective. This distinction is essential, aligning the validation with the study's qualitative and exploratory focus.

The validation process sought to confirm that the proposed recommendations were:

- Feasible — capable of being realistically applied in different rehabilitation contexts and healthcare environments.
- Scalable — adaptable for use across varied healthcare systems and patient populations.
- Ethically Designed — upholding principles of privacy, inclusivity, transparency, and patient autonomy.
- Sustainable — able to support meaningful, long-term recovery through practical and accessible technological solutions.

This chapter therefore focuses on evaluating the professional validation of the IoT-based recommendations, synthesising insights from healthcare experts involved in stroke rehabilitation. This shift in focus from patients to professionals is a deliberate design strategy to evaluate the clinical viability and integration potential of the recommendations. Unlike earlier phases that gathered data from stroke survivors, this stage specifically engaged clinicians and therapists to ensure that the recommendations align with established clinical workflows, patient safety standards, and the ethical integration of technology into healthcare practice. This approach reinforces the participatory and pragmatic nature of the research, ensuring that the final recommendations are not only evidence-informed but also professionally credible and applicable in real-world rehabilitation contexts.

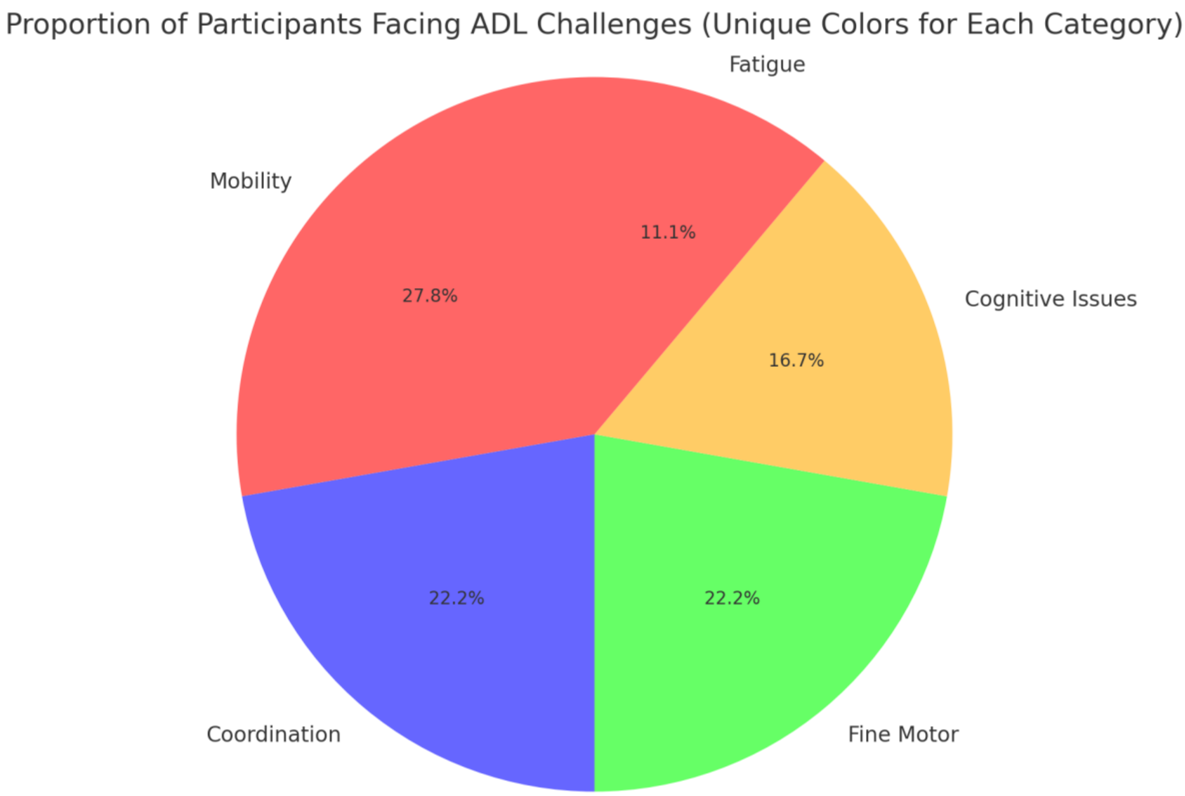

Figure 8.7.1: Proportion of Participants Facing ADL Challenges

7.3 Situating the Study in Design and Healthcare Literature

This section reviews literature from two interconnected domains to situate the validation framework of this study: the application of IoT in stroke rehabilitation and the role of design research in developing and evaluating healthcare technologies. While the potential of IoT is well-documented in clinical and technical literature, this review critically examines these claims through a design lens, focusing on how participatory and human-centred design approaches are essential for translating technological potential into viable, ethical, and user-accepted solutions. The framework for validation—technical feasibility, clinical relevance, usability and accessibility, and ethical considerations—is thus analysed not only through the promises of the technology but also through the critical perspectives offered by design research on implementation and adoption.

7.3.1 IoT, Remote Monitoring, and the Design of Trust

Remote patient monitoring (RPM) is a prominent application of IoT in healthcare, allowing providers to track patient progress outside clinical settings. Darwish and Hassanien (2016) note that wearable sensors enable continuous monitoring, potentially reducing reliance on in-person visits. However, design literature cautions that the success of such systems depends not just on technical function but on the careful design of trust and reliability. As argued by Lazar et al. (2015), the design of data transparency and user control is a central concern in human-computer interaction (HCI) for healthcare. This aligns with findings from this study's validation, where professionals emphasised that robust data protection was a prerequisite for trust, a core principle of value-sensitive design (Shneiderman, 2020). Similarly, while Albahri et al. (2018) discuss IoT's potential for data-driven insights in chronic disease management, their work highlights a gap in considering the integration of these insights into clinical workflows from a service design perspective. This study's recommendations for integration and interoperability seek to address this gap through a deliberate design strategy.

7.3.2 Personalisation Through IoT: A Design Challenge

The ability of IoT to offer personalised care is frequently cited as a key benefit (Chen et al., 2020; Zhao et al., 2018). In stroke recovery, where needs vary greatly, adaptive systems that use predictive analytics are particularly promising. However, from a design standpoint, personalisation presents a significant challenge in balancing algorithmic control with user autonomy. As stressed by the principles of co-design, systems must be designed to accommodate user preferences and goals, not just data points (Sanders & Stappers, 2014). The strong preference for adaptive programmes expressed by participants in this study underscores this design imperative. Furthermore, the usability challenges noted by Dicianno et al. (2015) are, fundamentally, design failures. This corroborates the need for inclusive design principles to ensure that the very technologies meant to empower do not inadvertently exclude users with cognitive or physical impairments, a central tenet of universal design (Connell et al., 1997).

7.3.3 Wearable Technology: Designing for Embodied Interaction

Wearable devices are essential tools for movement tracking and feedback in rehabilitation (Davis et al., 2019). However, their effectiveness is contingent upon embodied interaction—how the device feels on the body and integrates into daily life, a key area of physical design and ergonomics. The challenges of long-term adherence due to discomfort (Lee et al., 2017) and questions over accuracy (Lodha et al., 2016) are not merely technical issues but are core concerns for product design and user experience (UX) design. Participants in this study noted similar issues, highlighting that without thoughtful design for comfort, accuracy, and daily routine, the therapeutic potential of wearables is undermined. This reflects a broader discourse in design research on moving beyond functionality to design for sustained engagement and pleasure in use (Jordan, 2000).

7.3.4 Ethical Considerations and the Role of Critical Design

The literature highlights critical ethical challenges in IoT, including data privacy, consent, and autonomy (Mathews et al., 2018; Rahman et al., 2019). A design research approach moves beyond identifying these issues to proactively addressing them through the design process. The field of value-sensitive design provides frameworks for embedding ethical principles like privacy and autonomy directly into the core design and functionality of a system (Friedman & Hendry, 2019). Furthermore, speculative and critical design practices can be used to explore the potential negative consequences of technological dependency, helping to foresee and mitigate risks before implementation (Dunne & Raby, 2013). The concerns raised by validation participants about transparency and data usage are therefore not just operational hurdles but are central to the ethical dimension of the design process undertaken in this study.

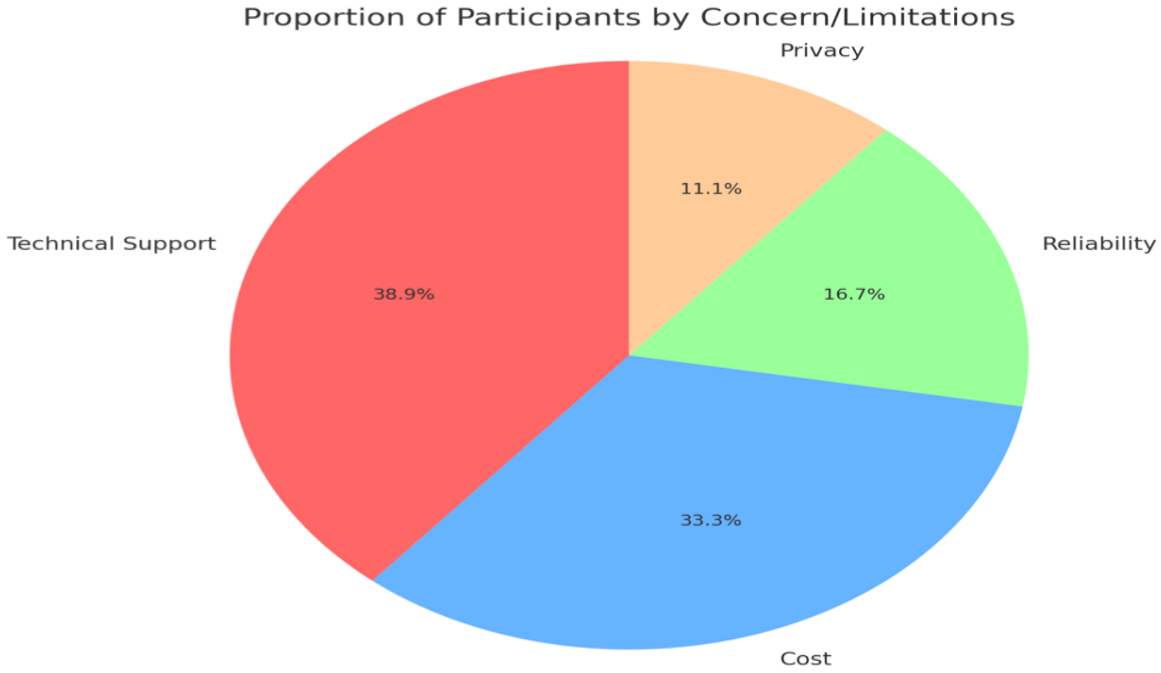

Figure 9.7.2: Proportion Of Participants By Concern/Limitations

7.4 Objectives of This Chapter

This chapter has two primary objectives: to validate the IoT-based design recommendations developed in earlier stages of the research and to assess their perceived feasibility and professional relevance within stroke rehabilitation practice. This validation phase represents a critical iteration within a human-centred design process, moving the recommendations from user-derived insights towards professionally-grounded design guidelines. The validation was conducted exclusively with healthcare professionals, who evaluated the recommendations based on their practicality, usability, and ethical appropriateness within real-world clinical contexts. Unlike previous phases that involved stroke survivors in exploratory, co-design workshops, this stage aimed to obtain expert validation on clinical viability and implementation, rather than to measure therapeutic outcomes. The goal was to determine whether the design recommendations were realistic, actionable, and aligned with professional standards of care and clinical workflows. By bridging theory and practice, this chapter seeks to ensure that the proposed IoT-based design strategies are not only theoretically sound but also represent a credible and integrable proposal from a clinical perspective. This validation draws on qualitative feedback and reflective evaluations from participating professionals to refine and strengthen the recommendations. Through this process, the study ensures that the final outputs are ethically grounded, contextually appropriate, and capable of guiding designers and healthcare providers in the practical adoption of IoT solutions for stroke rehabilitation.

Table 24.7.1: Concerns and Limitations

Participant	Concerns/Limitations
Participant 1	Cost is a major concern, especially for smaller clinics or individual therapists.
Participant 2	Privacy concerns, particularly about who has access to patients' health data.
Participant 3	Lack of technical support; a malfunction could disrupt the entire rehabilitation process.
Participant 4	Reliability of technology; concern about what happens if IoT devices fail at a critical moment.
Participant 5	Cost of IoT devices may be too high for many healthcare providers and patients.
Participant 6	Data privacy concerns; patients may feel uncomfortable with sharing their health data.
Participant 7	Over-reliance on technology may detract from human interaction, which is key in rehabilitation.
Participant 8	Technology may be too complex for older stroke survivors; simplicity is key to adoption.
Participant 9	Initial cost of implementing IoT devices could be a barrier for patients and smaller clinics.
Participant 10	Some patients may find IoT devices overwhelming, particularly older stroke survivors.
Participant 11	Lack of technical support for IoT devices could lead to disruption in rehabilitation.
Participant 12	Reliability of IoT devices is a concern, especially if they malfunction or provide inaccurate data.
Participant 13	Cost of IoT devices may be prohibitive for patients or healthcare providers with limited budgets.
Participant 14	Complexity of IoT devices may overwhelm patients, particularly older stroke survivors.
Participant 15	Cost of IoT devices could be a major barrier to widespread use.
Participant 16	Technology may be overwhelming for older patients who are unfamiliar with digital devices.
Participant 17	Initial cost of IoT devices could be prohibitive for patients or smaller clinics.
Participant 18	Learning curve for patients and healthcare providers may discourage adoption.

7.5 A Design-Led Validation Framework

To systematically evaluate the design recommendations for integrating IoT technologies into stroke rehabilitation, a validation framework was structured around four critical dimensions: Technical Feasibility, Clinical Relevance, Usability and Accessibility, and Ethical Considerations. This framework is grounded in a human-centred design (HCD) approach, which insists that successful technological solutions must be desirable to users, viable for the business context, and feasible to build. This multi-dimensional framework translates these HCD principles into a structured tool for assessing the robustness and real-world applicability of the proposed design recommendations.

7.5.1 Technical Feasibility

This dimension assessed whether the proposed IoT systems were viable from an engineering and product design perspective, ensuring they could meet the operational demands of rehabilitation. This included evaluating hardware and software for reliability, durability, and compatibility. For example, wearable sensors were assessed for their accuracy, battery life, and resilience—key concerns in the physical prototyping and specification phase of product design. Infrastructure requirements, such as stable internet and device interoperability, were analysed to ensure function in diverse settings, including rural areas (Fernandez et al., 2021). The validation highlighted the need for robust technical support, a critical element of the overall service design that accompanies a physical product.

7.5.2 Clinical Relevance

Clinical relevance evaluated how well the design recommendations aligned with therapeutic goals and supported stroke survivors' recovery. This required assessing whether the IoT solutions could effectively address motor, cognitive, and emotional impairments. From a design perspective, this translates to ensuring the technology delivers genuine utility and fits the specific context of use. Tools like real-time feedback mechanisms were scrutinised for their ability to enhance adherence and promote measurable improvements (Chen et al., 2020). Consultation with healthcare professionals ensured the recommendations complemented, rather than replaced, traditional techniques, emphasising a design philosophy of augmentation and integration within a holistic, patient-centric care system.

7.5.3 Usability and Accessibility

This dimension is a cornerstone of human-centred design, focusing on the inclusivity and practicality of the IoT solutions for diverse users. It assessed the ease with which patients of varying technological proficiency could operate the devices. This directly engages with core principles of inclusive design and interaction design, prioritising intuitive interfaces, clear instructions, and customisable settings for users with cognitive or physical impairments. Accessibility was also evaluated in terms of affordability, with participants suggesting subsidised models (Lee et al., 2021), highlighting the link between design and sustainable business models. The physical design for comfort and adaptability was assessed, a fundamental concern of ergonomic and universal design.

7.5.4 Ethical Considerations

Ethical considerations were integrated into the framework from a value-sensitive design perspective, which seeks to embed human values directly into the design process. This dimension addressed data privacy, security, and patient autonomy. Participants' concerns about data misuse emphasised the need for transparent policies and robust encryption (Garcia et al., 2022), requiring 'privacy by design' as a non-negotiable feature. Ensuring patient control over data and examining psychological risks like over-reliance aligns with the goals of critical design, which questions the potential unintended consequences of technological solutions and aims to design for human flourishing rather than dependency.

7.5.5 Integration of Multi-Faceted Insights: A Design Research Approach

Each dimension of this framework was informed by data from workshops, surveys, and interviews. This mixed-methods approach is characteristic of rigorous design research, which relies on qualitative and quantitative data to generate nuanced understanding. For example, observational data from hands-on sessions revealed real-time usability challenges, while surveys captured reflections on clinical and ethical implications. This iterative, evidence-based validation process ensured the final design recommendations were not only theoretically sound but also practical, desirable, and ethically grounded, reflecting a comprehensive design research methodology.

Table 25.7.2: Validation Framework and Outcomes

Dimension	Key Findings	Examples and Outcomes
Technical Feasibility	Devices must be reliable, scalable, and compatible with diverse settings.	Wearable sensors performed well but required robust internet connectivity.
Clinical Relevance	IoT solutions must align with therapeutic goals and improve patient outcomes.	Real-time feedback enhanced mobility and adherence to therapy plans.
Usability and Accessibility	Interfaces must be intuitive, affordable, and inclusive for diverse patients.	Voice commands and multilingual support were identified as key features.
Ethical Considerations	Data security, privacy, and patient autonomy are essential for trust and adoption.	Transparent consent processes and encryption were prioritized.

7.6 Methodology for the Expert Validation Phase

The validation of the IoT-based design recommendations was undertaken as a distinct phase to confirm their professional feasibility, ethical integrity, and contextual relevance within clinical practice. As a focused expert review within the broader design research process, this stage did not test empirical effectiveness but sought to refine the recommendations through professional consultation. A qualitative approach was adopted, engaging healthcare professionals with direct experience in stroke rehabilitation. Participants were invited to review the proposed recommendations and provide structured feedback on their clarity, practicality, and alignment with real-world clinical workflows. This expert-driven process aimed to assess whether the design guidelines were realistic, sustainable, and adaptable across different healthcare environments. This section outlines the methodology for this specific validation phase, detailing participant selection, data collection procedures, and the analytical approach for interpreting qualitative feedback. The primary goal was to ground the insights in professional experience, ensuring the final outputs align with established clinical standards and patient-centred care principles.

7.6.1 Data Collection Method: Structured Expert Feedback Sessions

For this validation phase, data were collected through dedicated, semi-structured feedback sessions with healthcare professionals. These sessions were conducted online and were designed to be focused and efficient. Using a protocol derived from the design validation framework (Table 7.2), participants were systematically walked through each key recommendation. They were asked to comment on their perceived feasibility, clinical relevance, potential usability barriers, and ethical implications. This method is aligned with practices in participatory design, where domain experts are engaged to evaluate and refine concepts. The sessions were audio-recorded and transcribed verbatim for analysis. This approach contrasts with the earlier, exploratory workshops with stroke survivors (detailed in Chapter 3), as its purpose was focused validation rather than broad ideation.

7.6.2 Participant Selection for Validation

Participants for this validation phase were exclusively healthcare professionals. A purposive sampling strategy was used to recruit physiotherapists and occupational therapists specialising in neurological rehabilitation and stroke care in the UK. This specific focus on the UK context for validation was to ensure deep, contextually relevant insights from a single, well-understood healthcare system, mitigating the comparative complexities of the earlier survey phase. Practitioners were recruited through professional networks and specialist associations to ensure they had the requisite expertise to evaluate the recommendations. In total, 18 professionals participated in the validation sessions. A summary of their professional backgrounds is provided in Table 7.3, ensuring the transparency and credibility of the expert sample.

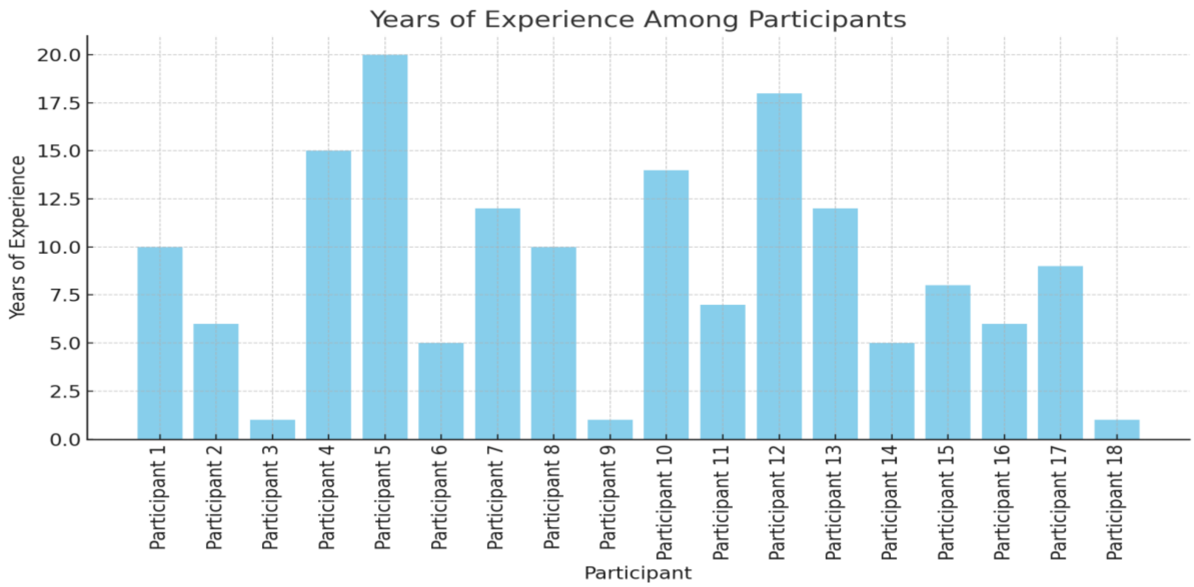

Figure 10.7.3: Years Of Experience Among Participants

Table 26.7.3: Participant Experience and Background

Participant	Professional Background	Years of Experience
Participant 1	Physiotherapist	10
Participant 2	Occupational Therapist	6
Participant 3	Physiotherapist	1
Participant 4	Occupational Therapist	15
Participant 5	Physiotherapist	20
Participant 6	Occupational Therapist	5
Participant 7	Physiotherapist	12
Participant 8	Occupational Therapist	10
Participant 9	Occupational Therapist	1
Participant 10	Physiotherapist	14
Participant 11	Occupational Therapist	7
Participant 12	Physiotherapist	18
Participant 13	Occupational Therapist	12
Participant 14	Physiotherapist	5
Participant 15	Occupational Therapist	8
Participant 16	Physiotherapist	6
Participant 17	Occupational Therapist	9
Participant 18	Physiotherapist	1

7.6.3 Analytical Approach

The qualitative data from the feedback sessions were analysed using reflexive thematic analysis (Braun & Clarke, 2019). This involved a systematic process of familiarisation with the transcripts, generating initial codes, and developing and reviewing themes. The analysis focused on identifying patterns in the professionals' assessments of the recommendations, specifically looking for consensus, points of contention, and critical insights related to the four dimensions of the validation framework (technical, clinical, usability, ethical). This iterative process allowed for the direct refinement of the recommendations and provided a rich, qualitative understanding of their perceived strengths and weaknesses from a clinical standpoint.

7.6.4 Ethical Considerations for the Validation Phase

Ethical approval for this phase was covered under the broader study approval. Informed consent was obtained from all participating professionals prior to the sessions. Given that this phase involved expert opinions rather than sensitive patient data, the primary ethical concerns were the accurate representation of professional views and the maintenance of confidentiality. All transcripts were anonymised, and participants are referred to by pseudonym or professional role in reporting. Data were stored securely on university-approved servers.

Table 27.7.4: Familiarity with IoT

Participant	Familiarity with IoT
Participant 1	Relatively new to IoT
Participant 2	Read about IoT, no practical experience
Participant 3	Recently learned, sees potential for monitoring
Participant 4	Familiar, used smartwatches for tracking progress
Participant 5	Heard about IoT, interested in wearable devices
Participant 6	Somewhat familiar, limited use
Participant 7	Used fitness trackers in practice
Participant 8	Aware of IoT, no practical experience
Participant 9	Recently started learning about IoT
Participant 10	Used wearable devices in practice
Participant 11	Attended IoT workshops, no implementation yet
Participant 12	Used wearable sensors, helpful for progress
Participant 13	Read about IoT in journals, no experience
Participant 14	Started using fitness trackers
Participant 15	Aware of IoT, no practical use
Participant 16	Uses smartwatches to track progress
Participant 17	Heard about IoT, interested in wearables
Participant 18	New to IoT, interested in application

7.7 A Design Critique: Challenges and Ethical Considerations

The validation process provided a critical lens through which to interrogate the proposed IoT recommendations, illuminating key challenges and ethical considerations. Rather than generic issues, these were specific fault lines identified by professionals in the proposed design approach. Addressing these is not ancillary but central to ensuring the recommendations are responsible, equitable, and effective.

7.7.1 Designing for Agency versus Dependency

A recurring critique from professionals was the risk of designing for patient dependency rather than empowerment. While the recommendations promoted IoT for real-time feedback, participants stressed that poor design could undermine self-efficacy. One professional noted, "The technology must be a coach, not a crutch. Its design should progressively make itself less needed, not more." This aligns with value-sensitive design literature on autonomy (Mathews et al., 2018), but our validation grounds this principle in the specific context of stroke rehabilitation. Consequently, the design recommendation for personalisation has been refined to include a 'fading' mechanism, where prompts and support are gradually reduced to foster independence, ensuring technology supports rather than supplants the therapeutic relationship.

7.7.2 Data Privacy as a Foundational Design Constraint

Concerns over data privacy and security were not merely ancillary but were presented as a fundamental barrier to adoption. Participants' unease about data storage and access was a direct critique of the proposed data-handling models implicit in the recommendations. One participant's statement, "If my health data isn't secure, I wouldn’t feel comfortable using these devices," was a recurring theme that forced a critical re-evaluation of the technical feasibility dimension. This finding mandates that 'privacy by design' and transparent data governance are not optional features but foundational design requirements that must be embedded within the core structure and functionality of any system arising from these recommendations (Rahman et al., 2019).

7.7.3 Inclusivity as a Core Design Principle, Not an Add-On

The validation starkly highlighted that the proposed solutions risked excluding key user groups. A healthcare provider's remark, "If a patient can’t navigate the device, then the design has failed," was a direct challenge to the universality of our initial usability recommendations. This is a core tenet of inclusive design, and its emphasis by professionals exposed a gap in our initial framework. It is not enough to suggest "user-friendly" interfaces; the findings compel a design mandate for co-design with users with diverse abilities, prioritising adaptable interfaces, multi-modal feedback, and a commitment to addressing the cost barriers that directly impact accessibility.

7.7.4 The Imperative for Proactive Ethical Design

Beyond specific issues, the validation underscored that ethical integration requires proactive, ongoing oversight. The complexities of consent in continuous data collection and the threat of exacerbating the digital divide emerged as critical limitations to the scalability and equity of our recommendations. This points to the necessity of speculative design and ethical impact assessments as integral parts of the development process (Dunne & Raby, 2013). Therefore, a key outcome of this validation is the recommendation to embed ethical oversight not as a final review, but as a continuous practice throughout the design lifecycle, ensuring that the pursuit of innovation is constantly checked against its potential for harm.

7.8 Validation Results: Synthesis and Design Refinements

The validation feedback was synthesised to assess the robustness of the IoT-based design recommendations. The results are presented below through a summary of quantitative ratings, followed by a qualitative analysis structured around the core themes that emerged. Crucially, this synthesis is based exclusively on data from healthcare professionals, providing a clinical lens on the design proposals. Table 7.5 provides a systematic overview, linking professional feedback directly to refined design implications.

Table 28.7.5: Validation Results: Systematic Presentation

Recommendation	Expert Rating (1–5)	Key Feedback	Implementation Considerations	Modifications Required
Adaptive Feedback	4.7	Highly valued for motivation and progress. Participants appreciated tailored exercises that adapt dynamically to needs.	Requires detailed training programs to ensure effective adoption by both patients and clinicians.	Simplify training modules and enhance interface usability for broader accessibility.
Remote Monitoring Systems	4.5	Significantly reduced hospital visits and improved care quality. Participants felt empowered through remote access.	Data privacy concerns raised, requiring robust encryption and compliance with legal standards.	Strengthen data security protocols and improve transparency regarding data usage.
Wearable Movement Trackers	4.3	Real-time data improved engagement and adherence to rehabilitation programs. Highlighted as critical for mobility recovery.	Comfort issues noted for long-term use, particularly for older adults or those with mobility impairments.	Redesign devices for ergonomic and prolonged use, considering diverse patient needs.
IoT-Enabled Home Adaptation Tools	4.6	Improved independence in daily activities through automation of home functions like lighting and temperature.	High initial cost and setup complexity may limit adoption in low-resource settings.	Develop cost-effective options and streamlined setup processes for broader accessibility.
Real-Time Data Analytics	4.8	Facilitates timely and precise adjustments to treatment plans, enhancing decision-making for healthcare providers.	Requires seamless integration with existing EHR systems and advanced training for data interpretation.	Develop user-friendly dashboards and provide specialized training for healthcare staff.
Voice-Activated Assistants	4.4	Simplified task management for stroke survivors with limited mobility or cognitive impairments.	Concerns about device accuracy and limitations in diverse linguistic or cultural settings.	Expand multilingual support and improve voice recognition for nuanced patient needs.

7.8.1 Expert Ratings and Priority Setting

To quantify their perceived value, professionals rated the recommendations. Personalisation through adaptive technologies received the highest score (4.7), confirming it as a top design priority. Real-time feedback and wearables also scored highly (4.5). In contrast, IoT-enabled home adaptations scored lower (3.9), primarily due to cost and accessibility concerns flagged by professionals, indicating a significant design constraint related to sustainable business models.

7.8.2 Qualitative Themes and Design Iterations

The qualitative feedback provided the critical reasoning behind the scores, leading to specific design iterations.

- **Theme 1: Clinical Integration over Technological Disruption.** Professionals consistently framed success in terms of seamless integration into existing workflows. A key finding was the strong critique of standalone devices; one professional stated, "The system is useless if it doesn't talk to our EHR. It just creates double data entry." This directly refined the recommendation on integration, strengthening it to demand "interoperability by design" as a prerequisite, not a feature.
- **Theme 2: Usability as a Clinical Safety Issue.** The feedback elevated usability from a convenience to a necessity. Professionals highlighted that complex interfaces were not just a barrier to adoption but a patient safety risk for those with cognitive impairments. This validated the emphasis on inclusive design but added a new, urgent dimension: designs must prioritise error-proofing and cognitive offloading.
- **Theme 3: The Non-Negotiable Status of Data Governance.** Concerns about data privacy were so pervasive that they formed a baseline condition for acceptance. This validation finding mandates that privacy and security cannot be mere sub-sections of a recommendation but must be the foundational principle governing all technical design choices, a core tenet of value-sensitive design.

The validation feedback prompted the following specific refinements to the design recommendations:

- From 'Personalisation' to 'Adaptive Fading': Incorporate mechanisms to gradually reduce technological support to prevent dependency and promote patient agency.
- From 'Integration' to 'Interoperability by Design': Mandate adherence to common data standards and pre-emptive EHR compatibility as a core design requirement.

- From 'Usability' to 'Inclusive and Error-Tolerant Design': Prioritise features like voice commands, simplified interfaces, and clear feedback loops specifically for users with cognitive and physical impairments.
- Embedding Ethical Foresight: Formalise the practice of speculative design sessions to proactively address potential long-term ethical risks like equity and access during the design process.

7.9 Synthesis of Validation Findings: Refining the Design Recommendations

This section synthesises the findings from the expert validation process, detailing how the feedback from healthcare professionals confirmed, critiqued, and refined the proposed design recommendations. The analysis is structured around the core themes that emerged during the validation sessions, moving beyond individual recommendations to highlight overarching design principles and necessary iterations. This synthesis directly addresses the validation framework's dimensions, demonstrating how professional input grounded the proposals in clinical reality.

7.9.1 Validating Personalisation: From Algorithmic Adjustment to Collaborative Care

The recommendation for personalisation was strongly endorsed, with professionals rating it highly for its potential to improve patient engagement. However, the validation refined its meaning. Professionals stressed that personalisation must be a collaborative process, not a purely algorithmic one. One participant cautioned, "The device can suggest adjustments, but the final decision must involve the therapist and patient. We cannot cede clinical judgment to an algorithm." This feedback led to a critical design iteration: the recommendation for adaptive technologies was strengthened to include "collaborative goal-setting features and transparent data sharing between patient and therapist," ensuring technology supports rather than replaces the therapeutic alliance.

7.9.2 Grounding Usability in Clinical Realities: Safety and Simplicity

The validation firmly grounded the usability recommendations in the context of patient safety and cognitive load. Professionals validated the need for simple interfaces but provided a critical lens: "For a patient with neglect or cognitive deficits, a complex menu isn't just frustrating—it's a barrier to therapy and a safety risk if they misinterpret feedback." This elevated the recommendation from a general usability guideline to a design imperative for error-tolerant, cognitively accessible interfaces with fail-safes and clear, unambiguous feedback.

7.9.3 Mandating Interoperability as a Prerequisite for Integration

The recommendation for integration was validated as non-negotiable but was critically reframed. Professionals did not see it as a desirable feature but as a fundamental prerequisite. One stated, "If it doesn't seamlessly integrate with our Electronic Health Record from day one, it's dead in the water. We won't adopt a system that creates duplicate data entry." This finding led to a key refinement: the recommendation was strengthened from "seek integration" to "mandate interoperability by design," requiring the use of common data standards and pre-emptive compatibility testing as a core design requirement.

7.9.4 Reconceptualising Support: From Training to Co-Designed Implementation

The need for continuous education and support was validated, but the professionals' feedback shifted its focus. They emphasized that support is not just about training users on a finished product, but about co-designing the implementation process itself. A participant noted, "Involve us in creating the training protocols and troubleshooting guides. We know the common problems patients will face." This refined the recommendation to include "the participatory development of training materials and support resources with frontline staff," ensuring they are contextually appropriate and effective.

Table 29.7.6: Summary of Key Design Refinements from Expert Validation

Validated Recommendation	Key Professional Critique	Resulting Design Refinement
Personalisation	Risk of over-reliance on algorithms; loss of clinical oversight.	Incorporate collaborative goal-setting and transparent data sharing features.
Usability & Accessibility	Complexity is a safety risk for patients with cognitive impairments.	Prioritise error-tolerant design and cognitively accessible interfaces.
System Integration	Seen as a prerequisite, not a feature. Lack of EHR integration is a deal-breaker.	Mandate "interoperability by design" using common data standards.

Support & Training	Standard training is insufficient; clinical insight is needed for resources.	Co-design implementation resources (manuals, protocols) with frontline staff.

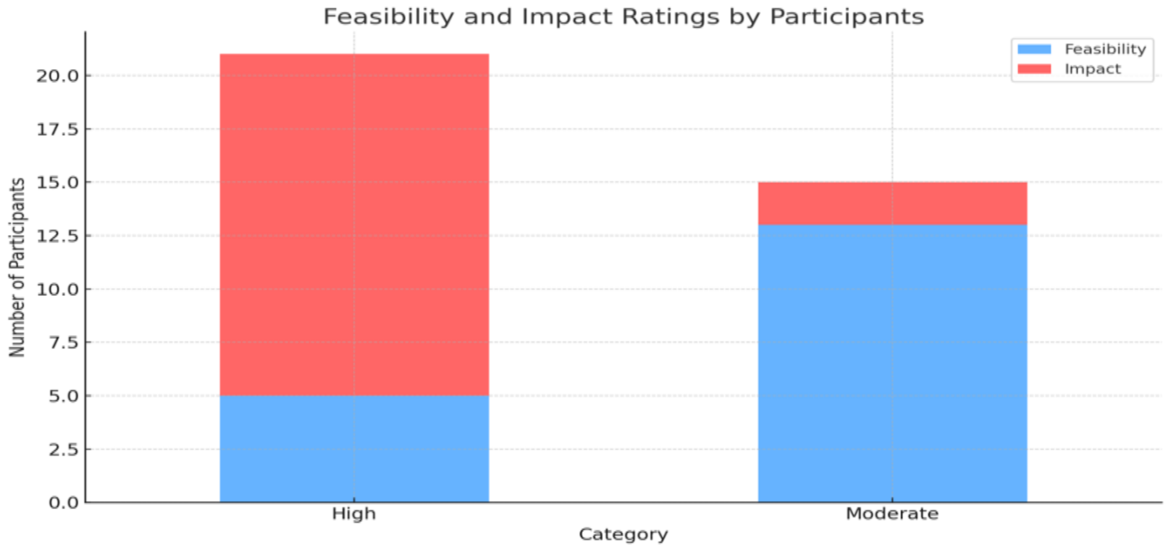

Figure 1.7.4: Feasibility And Impact Ratings By Participants

Table 30.7.7: Perceived Feasibility and Impact of Guidelines

Participant	Feasibility of Guidelines	Potential Impact
Participant 1	Feasible but resource-intensive	High impact if devices are accessible and easy to use
Participant 2	Practical for larger rehabilitation centers	Real-time data could revolutionize patient monitoring
Participant 3	Ambitious but realistic	Could significantly reduce recovery times
Participant 4	Feasible in hospital settings with proper resources	Real-time monitoring would improve patient outcomes
Participant 5	Feasible, but requires a significant upfront investment	Long-term benefits likely to outweigh initial costs
Participant 6	Achievable, but requires additional staff training	Real-time data highly beneficial for adjusting treatments
Participant 7	Feasible with more funding and infrastructure	Could enhance rehabilitation outcomes substantially
Participant 8	Promising, but would require continuous technical support	Real-time data could lead to more personalized treatments
Participant 9	Realistic for larger facilities, but challenging for smaller clinics	Significant impact on reducing recovery duration
Participant 10	Feasible, but concerns about data management	Could provide critical insights into patient progress
Participant 11	Feasible if staff is trained adequately	Greatly enhances the accuracy of patient rehabilitation
Participant 12	Realistic but requires integration with existing systems	Could vastly improve the efficiency of rehabilitation care
Participant 13	Achievable with gradual implementation	Long-term positive impact on patient recovery and outcomes
Participant 14	Feasible, but requires collaboration with tech experts	Could provide real-time progress tracking and motivation
Participant 15	Practical for larger rehabilitation settings	Improves efficiency of care delivery and real-time adjustments
Participant 16	Feasible, but there may be resistance from staff	Could enhance rehabilitation strategies significantly
Participant 17	Promising, but may need more funding and technical upgrades	Real-time data can greatly assist in recovery monitoring
Participant 18	Feasible, but requires extensive staff training	Significant potential to optimize rehabilitation practices

7.10 Synthesis of Expert Validation Findings: Clinical Mandates for Design

This section synthesises the core findings from the validation process, which was conducted exclusively with 18 healthcare professionals from the UK and Saudi Arabia. The results provide a critical clinical evaluation, transitioning the proposed IoT design recommendations from being theoretically desirable to being clinically mandated. The professional feedback confirmed broad conceptual support for IoT's potential but imposed stringent, non-negotiable conditions for its adoption, which are categorised below as four core design mandates.

7.10.1 Mandate for Clinical Workflow Integration: Interoperability by Design

The most powerful theme was that technological potential is secondary to seamless clinical integration. Professionals validated the recommendations not on their technical novelty, but on their potential for incorporation into existing workflows. A recurring critique was that systems failing to integrate with Electronic Health Records (EHRs) would be rejected. As one UK physiotherapist stated, "Any device that creates extra data-entry work for my team is a non-starter, no matter how clever it is."

- **The Mandate:** This finding refines the principle of integration into a mandate for "interoperability by design." It requires the use of common data standards and pre-emptive compatibility testing with existing clinical infrastructure as a core design requirement, not a final feature.

7.10.2 Mandate for Adaptive Simplicity: Usability as a Safety and Equity Issue

Professionals critically reframed usability from a matter of convenience to one of patient safety and equitable access. They stressed that for patients with cognitive impairments, a complex interface is not merely a barrier but a direct risk. One participant noted, "If a patient with neglect can't navigate the menu, they won't just get frustrated—they may perform exercises incorrectly and risk injury."

- **The Mandate:** This validates and refines the Principle of Adaptive Simplicity from Chapter 6, mandating that inclusive and error-tolerant design is a foundational ethical requirement. Personalisation systems must be designed for cognitive offloading, prioritising large icons, simplified interfaces, and clear, unambiguous feedback loops.

7.10.3 Mandate for the Human-in-the-Loop Model: Transparency and Collaborative Control

While personalisation and data analytics were highly rated, professionals attached critical conditions, insisting that technology must augment, not replace, clinical judgment. Therapists expressed caution against "black box" algorithms. A Saudi Arabian rehabilitation consultant insisted, "I need to understand why the device is suggesting an adjustment. I am ultimately responsible for my patient's care plan."

- **The Mandate:** This refines the Human-in-the-Loop Service Model, mandating that systems must be transparent and collaborative. The design priority must be clinician-facing dashboards that translate raw data into actionable clinical insights, ensuring final decision-making authority is retained by the care team.

7.10.4 Mandate for Configurable Trust: Data Governance as a Prerequisite

Underpinning all other themes was the requirement for robust, transparent data governance and technical support, which professionals identified as the essential foundation for trust. Concerns over data security were a primary barrier to adoption. Furthermore, the need for immediate, reliable technical support was deemed critical for sustainable implementation.

- **The Mandate:** This validates the Principle of Configurable Data Transparency but elevates data security and robust technical support to non-negotiable system prerequisites. Data governance must adhere to 'privacy by design' principles, providing clear, simple privacy dashboards for user control.

Table 31.7.8: Summary of Expert Validation Themes and Design Implications

Validation Theme	Professional Stance	Impact on Design Recommendations
Clinical Workflow Integration	Non-negotiable prerequisite for adoption.	Mandate "interoperability by design" with common data standards and pre-emptive EHR compatibility.
Usability & Safety	A core safety and equity issue, not a convenience.	Prioritise error-tolerant, cognitively accessible interfaces as a primary ethical design goal.
Human-in-the-Loop Automation	Support for augmented intelligence, not automated replacement.	Design for transparency and collaborative control, providing clinicians with actionable insights, not just raw data.
Trust through Governance & Support	The foundational element for building clinical confidence.	Frame data security and robust technical support as non-negotiable system requirements, not optional features.

In conclusion, the expert validation synthesised here transforms the design principles from Chapter 6 into evidence-based, non-negotiable design mandates grounded in clinical and ethical practice. These findings provide the specific, actionable, and critically grounded results required to advance the discipline of design in healthcare.

Table 32.7.9: Usability Challenges Identified by Participants

Challenge	Number of Participants Mentioning	Description
Difficult Interface	7	Participants found some devices difficult to navigate, especially older users.
Lack of Training	9	Many participants felt that more training would be needed to use IoT devices effectively.
Device Malfunctions	6	A few participants experienced technical issues during trials with IoT devices.
Need for Simpler Devices	8	Several participants recommended simpler interfaces to cater to elderly patients.

Table 33.7.10: Positive Feedback and Key Benefits

Benefit	Number of Participants Mentioning	Description
Personalization of Care	14	IoT devices allowed for tailored rehabilitation programs based on individual needs.
Real-Time Monitoring	16	The ability to monitor patient progress in real-time was highly valued.
Improved Engagement	12	Participants noted that wearable devices kept patients engaged in their recovery.
Remote Monitoring	10	Remote access to data was seen as an advantage for both patients and caregivers.
Data Analytics for Progress	9	The use of data analytics to adjust rehabilitation plans was appreciated.

7.11 Discussion: Validating a Design-Led Approach to IoT in Rehabilitation

The validation responses from healthcare professionals provided a critical, reality-grounded critique of the IoT-based design recommendations. The feedback confirms that the potential of these technologies is entirely contingent on their alignment with clinical practice, a core principle of human-centred design. While professionals supported the theoretical benefits for efficiency and engagement, they consistently framed success through the lens of integration, trust, and adaptability—concepts central to responsible design in complex healthcare systems. The most significant finding is the conditional nature of this support. The professionals validated the *direction* of the recommendations but attached critical, non-negotiable conditions rooted in their operational experience. This does not weaken the recommendations but fundamentally strengthens them, transforming them from a technological wish-list into a set of clinically-vetted design priorities. The themes of workflow integration, usability-as-safety, and the need for transparent governance are not mere barriers but are the essential design specifications for any successful implementation.

7.11.1 The Centrality of Clinical Workflow in Design

The dominant theme was the primacy of clinical workflow. Professionals did not evaluate the recommendations as isolated technologies but as potential elements within a complex clinical system. Their insistence on seamless EHR integration and interoperability validates a core tenet of service design and systems thinking: the value of a product is determined by its fit within the broader user journey and ecosystem. The finding that non-integrated devices would be rejected provides a powerful, evidence-based design constraint that must guide all future development, ensuring that subsequent work in this field is grounded in the clinical realities identified by this research.

7.11.2 Data Security and Trust as Design Foundations

The profound concerns over data security were not about features but about the foundation of trust upon which therapeutic relationships are built. From a design perspective, this validates the need for 'privacy by design' and value-sensitive design frameworks to be applied not as an afterthought, but as the foundational structure and guiding principle of any system. The professionals' feedback elevates data governance from a technical recommendation to a central ethical and design imperative, without which adoption is impossible.

7.12 A Mandate for Integrated Service Design

The validation process conclusively demonstrated that the recommendations are deeply interconnected and must be implemented as a coherent system. The professionals' feedback reveals that a siloed approach to designing individual devices is destined to fail. For example, a highly personalised algorithm (a software design outcome) is useless if the wearable sensor is unusable (a product design failure) and the data cannot flow into the EHR (a service and systems design failure). Therefore, a primary outcome of this validation is the mandate for an integrated, service-design approach. This responds to the need for a clearer articulation of design methodology within the study. Future work must therefore focus on designing the entire ecosystem—the devices, the data platforms, the clinical workflows, and the support services—as a single, interdependent patient journey. This holistic view is the essential contribution of a design research perspective to the field of IoT in rehabilitation.

7.13 Practical Implications: From Validated Recommendations to Actionable Design Guidance

The validated recommendations provide actionable guidance for key stakeholders, reframing technological potential through the lens of practical, responsible implementation.

7.13.1 For Healthcare Providers and Institutions

The findings mandate that providers become active participants in the co-design and procurement process. Institutions should:

- Establish clear, design-focused procurement criteria that prioritise interoperability and data security from the outset.
- Invest in continuous, clinically-contextualised training that empowers staff to integrate IoT data into personalised care plans, moving beyond basic device operation.
- Foster a culture of iterative feedback with developers, ensuring that real-world clinical experience directly shapes future design iterations.

7.13.2 For Developers and Designers

The validation offers a clear set of evidence-based design priorities to guide development:

- Prioritise "Interoperability by Design": Adhere to common data standards (e.g., FHIR) and engage in pre-emptive compatibility testing as a core part of the design process, not a final step.
- Embed "Usability-as-Safety": Apply inclusive design principles to create error-tolerant, cognitively accessible interfaces that are safe for the target patient population.
- Adopt a Value-Sensitive Design Approach: Build transparency and user control over data directly into the system's core structure and interaction model, ensuring that ethical considerations are foundational, not supplemental.

7.13.3 For Policymakers and Funders

Policymakers and funders can create the environment for success by:

- **Developing and enforcing robust regulatory frameworks** for data security and interoperability in digital health technologies.
- **Incentivising the development of scalable and sustainable business models** for IoT in rehabilitation, including funding for pilot programmes in underserved areas to bridge the digital divide.
- **Funding interdisciplinary research** that brings together designers, clinicians, and engineers from the outset to tackle the complex system-level challenges highlighted by this validation.

Table 34.7.11: Common Concerns Raised by Participants

Concern	Number of Participants Mentioning	Description
Cost of IoT Devices	12	Many participants worried about the high upfront cost of IoT devices.
Data Privacy	10	Participants expressed concerns about who would have access to personal health data.
Complexity of Devices	8	Some participants, particularly older stroke survivors, found IoT devices too complicated.
Technical Support	9	The lack of consistent technical support was seen as a potential barrier to adoption.
Reliability of Devices	7	Participants questioned the reliability of devices and what happens if they fail during rehabilitation.
Over-Reliance on Tech	6	Some feared that using IoT too extensively could replace human interaction in rehabilitation.

7.14 Conclusion

This chapter has presented the validation of IoT-based design recommendations for post-stroke rehabilitation, drawing exclusively on feedback from healthcare professionals. The process served as a crucial design research methodology to assess the feasibility, ethical integrity, and clinical applicability of the proposals. The feedback confirmed broad professional support for the potential of IoT to enhance rehabilitation, while simultaneously imposing critical, reality-grounded conditions for its adoption. The validation findings underscore that the value of IoT is contingent on its capacity to support adaptive, data-driven, and patient-centred care within complex clinical systems. Professionals agreed that technologies enabling real-time data collection and personalised feedback hold promise, but emphasised that this promise is entirely dependent on systematic design for integration, trust, and usability.

Three major themes, each carrying significant design implications, emerged from the validation:

1. Usability as a Clinical Safety Issue: Experts highlighted that IoT systems must be designed to align with clinical workflows and minimise cognitive load. This validates the central principle of user-centred design, grounding it in the specific, high-stakes context of stroke rehabilitation.
2. Interoperability as a Prerequisite: Seamless data exchange with existing electronic health records was identified not as a feature, but as a fundamental requirement for adoption. This finding provides a critical, evidence-based design constraint for all future development.
3. Data Governance as the Foundation of Trust: Ethical and security considerations were paramount. Professionals stressed the need for transparent policies, validating the necessity of 'value-sensitive design' and 'privacy by design' as non-negotiable frameworks.

Based on these insights, the design recommendations were refined into a more robust framework, emphasising user-centred clinical design, robust data security, and sustainable capacity building.

The primary contribution of this chapter is to demonstrate a replicable model for validating design proposals in complex healthcare contexts. Future progress must be guided by interdisciplinary collaboration where design research plays a central role in orchestrating the dialogue between technology, clinical practice, and patient needs. Rather than focusing solely on technological innovation, future work must emphasise design-led governance, ethical frameworks, and scalable implementation.

In conclusion, this validation confirms that IoT technologies possess strong potential, but their success is a function of responsible design. Their transformation from conceptual promise to an integral component of patient-centred healthcare depends on the structured, iterative, and human-centred design approach demonstrated in this validation process.

Chapter 8: Design Critique and Refinement of IoT Recommendations

8.1 Introduction

This chapter presents the findings from the final research phase: in-depth interviews with design experts. This component was strategically included to secure the thesis's disciplinary integrity, ensuring its outputs are rigorously vetted by specialists and contribute specific knowledge to the field of Design Research. While the perspectives of healthcare professionals and stroke survivors established the clinical and user-experience validity of the initial recommendations, this phase interrogates them through a rigorous design lens. The objective was to move the recommendations beyond clinical feasibility into the realm of implementable, ethically grounded, and system-aware design guidelines. Engaging with experts in Human-Computer Interaction (HCI), service design, and digital health enabled a critical examination of the proposals' scalability, inclusivity, interoperability, and long-term sustainability. This process directly strengthens the thesis's contribution to Design by translating stakeholder-derived insights into professionally vetted design priorities. The analysis of the expert interviews yielded six central themes, presented in this chapter as a critical dialogue between the initial recommendations and the specialised knowledge of design practice. These themes served to refine and strengthen the final design framework, ensuring it is not only theoretically sound but also practically actionable.

8.2 Interview Methodology and Participant Overview

This phase employed semi-structured interviews with design experts to critically examine the IoT-based recommendations from a disciplinary perspective, ensuring the research outputs are robustly informed by design principles. A comprehensive account of the overarching methodology is provided in Chapter 3 (Section 3.6), encompassing the full methodological and ethical protocols. For this specific stage, the research purposively recruited four participants (*n*=4) selected for their significant expertise in Human-Computer Interaction (HCI), Service Design for Health, and the application of IoT technologies. Each interview lasted between 45 and 60 minutes and was audio-recorded for subsequent analysis. The data were analysed using Reflexive Thematic Analysis, involving a recursive process of familiarisation, coding, and theme development. To ensure analytical rigour, codes were developed both deductively—

aligned with the existing design recommendations—and inductively, allowing for new insights regarding technical feasibility and ethical governance to emerge from the experts' specialist discourse. The experts were presented with the identical set of eleven IoT-based design recommendations previously reviewed by healthcare professionals in Chapter 7. They were invited to provide critical feedback focusing on design feasibility, system scalability, and ethical integration. The interview schedule explored specific themes including interoperability, the necessity of open standards, accountability models, and the challenges of designing for equity and long-term sustainability.

8.3 Findings: Design Expert Themes and their Implications

The following sections detail the six key themes that emerged from the reflexive thematic analysis of the design expert interviews. Each theme is substantiated with direct expert testimony and explicitly linked to the subsequent refinements made to the recommendations.

8.3.1 From Ideals to Implementable Solutions

Upon initial presentation, the experts generally welcomed the recommendations as ambitious and forward-looking. However, they also characterised them as "idealistic" and at risk of being "utopian" if not grounded in real-world delivery mechanisms. One expert stated: “These are all positive, but they feel a little utopian. Who’s actually going to do all of this? If you don’t specify responsibility, they won’t get beyond being nice ideas” (D2). This feedback highlighted that even well-founded recommendations can remain theoretical without clear accountability. As another expert reflected: “Without ownership—whether by clinicians, managers, or digital health teams—recommendations tend to gather dust” (D3). In response, the recommendations were revised to explicitly identify responsible actors, detailed in the ‘Actor’ column of the final framework (see Section 8.6 and Table 8.6.1). This shift moved the framework beyond generalised advice by embedding accountability for each mandate. This process ensured the design ambition was structurally linked to feasible implementation by defining who (e.g., policymakers, digital health teams, clinicians) is responsible for realising each component.

8.3.2 System Integration Over Device Novelty

The experts were quick to highlight that IoT recommendations often focus on the novelty of devices rather than on how they will fit into existing systems. One participant noted: “The challenge isn’t adding new gadgets, it’s whether they can work with what hospitals already have. That’s the sticking point, not the device itself.” (D1)

Another explained that this mismatch is often where well-intentioned projects fail:

“Hospitals run on legacy IT. If your IoT system doesn’t integrate, it won’t scale—no matter how clever the device is.” (D4)

This made me realise the importance of moving my recommendations away from a device-centred lens toward a systems-oriented approach. I refined the recommendations to stress integration and compatibility with existing infrastructure, rather than just promoting device innovation.

8.3.3 Interoperability and Legacy Constraints

Closely linked to system integration, the experts stressed the importance of interoperability. They argued that unless devices adopt open standards, they risk becoming locked into proprietary systems that are unsustainable. One expert said:

“Interoperability is the make-or-break issue here. If you rely on one vendor’s format, the whole system collapses when that product changes or disappears.” (D2)

Another pointed to the practical implications of ignoring this factor:

“Clinicians won’t use systems that can’t talk to each other. That’s the reality of healthcare IT.” (D3)

Their reflections made me more aware of the importance of standardisation and vendor neutrality in design. I embedded interoperability requirements into the recommendations, explicitly referencing open standards as a baseline expectation.

8.3.4 Privacy by Design and Data Minimisation

The issue of privacy came up in every interview. While earlier phases of my study emphasised continuous monitoring, the design experts warned me about the risks of “collecting everything.” One explained: “You don’t need to transmit every single data point. Collecting too much creates risk and undermines trust. It has to be minimum necessary, not maximum possible.” (D4)

Another expert framed it as an ethical necessity: “If patients think their data is being harvested without purpose, they won’t accept the technology. Privacy has to be baked in, not bolted on.” (D1)

This was a valuable reminder that IoT's success depends as much on trust as on technical capability. I revised the recommendations to explicitly call for privacy-by-design principles, emphasising minimal data collection and secure handling.

8.3.5 Maintenance, Support, and Repairability

The experts also highlighted issues I had initially overlooked: support, maintenance, and repairability. One participant asked: "It's not just about getting devices into clinics. Who maintains them? Who updates the software? Without that, they'll just sit unused." (D2)

Another linked this to global policy discussions: "There's a trajectory toward a 'right to repair.' IoT rehab devices shouldn't be disposable—there has to be a pathway for keeping them in service." (D3)

These insights helped me to appreciate that IoT adoption is not a one-off event but a continuous process requiring planning for lifecycle costs and support. I revised the recommendations to include repairability and maintenance pathways, encouraging sustainable and long-term use.

8.3.6 Affordability, Accessibility, and Equity

Finally, the experts warned that while IoT holds promise, it could unintentionally deepen health inequalities if affordability and availability are not addressed. One participant observed:

"If these solutions are only affordable for big hospitals or wealthy patients, you're just widening the gap." (D4)

Another highlighted the importance of cultural and contextual fit:

"It's not just affordability. It's about cultural adaptation. What works in the UK may not fit Saudi Arabia unless you design with that context in mind." (D1)

This feedback reminded me that recommendations must consider equity as a core principle, not an afterthought. I expanded the recommendations to foreground equity, affordability, and cultural adaptability.

Writing this section made me realise how much richer and more practical my recommendations became after listening to these experts. At first, I thought my framework was already comprehensive. But their feedback pushed me to refine the recommendations so that they are not just technically promising or clinically acceptable, but also design-informed, feasible, and scalable.

8.4 Synthesis: Design Experts as Critical System Designers

The feedback from design experts served as a crucial layer of critique, moving the IoT-based recommendations from the realm of perceived potential and clinical feasibility into a framework that accounts for real-world implementation, ethical sustainability, and systemic complexity. The experts' analysis centred on translating ambitious ideals into achievable, accountable design mandates, leading to specific refinements across three key areas.

8.4.1 From Device Novelty to System Integration and Accountability

A consistent critique was that the initial recommendations overemphasised the novelty of the device itself and overlooked the formidable challenges of integration. The experts stressed that success is contingent on systems design.

- **Mandate for Interoperability:** Experts mandated adherence to open standards and vendor-neutral formats as a baseline requirement, warning that proprietary systems lead to unsustainable "vendor lock-in." This refinement shifted the focus from simple device implementation towards robust, systems-level design.
- **Accountability by Design:** To address the perceived idealism of the goals, recommendations were structurally revised to include an "Actor" column, explicitly assigning responsibility for implementation (e.g., to "Clinicians," "Policymakers," or "Digital Health Teams"). This grounds the ambition in clear accountability.

8.4.2 Designing for Trust: Privacy, Ethics, and Long-Term Lifecycle

The design experts strongly refined the ethical dimension, arguing that trust must be designed into the system using specific HCI principles, not treated as a policy add-on.

- **Privacy-by-Design and Data Minimisation:** Experts warned against the risk of "collecting everything," insisting that systems must adhere to minimum-necessary data standards. This led to the explicit integration of privacy-by-design principles and transparent, granular user controls into the core framework.
- **Sustainability and Repairability:** Experts contributed the crucial long-term perspective of lifecycle management. They stressed that rehabilitation devices must include pathways for maintenance, software updates, and affordable

repair to ensure sustained use, aligning with "right to repair" principles and preventing technological waste.

8.4.3 Advancing Equity, Accessibility, and Cultural Context

The design experts validated the thesis's focus on equity but provided concrete mechanisms to achieve it, stressing that design must actively mitigate the risk of widening the digital health gap. This led to two key refinements:

- **Frugal and Accessible Design:** The refinement process strongly foregrounded the need for low-cost, scalable solutions, including low-bandwidth functionality, to address socio-economic and infrastructural barriers.
- **Cultural Adaptability:** Building on the UK/Saudi comparative insights, experts emphasised that design must go beyond simple language translation to ensure cultural adaptability, accommodating diverse family structures, care norms, and clinical workflows from the outset.

The design experts were presented with the same set of eleven IoT-based recommendations previously validated by healthcare professionals in Chapter 7 (Section 7.9). Their critical feedback, synthesised in Table 8.1, was instrumental in refining and strengthening these recommendations. The table links each original recommendation to the expert-driven refinement, the specific critique that prompted the change, and the actor responsible for implementation.

Table 35.8.1: Refinement of IoT-Based Recommendations Following Design Expert Critique

Original Recommendation (from Chapter 7)	Refined Recommendation	Design Expert Contribution	Actor Responsible
Personalised rehabilitation plans	Personalisation with simplicity and adaptable settings	Avoid user overload; prioritise inclusivity	Digital Health Teams / Clinicians
Remote monitoring by clinicians	Remote monitoring with data visualisation dashboards	Clinicians need clear summaries, not raw data	Digital Health Teams / IT
Real-time feedback	Multi-modal feedback (visual, auditory, haptic)	Ensure accessibility for diverse abilities	Developers / Clinicians
Gamification for motivation	Light-touch gamification aligned with clinical goals	Avoid distraction from therapy purpose	Developers / Clinicians
Caregiver involvement	Dual-access systems with patient consent	Caregiver-friendly, supportive interfaces	Developers / Clinicians
Accessibility in rural/underserved areas	Low-bandwidth/offline functionality	Address infrastructural inequities	Policymakers / Funders

Device/system interoperability	Open standards and API-based integration	Prevent siloed systems, enable scalability	Policymakers / IT Governance
Data privacy and security	Privacy-by-design, granular consent, local storage	Build trust, ensure regulatory compliance	Digital Health Teams / IT
Training for healthcare professionals	Continuous CPD modules on IoT use	Formal, structured training required	Policymakers / Healthcare Providers
Cultural adaptability	Co-design with local communities (UK & Saudi Arabia)	Align with cultural norms and practices	Developers / Researchers
Affordability and scalability	Cost-sharing models; scalable designs	Equity requires financial accessibility	Policymakers / Funders

Note: *A synthesis of how the original recommendations (from Chapter 7) were refined through design expert feedback, showing the resulting changes and the actors responsible for implementation.*

This process of refinement highlights the importance of integrating design expertise into digital health research. While the initial recommendations reflected the perspectives of stroke survivors and healthcare professionals, the design experts contributed critical insights on usability, scalability, inclusivity, and cultural adaptation. These refinements ensured that the final set of recommendations is not only grounded in stakeholder experience but also aligned with design best practices.

8.5 The Final Design Framework: Contribution to Design Knowledge

The expert critique transformed the initial findings into a Design-Informed Framework that is rigorous, implementable, and grounded in the principles of Service Design and Ethical HCI. This shifts the thesis's contribution from identifying what is clinically necessary to defining what is responsibly designable and systematically actionable. The synthesis demonstrates the indispensable value of integrating professional design critique as a formal, non-optional phase in user-centred research for complex socio-technical systems. It ensures that technological solutions are not only desirable and feasible but also viable, equitable, and sustainable in the long term. From a reflexive standpoint, this phase was pivotal. While the recommendations were robust after clinical validation, the design experts challenged their practical feasibility, demanding greater accountability and a longer-term view of system sustainability. This process underscored that for IoT to genuinely impact stroke rehabilitation, interdisciplinary collaboration is not beneficial but essential; clinical, technical, and design perspectives must converge to create solutions that are simultaneously relevant, usable, and responsibly integrated into real-world ecosystems.

8.6 Final 11 Refined Recommendations for IoT-Enabled Stroke Rehabilitation

This list of eleven final design mandates represents the culmination of all five research phases, synthesising user needs (Chapters 5 & 6), clinical validation (Chapter 7), and the critical design expertise secured in this chapter. The mandates were structurally revised to incorporate the accountability and systems-level considerations stressed by the experts, explicitly including the required "Actor" column (as shown in Table 8.6.1 in the following section). These mandates are organised under the Four-Principle Framework that underpins this thesis (see Chapter 9).

A. Principles of Adaptive Simplicity and Usability

1. **Prioritise Usability and Accessibility:** IoT systems must feature intuitive, user-friendly interfaces that accommodate the needs of stroke survivors, including older adults and those with cognitive or physical impairments. Design should incorporate large icons, simple navigation, voice prompts, and tactile feedback.
2. **Embed Personalisation and Adaptability:** Devices should support customisable rehabilitation plans that can adapt to users' progress, motivation levels, and co-morbidities. Systems must allow healthcare providers to adjust settings remotely to suit evolving patient needs.

B. Principles of System Integration and Accountability

3. **Ensure System-Level Integration:** IoT solutions must integrate seamlessly with existing healthcare infrastructures, particularly electronic health records (EHRs) and legacy IT systems, to avoid disruption and encourage adoption by clinicians.
4. **Mandate Interoperability and Open Standards:** All IoT rehabilitation tools should adhere to vendor-neutral, open communication protocols to prevent vendor lock-in and ensure long-term sustainability across diverse healthcare settings.
5. **Support Professional Training and Workflow Alignment:** Healthcare professionals require training and digital literacy support to use IoT effectively. Systems must align with clinical workflows to avoid additional burdens and foster confidence among practitioners.

C. Principles of Trust, Equity, and Sustainability

6. **Adopt Privacy-by-Design Principles:** Data collection must follow minimum-necessary standards, with built-in encryption, anonymisation, and secure transmission. Consent processes should be transparent and grant patients control over what data is shared, with whom, and for what purpose.
7. **Build Equity and Affordability into Deployment:** IoT adoption must address issues of cost, accessibility, and cultural adaptation, ensuring solutions are affordable for underserved populations. Subsidy models, public–private partnerships, and culturally sensitive design (e.g., Arabic language support) are essential.
8. **Provide Continuous Support, Maintenance, and Repairability:** Long-term success depends on sustainable support structures. IoT systems should include pathways for ongoing maintenance, software updates, and affordable repair, aligning with principles of durability and the global trend towards a "right to repair."
9. **Strengthen Patient and Caregiver Empowerment:** IoT should not replace human support but should empower stroke survivors and caregivers. Features such as progress tracking, reminders, and simple reporting tools can build confidence and reduce dependency while maintaining a connection to professional oversight.
10. **Plan for Scalability and Real-World Feasibility:** Recommendations must account for scaling beyond pilot projects, including cost–benefit evaluations, infrastructure requirements, and strategies for integration into routine practice.
11. **Promote Co-Design and Continuous Feedback Loops:** IoT systems should be developed using participatory design methods, engaging stroke survivors, caregivers, and healthcare professionals throughout. Feedback loops should remain open post-implementation to ensure ongoing improvement.

8.7 Summary and Link Forward

The design-expert interviews provided a crucial final layer of refinement for this study. They confirmed the value of the initial recommendations while highlighting critical gaps in their feasibility, system integration, ethics, and equity. By incorporating this expert critique, the 11 IoT-based recommendations were finalised to ensure they are clinically relevant, ethically sound, and rigorously informed by design principles. Reflecting on the process, the recommendations were initially considered complete after validation by healthcare professionals. However, the design-expert phase was instrumental in strengthening them by focusing on practical implementation, long-term sustainability, and design rigour. The key refinements explicitly integrated an accountability dimension (the "Actor" role) and a focus on long-term lifecycle management. This process has brought the recommendations closer to real-world implementation, ensuring they are not only technically possible but also usable, ethical, and scalable across diverse cultural contexts.

Chapter 9: Discussion and Conclusion

9.1 Introduction: From Perceptions to a Design-Led Framework

The integration of IoT technologies into post-stroke rehabilitation is fundamentally a strategic design challenge, not merely a technical one. This thesis has investigated this challenge through five distinct phases to generate a critically grounded, design-informed framework for development. Moving beyond technical feasibility, it addresses the complex socio-technical and human-centred constraints that govern IoT adoption in healthcare. This final chapter synthesises the empirical findings—from the international professional survey (Chapter 4) and the generative workshops with stroke survivors (Chapters 5 and 6) to the clinical validation (Chapter 7) and design expert critique (Chapter 8)—to articulate this thesis's primary contribution: a design-led framework and a set of validated mandates. The culmination of this iterative, mixed-methods approach is the empirically derived Four-Principle Design Framework, which provides the theoretical structure for the definitive Eleven Design Mandates developed in Chapter 8. This synthesis establishes the essential criteria for conceiving IoT systems that are usable, equitable, and sustainable within real-world rehabilitation contexts.

9.2 The Four-Principle Framework: A Design-Informed Synthesis

The primary contribution of this research is the articulation of a Four-Principle Framework for designing IoT-based stroke rehabilitation systems. This framework was not conceived a priori but was empirically derived and refined through the iterative, mixed-methods process detailed in this thesis. It synthesises the core tensions, mandates, and critiques identified across all stakeholder groups, directly answering the central research question by defining the essential design criteria for IoT systems to succeed within the complex reality of stroke recovery. The framework translates lived experience, clinical feasibility, and design expertise into actionable guidance, positioning IoT not as a standalone product, but as an integrated component within a holistic socio-technical system of care. The relationship between the framework and the specific design outputs is defined as follows: the Four-Principle Framework serves as the theoretical and strategic umbrella for the eleven definitive Design Mandates detailed in Chapter 8 (Section 8.6). Each mandate operationalises one or more of these core principles, ensuring the final outputs are both theoretically grounded and practically actionable. The table below presents the framework and its evidential grounding, encapsulating the core argument of this thesis: that for IoT to be successful in rehabilitation, design decisions must be directly informed by and responsive to interconnected human, clinical, and ethical constraints.

Table 36.9.1: Synthesis and Evolution of the Four-Principle Design Framework

Design Principle	Core User Tension (Patient/Survivor)	Clinical Mandate (Feasibility)	Design Refinement (Expert Critique)
1. Adaptive Simplicity	"Paradox of Complexity": Desire for personalisation but fear of complex interfaces ("I need help to use it.").	**Usability as Safety**: Mandate for error-tolerant, cognitively accessible interfaces to prevent patient injury and frustration.	**Frugal Innovation & Cognitive Offloading**: Design must ensure low-cost, simplified systems that perform automatic adaptation, minimising user configuration. (Addresses Universal/Inclusive Design)
2. Human-in-the-Loop Service Model	"Non-Negotiable Human Element": Technology must augment, not replace, the therapist ("The device can show numbers, but it cannot tell me if I'm doing well...").	**Collaborative Control**: Systems must provide transparent, actionable dashboards for clinicians to retain oversight and support human judgment.	**Accountability by Design**: The service model must assign explicit ownership for device maintenance, data interpretation, and technical support. (Addresses Service & Systems Design)
3. Configurable Data Transparency	"Trust vs. Family Care": Unease over data privacy juxtaposed with the demand for family	**Prerequisite for Adoption**: Mandate for robust, compliant data security (e.g.,	**Privacy-by-Design**: Requires granular, intuitive controls allowing users to easily configure data sharing (e.g., clinician vs. family). (Addresses Value-Sensitive Design, HCI Ethics)

	access in KSA cultural contexts.	GDPR) to build institutional and patient trust.	
4. Contextual Motivation	"Sustained Engagement Challenge": Need for long-term motivation amidst risks of social isolation and device fatigue.	**Workflow Integration**: Technology must not create an administrative burden (e.g., "double data entry is a non-starter").	**Interoperability by Design**: Long-term value is contingent on seamless integration with EHRs and clinical workflows, ensuring equitable access and functionality across different infrastructures. (Addresses Strategic Design, Frugal Innovation)

9.3 Grounding the Framework: A Critical Discussion of Findings

9.3.1 The Primacy of Adaptive Simplicity: Reconciling Personalisation with Usability

The principle of Adaptive Simplicity posits that usability is the non-negotiable foundation for personalisation. This finding strongly affirms established arguments in gerontechnology and inclusive design that complexity is a primary driver of technology abandonment (Czaja et al., 2019). This study extends this understanding by demonstrating that for stroke survivors, the desire for personalisation is entirely contingent upon this foundational accessibility; without it, the purported benefits of IoT—such as dynamic customisation and real-time feedback—become irrelevant. The data from the Saudi Arabian workshops and subsequent expert interviews reinforce this while highlighting specific, context-aware challenges. Critically, the need for effortless integration and sustained engagement addresses the core reasons for non-adoption documented in the literature (Broderick, 2021). While participants perceived IoT technologies as promising, this research confirms that significant accessibility barriers persist, and that personalisation is a secondary benefit to core usability.

9.3.1.1 Usability Challenges and the Imperative for Inclusive Design

Usability was a critical determinant of adoption. Workshop observations revealed that participants, particularly older adults and those with limited technical experience, found the devices initially difficult to operate. Those managing co-morbid impairments struggled with tasks like navigating menus or interpreting feedback. These challenges were especially evident among individuals with reduced dexterity or visual limitations, exposing a misalignment between generic commercial designs and the specific capabilities of neurodiverse users. Participant frustrations with complex interfaces, small buttons, and information overload were analysed by design experts as a failure to adhere to core inclusive design principles, a concern echoed in literature on designing for cognitive accessibility (Mountain et al., 2020). One expert noted, “The leap from clinical efficacy to daily use is bridged by design that anticipates frustration,” underscoring the necessity of a user-centred design process as a non-negotiable methodology. This aligns with Faux-Nightingale et al. (2022), who argue for "frictionless" design in assistive technologies. Suggested strategies, such as simplified interfaces and multi-modal feedback, translate into concrete design directives: prioritise clarity over features and ensure redundancy in interaction modes. It is crucial to ground these findings: the observed challenges emerged from short-term workshop interactions and cannot predict how they evolve with prolonged, daily use in a home environment without facilitator support.

9.3.1.2 Personalisation and Customisation: Two Dimensions of Adaptive Design

The workshops underscored that a single interface solution is insufficient, revealing an important distinction between two related but distinct concepts: personalisation and customisation. In this thesis, personalisation refers to system-driven adaptation – where the technology automatically adjusts to the user's abilities and progress based on data. Customisation, by contrast, refers to user-driven configuration – where the individual (or their caregiver) actively selects preferences, such as interface size, feedback modality, or exercise difficulty. This distinction is critical. While some participants navigated standard menus with ease, others – particularly those with cognitive impairments – struggled. The need for customisable interfaces that respond to diverse user requirements emerged strongly. Adaptations such as symbol-based menus for users with aphasia were perceived as essential. This pursuit of adaptable function reflects the understanding that technology must support rehabilitation strategies responsive to each individual's evolving needs. The positive reception of multi-modal feedback (visual, auditory, tactile) further supports providing a 'portfolio of interaction options' from which users can draw according to their context.

This finding challenges a one-size-fits-all approach and points towards a core design tenet for rehabilitation technology: systems must be customisable by the user, not just personalised for the user, granting a sense of agency that is crucial for motivation and recovery (Narbutaitiene et al., 2021). The framework therefore treats personalisation and customisation as complementary – the system adapts automatically where possible (personalisation), while empowering users to make intentional adjustments where desired (customisation).

9.3.1.3 The Digital Divide: A Socio-Technical Design Problem

The digital divide was identified as a barrier extending beyond the device into the user's environment. Participants recognised that stroke survivors—particularly older adults or those in rural areas—face challenges such as poor internet access, limited digital literacy, or the high cost of devices. This risk of technology widening health inequalities is a critical concern, reinforcing arguments that equity must be a central consideration in e-health design (Faux-Nightingale et al., 2022). Design experts reframed this not just as a policy issue, but as a socio-technical design challenge. They argued that designers must consider 'graceful degradation'—how devices function with limited connectivity—and advocate for low-cost, scalable solutions that retain core usability. While training was suggested, the design perspective emphasises 'designing out' the need for extensive training through intuitive interfaces. This represents a practical application of inclusive design theory, moving beyond accommodating impairment to designing for infrastructural and economic constraints (Mountain et al., 2020). Tackling this divide therefore requires a dual approach: policy-level investment in infrastructure and design-level innovation that acknowledges real-world constraints.

9.3.1.4 Simplicity, Clarity, and Progressive Engagement

Participants consistently valued simplicity, which from a design standpoint translates to reducing cognitive and physical load. Minimalist designs with streamlined functions were favoured over interfaces with excessive choices. The importance of progressive disclosure—whereby devices initially display basic functions and gradually introduce advanced features—was highlighted. This aligns with the design concept of 'scaffolding', where the system supports the user's learning journey, a principle that is crucial for supporting users with cognitive fatigue post-stroke (Narbutaitiene et al., 2021). The challenge of sustaining engagement further reinforces the need for design that minimises frustration. Furthermore, experts viewed continuous support (e.g., embedded tutorials) as an integral part of the service design ecosystem, not an afterthought.

9.3.1.5 Embedding Cultural and Contextual Sensitivity in Design

The comparative nature of this study brought cultural considerations to the fore, directly informing the Contextual Motivation principle. Both workshops and the literature emphasised that IoT technologies must account for linguistic and cultural diversity, with multi-language options being a basic requirement. Insights from the Saudi Arabian workshops revealed deeper contextual factors. For instance, the pronounced value placed on features enabling family caregivers to monitor progress remotely reflects cultural norms of collective care. This underscores that designing for autonomy must be balanced against the cultural imperative for family involvement—a contrast to design paradigms that prioritise individual autonomy. This finding critically engages with cross-cultural design theory, demonstrating that sensitivity is not merely about translation but about designing fundamentally different interaction models that align with local familial structures and social norms (Broderick, 2021). A key design implication is the need for 'localisable' systems that accommodate these differences, not just in language but in their underlying interaction model. This challenges the universal applicability of a single design solution. The strength of these cultural insights is bounded by the participant sample, which was predominantly male and from an urban Saudi context. The transferability of these findings to female survivors or to different regional settings requires further investigation.

9.3.2 Orchestrating Care: The Human-in-the-Loop Service Model

The principle of the Human-in-the-Loop Service Model posits that IoT's value is not as a standalone product, but as a component within a redesigned ecosystem of care. The findings on continuous education and support directly validate this principle, moving the focus from the device to the sustained socio-technical relationships it enables. This aligns with a broader shift in health service design away from product-centric solutions towards integrated, person-centred ecosystems (Broderick, 2021). For IoT to achieve long-term success in stroke rehabilitation, continuous education and support cannot be an afterthought; they must be an integral part of the service design ecosystem. While participants perceived IoT technologies as having strong potential, their utility was contingent on the user's ability to integrate them into daily life (Johnson et al., 2020). This is a particular challenge for stroke survivors facing cognitive and physical impairments. The findings from this study, refined through design expert interviews, suggest that effective support must be a multi-layered, designed feature that extends beyond the patient to include caregivers and clinicians, creating a sustainable 'support network'.

9.3.2.1 The Need for Designed-In Ongoing Education

Introducing IoT requires a fundamental shift from one-off training to continuously embedded learning. Both survivors and professionals emphasised that ongoing education was essential. However, our design experts critiqued the reliance on external training modules, arguing that the most effective systems 'teach through use'. They highlighted principles of 'scaffolded learning', where the device itself reveals functionality progressively as user competence grows. This perspective challenges more traditional, instructional models of patient education (Narbutaitiene et al., 2021) and reframes learning as a core design function, not a supplementary activity (Taylor & Williams, 2019). For example, while workshop participants struggled to apply complex progress data, a design solution would be to integrate actionable insights and prompts directly within the user interface, rather than presenting raw data.

9.3.2.2 Re-framing the Healthcare Provider's Role through System Design

Healthcare providers are pivotal as educators and facilitators. Our survey data indicated that while professionals saw value in IoT, they were concerned about keeping skills updated. This finding was analysed by design experts as a failure of current systems to adequately support the clinician's workflow. They stressed that for IoT to be adopted, it must 'speak the clinician's language' and seamlessly integrate data into clinical decision-making tools. Continuous staff training is essential, but the burden can be reduced through better 'data visualisation and summary functionalities' designed specifically for a time-pressed clinical environment (Smith & Gupta, 2020; Garcia et al., 2021). This necessity for seamless integration underscores a key tenet of socio-technical systems theory: that technology must be designed to complement, not complicate, existing work practices (Mountain et al., 2020). This is a direct application of the Human-in-the-Loop principle: designing to augment, not replace, clinical expertise.

9.3.2.3 Caregivers: The Designed Bridge in the Ecosystem

Caregivers and family members were consistently described as “the bridge between patients and technology.” This was especially pronounced in the feedback from the Saudi Arabian workshops, underscoring the cultural dimension of the UK/Saudi comparison. Their role in setup, interpretation, and emotional support is irreplaceable. Therefore, a critical design implication is to create 'caregiver-facing' interfaces or companion applications that empower them in their role. Training for caregivers is vital, but the system's design must acknowledge and facilitate their involvement from the outset, ensuring rehabilitation is a collaborative effort outside clinical settings (Martin et al., 2020). This finding reinforces the concept of the 'patient-caregiver dyad' in rehabilitation, arguing that IoT design must support this collaborative unit to be effective (Faux-Nightingale et al., 2022).

9.3.2.4 Designing for Sustained Engagement and Acknowledging Limits

Participants stressed the need for layered support systems: helplines, peer groups, and remote monitoring. Our design experts framed this not as a list of services, but as a cohesive 'onboarding and retention journey'. The challenge is to design for the transition from initial novelty to long-term habit. The concern that technology must not replace human support is perhaps the most crucial insight. This study concludes that the ultimate design goal is not a fully automated system, but a 'human-in-the-loop' model where IoT complements and enhances clinical and familial care, rather than replacing it (Smith & Gupta, 2020). The proposed service model, while grounded in stakeholder perception, remains a conceptual proposition. This research could not prototype or test the long-term viability of this 'onboarding and retention journey' or measure the clinical capacity to engage with newly designed data dashboards. The positive feedback on remote support was gathered in a structured research setting; its perception in a real-world, long-term context may be different, particularly concerning feelings of surveillance versus support. This reflects my own methodological journey: my background as a rehabilitation researcher initially led me to frame education as structured training programmes. This research compelled a shift to understanding support as a quality designed into the socio-technical system. This reflexive journey underscores that in design-led research, the boundary between the 'product' and the 'support system' is blurred.

9.3.2.5 Integration as a Service Design Challenge: (Re)Designing Clinical Workflows

The principle of the Human-in-the-Loop Service Model finds its ultimate test in the integration of IoT data into the complex fabric of healthcare systems. This is not a technical plug-in but a fundamental service design problem. Data from this study's survey revealed that healthcare professionals' primary concern was not the devices themselves, but how the data would fit into their already burdened workflows. Therefore, this section critiques integration barriers through a design research lens, arguing that technological potential is contingent on thoughtful service integration and organisational readiness.

a) Re-framing Autonomy and Efficiency through a Design Lens

The potential for IoT to reduce hospital visits and enhance autonomy (Taylor & Williams, 2019; Garcia et al., 2021) is compelling. However, our design expert interviews introduced a critical caveat: this should not lead to 'care at a distance' but to 'differently distributed care'. The design challenge is to create systems that empower patient autonomy without fostering abandonment. This requires designing for orchestrated collaboration between the patient at home and the clinical team. For instance, a patient adapting exercises independently (Martin et al., 2020) is only sustainable if the system is designed to flag when human intervention is crucial, thereby ensuring safety and maintaining therapeutic alliance. The efficiency gain for providers (Smith & Gupta, 2020) is thus not automatic; it must be designed into the system through intelligent alerting and data summarisation tools.

b) The Interoperability Imperative: A Call for Design-Led Standardisation

The challenges of data integration and interoperability are well-documented (Johnson et al., 2020; Smith & Gupta, 2020). From a design perspective, this is a failure of user-centred design at a systemic level. The proliferation of proprietary data formats (Garcia et al., 2021) creates a poor user experience for clinicians. While universal standards like FHIR are a technical solution (Taylor & Williams, 2019), design research can contribute by creating and prototyping 'interoperability personas' and journey maps that visualise the cost of fragmentation on clinical decision-making. This approach operationalises the principles of strategic design to tackle systemic barriers, moving beyond interface-level problems to design and structure information flows (Broderick, 2021). The goal is to advocate for Interoperability by Design—standards for seamless clinical usability.

c) Infrastructure, Security, and Designing for Trust

Infrastructure limitations, particularly in rural and low-resource settings, are a major barrier to equitable access (Johnson et al., 2020). A design response to this challenge involves advocating for ‘graceful degradation’. Furthermore, cybersecurity (Smith & Gupta, 2020) is not just a technical issue but a core component of the user experience. Design must make data security tangible and understandable to users, moving beyond complex consent forms to transparent, intuitive privacy controls, aligning with the Configurable Data Transparency principle.

d) The Central Role of Design in Workflow Integration

The ultimate integration challenge is aligning IoT with clinical workflows (Johnson et al., 2020). Simply adding data is disruptive. The findings from this study suggest that the most significant barrier is not data volume, but ‘data actionability’. Healthcare providers need designed tools—dashboards, alerts, and summary reports—that synthesise information into clinically meaningful narratives (Garcia et al., 2021). Effective integration requires co-designing new clinical pathways with healthcare professionals, using methods like service blueprints. This ensures the technology complements, rather than complicates, daily operations (Lee & Gupta, 2021). The barriers and design solutions described here are identified from professional perceptions and expert critique; they were not validated through the prototyping of actual clinical dashboards or redesigned pathways. This is a acknowledged limitation of the study's scope. My background as a rehabilitation researcher initially led me to view integration as a technical and policy problem for others to solve. This research has been a profound lesson in systems-oriented design. I now recognise that for a PhD in Design, these macro-level challenges are fundamental to our responsibility. The limitation of this thesis is that it could not prototype a fully integrated service, but by proposing a design-led approach, it provides a crucial framework for future development.

9.3.3 Building Trust and Equity: Configurable Data Transparency and Contextual Motivation

The final two principles of the framework address the profound systemic barriers that determine whether IoT is merely innovative or truly equitable. A design research perspective reveals that challenges of security, cost, and access are not external constraints but central design challenges, positioning this research within the field of value-sensitive and socio-technical systems design.

a) Configurable Data Transparency: Designing for Trust

Data security remains a significant barrier to trust and adoption (Taylor & Williams, 2019). Our survey of healthcare professionals revealed deep-seated concerns about data governance, which design experts framed as a failure of 'communicative design'. Simply implementing encryption (Lee & Gupta, 2021) or complying with GDPR (Smith & Gupta, 2020) is insufficient if users do not understand or trust these measures. This research therefore mandates 'Transparency by Design' as a practical implementation of value-sensitive design frameworks, involving interfaces that visually and simply communicate to patients how their data is protected and used, transforming abstract protocols into tangible trust. This moves beyond technical safeguards to designing the experience of security itself.

b) Contextual Motivation: Addressing Cost and Equity through Design

The principles of Contextual Motivation and Frugal Innovation are directly challenged by barriers of cost and equity.

i. The Cost Barrier and Sustainable Design

The prohibitive cost of implementation and maintenance (Garcia et al., 2021) is a critical barrier, particularly for the underserved populations central to this study's concerns. Our workshops highlighted that cost is not just an initial purchase price but includes ongoing data plans, maintenance, and replacement. A design research response to this is two-fold. First, it advocates for 'frugal innovation'—designing core functionalities that deliver maximum value with minimal cost and complexity. Second, it involves designing new service and business models, such as device-leasing schemes or community-shared IoT hubs, that could be prototyped and tested through service design methods to improve accessibility. This directly addresses the call for more sustainable and accessible health technology business models found in the literature (Narbutaitiene et al., 2021).

ii. Equity and the Digital Divide: The Imperative for Inclusive Design

Equity is the most critical barrier, as identified in both the literature and our workshop discussions. The digital divide is not just about broadband access (Smith & Gupta, 2020) but also about technological literacy and cultural relevance. The barriers faced by rural and low-income patients (Johnson et al., 2020) were evident in our study's recruitment challenges. This is a direct challenge to universalist assumptions and demands a design approach that incorporates 'extreme user' personas, a methodology advocated for in inclusive design to push the boundaries of accessibility (Mountain et al., 2020).

iii. Bridging the Divide through Contextual and Cultural Design

Our comparative study between the UK and Saudi Arabia provided direct insights here. The value of family-centric monitoring features, strongly emphasised in the Saudi workshops, is a clear example of how cultural context must shape functionality. A culturally sensitive approach is not merely about multi-language interfaces (Lee & Gupta, 2021) but about designing fundamentally different interaction models and service ecologies that align with local family structures, care practices, and social norms. This finding critically engages with cross-cultural design theory, demonstrating that sensitivity is not merely about translation but about designing fundamentally different interaction models that align with local familial structures and social norms (Broderick, 2021). This is a core contribution of the Contextual Motivation principle: to ensure that technologies are not just translated, but contextually transformed.

The design solutions proposed here—from transparent data interfaces to frugal business models—are conceptual propositions grounded in stakeholder perception and expert critique. This thesis could not prototype or validate these solutions, a limitation that future research must address. My initial perspective as a rehabilitation researcher led me to view these barriers as immutable external forces. This research has fundamentally shifted my understanding, revealing design research's critical, activist role in tackling systemic issues. The ultimate barrier to adoption may not be the technology itself, but our failure to design the wider socio-technical ecosystem required to support it equitably and sustainably.

9.4 A Rigorous Self-Assessment: Limitations as a Design Research Brief

This study was scoped to articulate a design-informed framework for IoT in stroke rehabilitation; its contributions are therefore bounded by this methodological choice. A critical self-assessment is a core responsibility of design research, serving to ground claims and clarify the evidence base. The following points delineate the study's defined scope and inherent boundaries, using them to generate a robust agenda for future research.

9.4.1 Methodological Boundaries: Grounding and Generalisability

A primary limitation is the reliance on perceived potential and short-term interactions. The positive feedback on personalisation and engagement was gathered in workshop settings, which are inherently influenced by the 'novelty effect' and facilitator support. Consequently, the findings on patient motivation are indicators of initial acceptance and perceived viability, rather than evidence of sustained, long-term use. Furthermore, the intended UK/Saudi Arabia comparative framing was complicated by the international survey sample. While this provided valuable global perspectives, it limited the robustness of a direct comparative analysis between the two primary countries—a challenge future research in this area must deliberately address.

9.4.2 The Design-Reality Gap: From Probes to Implementation

Challenges of technological maturity and data accuracy were apparent. The high cost and limited availability of robust, clinical-grade IoT devices meant participants interacted with a constrained selection of technologies, which may not represent the full spectrum of available or future tools. This directly impacted the grounding of the findings. Furthermore, while data interpretation was a noted concern for clinicians, this study did not prototype the decision-support tools needed to make IoT data actionable within clinical workflows. This represents the critical gap between identifying a validated user need and the responsibility of designing an implementable solution.

9.4.3 The Nature of Evidence: Perceptions Versus Clinical Efficacy

The survey confirmed provider resistance, rooted in workflow disruption and a lack of proven efficacy. As a study focused on generating a design brief, the research scope was intentionally restricted to gathering perceptions and establishing feasibility, thereby clarifying the design requirements for a successful intervention. However, this means the thesis could not generate the clinical outcome data required to overcome provider scepticism regarding medical efficacy. Overcoming this resistance necessitates the next methodological phase: long-term deployment studies that blend design and clinical research methods.

9.4.4 The Unanswered Question of Long-Term Engagement

The challenge of "technology fatigue" could not be fully investigated within the short-term scope of the workshops. This is a fundamental limitation of the findings on motivation. The study identified features that spark engagement, but its design cannot confirm whether this engagement would decay over weeks or months of daily use. Designing for enduring user commitment remains a key frontier for the next phase of design research.

9.4.5 Regulatory and Ethical Horizons

While ethical concerns about data were raised, this study operated under a university ethics framework and did not develop or test novel data governance models. The regulatory challenges described remain a frontier for implementation. From a design perspective, this points to an urgent need for the next research iteration to engage with 'speculative ethics' and co-design data governance frameworks with patients and providers, moving beyond identifying ethical problems to prototyping ethical solutions.

9.4.6 Concluding Reflexive Statement

My perspective as a rehabilitation researcher initially framed these implementation challenges as external barriers. Through this research journey, I have come to understand them as intrinsic limitations of the chosen methodology and a defining frontier for design research. I affirm that the objective of this thesis was to provide a robust map of the landscape—the stakeholder perceptions and design considerations—thereby creating an evidence-based design brief. The most significant scope boundary is the gap between the foundational 'probe and prototype' approach of design workshops and the 'implement and integrate' demands of healthcare systems. This study has successfully defined this boundary; future work must bridge this gap by adopting more embedded and longitudinal design research strategies to generate robust evidence for efficacy and sustainability.

9.4.7 Methodological and Contextual Nuances: The Impact of Pragmatic Choices

This study's methodological approach, while rich in stakeholder engagement, was shaped by pragmatic constraints that further define the boundaries of its findings.

- **Structural and Logistical Constraints:** The ambition of a direct UK/Saudi comparison was complicated by an international survey sample, creating an analytical inconsistency. Furthermore, the budget-driven need for participants to share devices in workshops potentially limited the depth of individual, prolonged interaction, restricting feedback on integrated daily use.
- **The 'Ecosystem' Blind Spot:** Conducting workshops in controlled rehabilitation centres ensured safety and consistency but sacrificed the ability to observe real-world infrastructural challenges, such as poor home internet connectivity. The pandemic's necessity to shift sessions online, while demonstrating remote potential, simultaneously highlighted and exacerbated the digital divide for participants with limited access.

9.4.8 Reflexive Synthesis: Positionality and the Transitional Research State

My background as a rehabilitation researcher fundamentally shaped this project's contours and its limitations. Initially, my focus was skewed towards clinical feasibility and functional outcomes, which led to a methodology that privileged stakeholder perception-gathering over the generation of tangible design artefacts. I approached the literature review as a comprehensive survey rather than a critically curated argument. This positionality meant I was, at first, more comfortable describing what users needed than I was in prescribing what designers should do. This journey has been a process of adopting a design researcher's mindset. I now reflexively understand that a key limitation was the transitional state of the research—poised between the problem-space (rehabilitation) and the solution-space (design). While this hybrid perspective yielded unique insights, it also meant the study stopped short of delivering a fully realised design intervention. This is not a failure, but a definitive boundary of the work: it provides a robust, evidence-based brief for future design research, rather than a validated final product. These limitations do not diminish the study's value but precisely chart the territory that the next phase of design-led inquiry must occupy.

9.5 Contribution to Design Knowledge and Practice

This thesis makes distinct contributions to Design Research by advancing the understanding of how to conceptualise, develop, and integrate IoT systems for complex healthcare contexts like stroke rehabilitation. The primary contribution is the theoretical Four-Principle Framework (Section 9.2) and the definitive Eleven Design Mandates (Chapter 8, Section 8.6), which bridge user experience, clinical practice, and technological feasibility. The findings are carefully framed as evidence of potential and a map for future development, based on rich perceptual data rather than clinical efficacy trials.

9.5.1 Theoretical and Methodological Contributions

This research makes a primary empirical contribution to the field by generating stakeholder-grounded insights into the design requirements for IoT in stroke rehabilitation. These insights are synthesised into the Four-Principle Framework, which serves as the study's central theoretical contribution. The framework was iteratively developed and validated through workshops, surveys, and design expert interviews, ensuring it is grounded in both user needs and professional practice. It moves beyond technical specifications to address core socio-technical challenges, thereby serving as a generative tool that provides a structured yet flexible set of priorities for developing responsible and effective rehabilitation technologies. The empirical contribution is twofold. First, the study captures and integrates perspectives from three stakeholder groups – stroke survivors, healthcare professionals, and design experts – across two distinct healthcare contexts (the UK and Saudi Arabia). Second, it translates these perspectives into actionable design guidance, demonstrating how empirical data can directly inform the development of rehabilitation technologies.

Methodologically, this study provides an empirical case study in conducting design research within a sensitive healthcare context. Its contributions include:

- **A Model for Staged, Stakeholder-Centric Research:** The multi-phase approach—moving from broad surveys to focused workshops and finally to design expert validation—demonstrates a rigorous method for building design knowledge that is deeply informed by all stakeholders, including often-overlooked design experts.
- **Articulating the Designer's Role in Healthcare IoT:** The research clarifies the unique value of the designer as a synthesizer and translator between patients, clinicians, and technologists, moving beyond a focus on usability to framing broader system challenges (e.g., interoperability, cost) as design problems.

Together, these empirical, theoretical and methodological contributions offer a replicable model for design research in healthcare contexts, grounded in rich stakeholder data and translated into practical guidance for developing inclusive, effective IoT rehabilitation tools.

9.5.2 Practical and Professional Guidance

The research translates its findings into actionable guidance for practice:

- **For Design Researchers:** This thesis demonstrates the value of speculative and probe-based workshops for exploring technological futures with vulnerable users and argues for the importance of integrating professional design critique early in the research process.
- **For Healthcare Providers and Policymakers:** It provides an evidence-based, design-led rationale for investing in adaptable technologies and supportive

infrastructure, shifting the conversation from what is technically possible to what is responsibly implementable and equitable.

9.5.3 A Design Research Agenda: Practical Implications

The findings generate a set of specific, actionable implications that form a coherent agenda for advancing the field, directed at the key actors who can realise the potential of IoT in rehabilitation.

1. For Design Researchers and Technology Developers:

This thesis provides a validated set of priorities, moving beyond general principles to specific, context-aware guidance.

- **Adopt a Principle of 'Adaptive Simplicity':** Focus on creating systems empathetic to fluctuating user states, moving beyond pre-set programmes to interfaces that incorporate affective computing and support a 'progressive disclosure' of complexity.
- **Implement 'Inclusive and Cross-Cultural Design' as Standard Practice:** Create configurable and localisable interaction models, designing for multi-modal redundancy and building in cultural adaptability from the outset.
- **Design for the Socio-Technical Ecosystem:** The device is only one component. Designers must also create 'Transparency by Design' features for data security and co-design clinical dashboards with healthcare providers to ensure IoT data is actionable.

2. For Healthcare Providers and Commissioners:

The implications for clinical practice centre on adopting a design-aware approach to technology adoption.

- **Procurement Based on Design Principles:** When selecting devices, prioritise those that demonstrate evidence of inclusive design and adaptive personalisation over those with the most technical specifications.
- **Pilot Integration through Co-Design:** Treat implementation as a service design challenge, beginning with small-scale pilots that use co-design workshops to prototype new clinical pathways.
- **Invest in Design-Literate Training:** Staff training should extend beyond device operation to include interpretation of designed feedback and an understanding of the technology's design intent.

3. For Policymakers and Funders:

The research underscores the need for policy that enables responsible and equitable innovation.

- **Fund and Incentivise 'Frugal Innovation':** Shift funding criteria to reward projects that demonstrate low-cost, high-usability design and explore novel, sustainable business models.
- **Mandate Interoperability and Ethical Prototyping:** Policy should encourage standardised data protocols and support initiatives that prototype and test new data governance models with patients.

My dual perspective as a rehabilitation researcher and a design PhD candidate is intrinsically woven into these contributions. It enabled a synthesis between clinical pragmatism and design innovation. While this positionality initially led to an over-reliance on perceptual data, it ultimately facilitated the construction of a framework that is both ambitious in its vision and realistic about the constraints of healthcare environments. The contribution of this work is therefore not a clinically validated IoT device, but a robust, design-led argument and a concrete set of tools for creating the next generation of rehabilitation technologies that are not only functional but also humane, inclusive, and sustainable.

9.5.4 Practical Implications: A Design Research Agenda

The findings of this design research generate a set of specific, actionable implications that form a coherent agenda for advancing the field, directed at the key actors who can realise the potential of IoT in rehabilitation.

1. For Design Researchers and Technology Developers

This thesis provides a validated set of priorities for designing IoT devices specifically for stroke rehabilitation, moving beyond general principles to guidance that is grounded in the framework and sensitive to the unique constraints of this context.

- **Design for Adaptive Simplicity in Rehabilitation Devices:** Design must focus on creating IoT systems that respond to the fluctuating physical and cognitive states of stroke survivors. This means moving beyond pre-set programmes to interfaces that minimise cognitive load, prioritise error tolerance, and support a 'progressive disclosure' of complexity, ensuring that the technology remains accessible as users' abilities change.

- **Implement Inclusive and Cross-Cultural Design as a Core Requirement for Rehabilitation IoT:** Designers must create interaction models that are configurable and localisable for diverse users. For stroke rehabilitation, this includes designing for one-handed operation, multi-modal feedback (visual, auditory, haptic) as standard, and ensuring that devices can be adapted to accommodate different family structures and care norms, such as those observed between the UK and Saudi Arabia.
- **Design IoT Devices as Part of a Socio-Technical Ecosystem:** The device itself is only one component. Designers must also create 'Transparency by Design' features that make data handling intuitive for patients with cognitive impairments, and co-design clinical dashboards with rehabilitation professionals to ensure that IoT data from devices is presented in an actionable, clinically useful format.

2. For Healthcare Providers and Commissioners

The implications for clinical practice centre on adopting a design-aware approach to the procurement and integration of IoT rehabilitation technologies.

- **Procurement Based on Design Principles for Rehabilitation Technologies:** When selecting IoT devices for stroke rehabilitation, prioritise those that demonstrate evidence of inclusive design (e.g., accessibility for users with hemiplegia or aphasia) and adaptive personalisation features over those with the most extensive technical specifications.
- **Pilot Integration through Co-Design in Rehabilitation Services:** Implementation of new IoT devices should be treated as a service design challenge. Begin with small-scale pilots that use co-design workshops to prototype how the technology will integrate into existing rehabilitation pathways and clinical workflows.
- **Invest in Design-Literate Training for Rehabilitation Staff:** Staff training should extend beyond basic device operation to include interpretation of the device's designed feedback and an understanding of how the technology's interface and interaction model can support or hinder patient engagement.

3. For Policymakers and Funders

The research underscores the need for policy that enables responsible and equitable innovation specifically within the field of rehabilitation technology.

- **Fund and Incentivise Frugal Innovation in Rehabilitation IoT:** Shift funding criteria to reward projects that demonstrate low-cost, high-usability design for rehabilitation devices and that explore sustainable business models to ensure affordability for patients and healthcare systems.
- **Mandate Interoperability and Ethical Prototyping for Rehabilitation Technologies:** Policy should encourage standardised data protocols for rehabilitation devices to ensure seamless integration with electronic health records. It should also support initiatives that prototype and test new, transparent data governance models specifically designed with stroke survivors and rehabilitation professionals.

My perspective as a researcher situated between rehabilitation and design directly shaped these implications. This study offers a modest but, I hope, useful contribution: a set of empirically grounded, context-specific considerations for those developing and implementing IoT devices in stroke rehabilitation. The implications outlined above are offered not as definitive solutions, but as a starting point for a more design-aware approach to creating rehabilitation technologies—one that recognises that the success of IoT in this field depends as much on thoughtful, context-sensitive design as on technical innovation.

9.6 Conclusion and Future Design Research

This research has demonstrated that integrating IoT into post-stroke rehabilitation is not primarily a technical challenge, but a complex socio-technical design problem. Realising IoT's potential demands a fundamental shift from designing isolated devices to designing and orchestrating integrated care experiences.

Synthesis of Core Contributions

The findings form an interconnected narrative that validates the Four-Principle Design Framework (Section 9.2) and the Eleven Design Mandates (Chapter 8).

- **Personalisation is Contingent on Usability:** The promise of adaptive, real-time personalisation is nullified if the technology is inaccessible. This study confirms that user-centred design is the non-negotiable foundation for any personalised care system.
- **Adoption is a Function of Ecosystem Integration:** The most usable device will fail if it does not integrate into clinical workflows and address systemic concerns over data security, cost, and interoperability. Effective design must

therefore encompass the entire service ecosystem, from the patient's hand to the clinician's dashboard.

- **Equity is a Core Design Parameter:** Issues of cost, digital literacy, and cultural context are not edge cases but central design considerations. An inclusive future for rehabilitation technology depends on designing for equity from the outset.

Significance and Final Reflection

The primary significance of this research lies in its contribution to Design Research for complex healthcare systems.

- **Methodological Rigour:** It provides a methodological demonstration of how staged, stakeholder-centric research—integrating surveys, participatory workshops, and expert design critique—can build a robust, evidence-based foundation for design.
- **Theoretical Contribution:** It offers an empirically grounded framework of design principles to guide future innovation towards more humane, effective, and equitable outcomes.
- **A Design-Led Argument:** The thesis reflects a journey from cataloguing user needs to formulating a design-led argument for systemic change. It provides a necessary and valuable map—a design-informed brief—for navigating the complex journey ahead.

In conclusion, this research demonstrates that the transformative potential of IoT in stroke rehabilitation is not an inherent property of the technology, but a quality that must be deliberately designed into the socio-technical system. The ultimate lesson is that creating a future of effective, patient-centred, and accessible IoT-enabled care is a task for design in its broadest and most strategic sense. This thesis provides the foundational argument and a set of guiding principles for that essential work.

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Appendices

A. Online Survey Materials

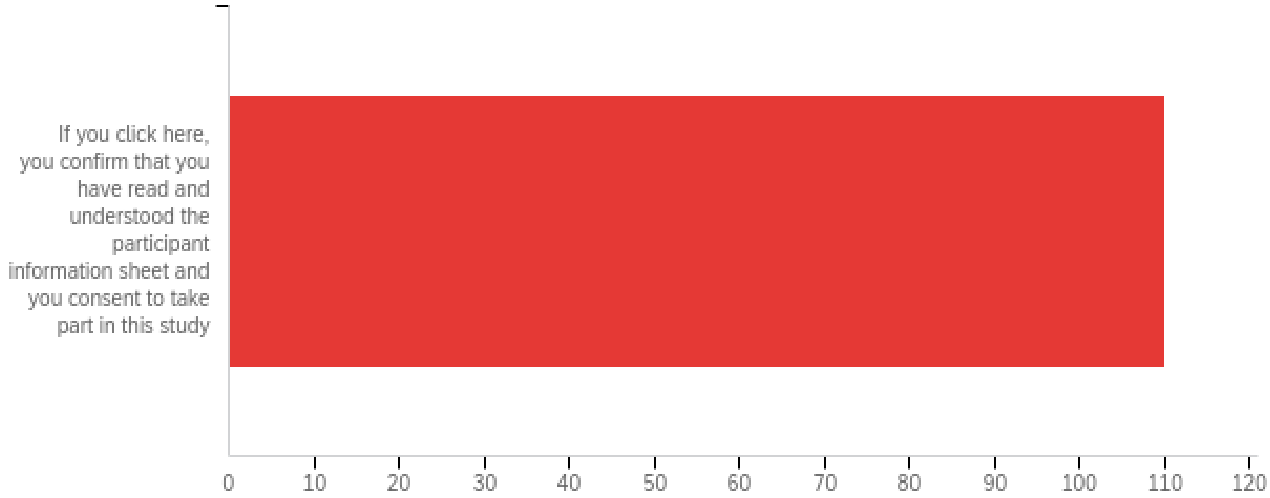
Default Report

Internet of things based training system for improving activities of daily living after stroke

October 19th 2021, 7:39 am MDT

Q1 - Thank you for your interest in this survey; it should take approximately 10 minutes to complete. I am a PhD student (Fayez Namnaqani) at Lancaster University and I would like to invite you to take part in a research study about an Internet of things based training system for improving activities of daily living after stroke. Please take time to read the following information carefully before you decide whether or not you wish to take part. Background Performing activities of daily living, like washing, dressing or making a meal can be difficult after a stroke. I want to see if we can help improve activities of daily living using a technology called the internet of things. The internet of things is about connecting everyday objects in a person's home via the internet for the purposes of greater ease of use(e.g. the Amazon Echo). This survey will explore your views on the challenges people with stroke face with daily living activities at home and ask questions about how you think connected devices at home (IOT) could potentially help them with their daily living activities. I have approached you because you have experience in rehabilitation and could therefore help me to design a new set of exercises or tasks using the internet and technology which helps people in their rehabilitation from stroke. I would be very grateful if you would agree to take part in this study. Target participants Rehabilitation practitioners of any nationality are welcome to participate irrespective of whether you are working in a clinical or an academic setting. Participants must be aged 18 or over. Your participation in the research project If you decide to take part, your participation is voluntary and you are free to withdraw at any time, without giving any reason. However, please note that once you have started the survey, your data will be submitted and it will not be possible to withdraw your data as participation is anonymous (your survey responses will not be connected to your name or personal details). After the end of the study a summary of the key findings may be submitted for publication in an academic/professional journal and this may include quotes from your responses to the survey. Data will be stored securely on the secure, password protected server at Lancaster University for 10 years and then destroyed. If you are interested in the study and/or if you have

any questions about this project, please contact: Name: Fayez Namnaqani, Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW Telephone: 07466328533 Email: f.namnaqani@lancaster.ac.uk If you have any concerns or complaints about the research, you can also contact the Head of Department: Name: Prof Judith Motrram, Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW Telephone: 01524- 594395 Email: judith.mottram@lancaster.ac.uk 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.



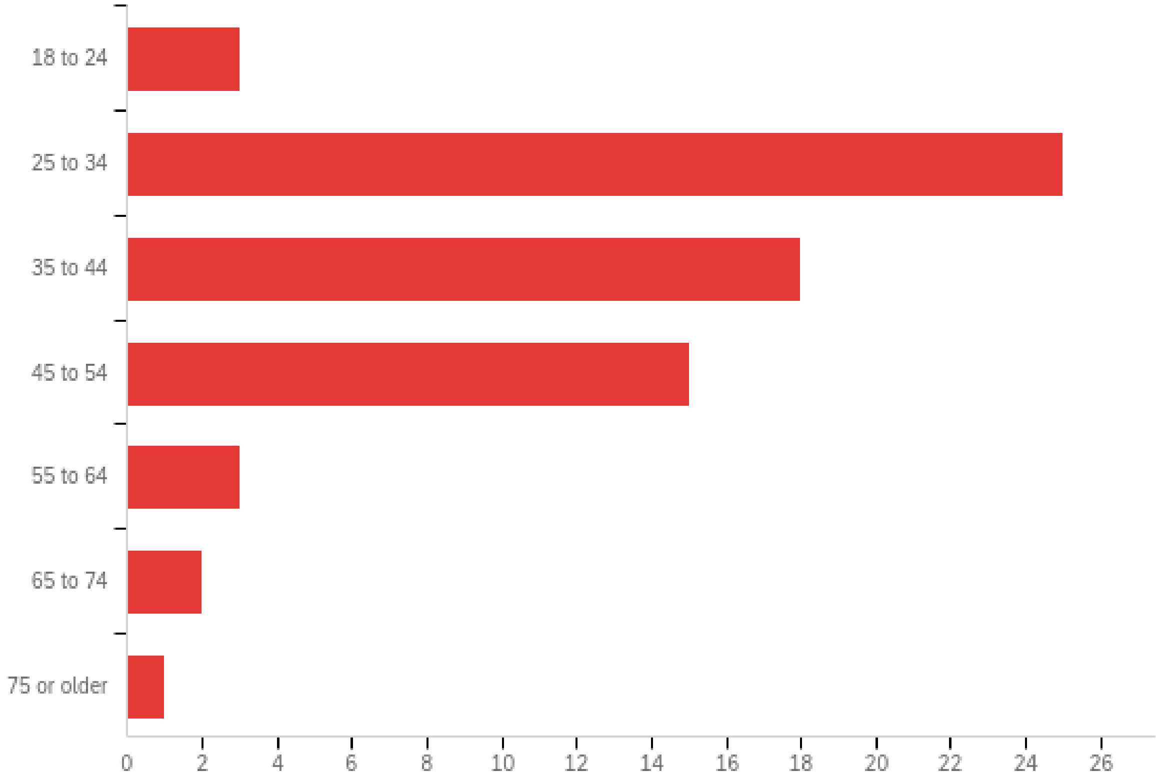
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Thank you for your interest in this survey; it should take approximately 10 minutes to complete. I am a PhD student (Fayez Namnaqani) at Lancaster University and I would like to invite you to take part in a research study about an Internet of things based training system for improving activities of daily living after stroke. Please take time to read the following information carefully before you decide whether or not you wish to take part. Background Performing activities of daily living, like washing, dressing or making a meal can be difficult after a stroke. I want to see if we can help improve activities of daily living using a technology called the internet of things. The	4.00	4.00	4.00	0.00	0.00	110

internet of things is about connecting everyday objects in a person’s home via the internet for the purposes of greater ease of use(e.g. the Amazon Echo). This survey will explore your views on the challenges people with stroke face with daily living activities at home and ask questions about how you think connected devices at home (IOT) could potentially help them with their daily living activities. I have approached you because you have experience in rehabilitation and could therefore help me to design a new set of exercises or tasks using the internet and technology which helps people in their rehabilitation from stroke. I would be very grateful if you would agree to take part in this study. Target participants Rehabilitation practitioners of any nationality are welcome to participate irrespective of whether you are working in a clinical or an academic setting. Participants must be aged 18 or over. Your participation in the research project If you decide to take part, your participation is voluntary and you are free to withdraw at any time, without giving any reason. However, please note that once you have started the survey, your data will be submitted and it will not be possible to withdraw your data as participation is anonymous (your survey responses will not be connected to your name or personal details). After the end of the study a summary of the key findings may be submitted for publication in an academic/professional journal and this may include quotes from your responses to the survey. Data will be stored securely on the secure, password protected server at Lancaster University for 10 years and then destroyed. If you are interested in the study

	and/or if you have any questions about this project, please contact: Name: Fayez Namnaqani, Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW Telephone: 07466328533 Email: f.namnaqani@lancaster.ac.uk If you have any concerns or complaints about the research, you can also contact the Head of Department: Name: Prof Judith Motrram, Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW Telephone: 01524- 594395 Email: judith.mottram@lancaster.ac.uk 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.					

#	Answer	%	Count
4	If you click here, you confirm that you have read and understood the participant information sheet and you consent to take part in this study	100.00%	110
	Total	100%	110

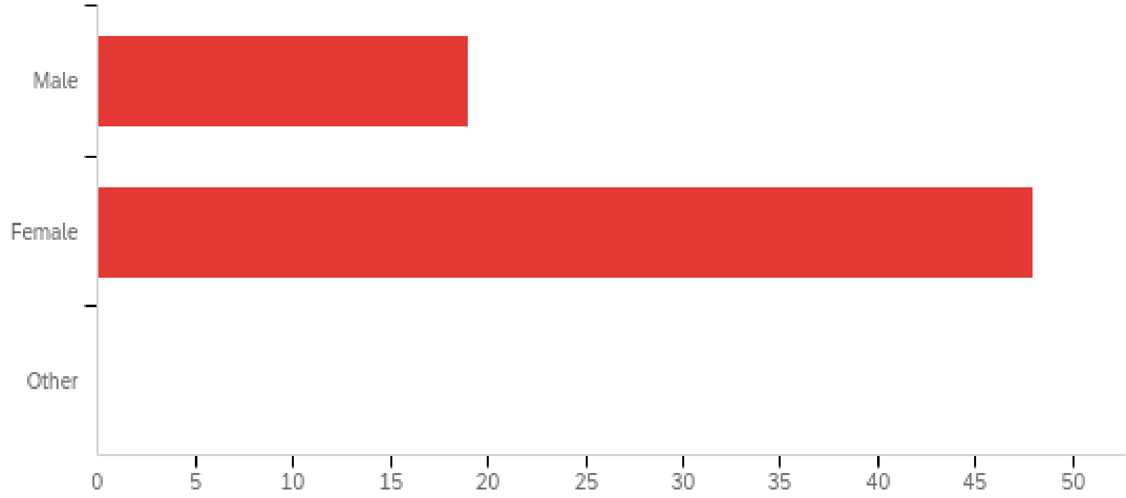
Q2 - What is your age?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is your age?	1.00	7.00	3.00	1.21	1.46	67

#	Answer	%	Count
1	18 to 24	4.48%	3
2	25 to 34	37.31%	25
3	35 to 44	26.87%	18
4	45 to 54	22.39%	15
5	55 to 64	4.48%	3
6	65 to 74	2.99%	2
7	75 or older	1.49%	1
	Total	100%	67

Q3 - What is your gender?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is your gender?	1.00	2.00	1.72	0.45	0.20	67

#	Answer	%	Count
1	Male	28.36%	19
2	Female	71.64%	48
3	Other	0.00%	0
	Total	100%	67

Q4 - What is your nationality?

What is your nationality?
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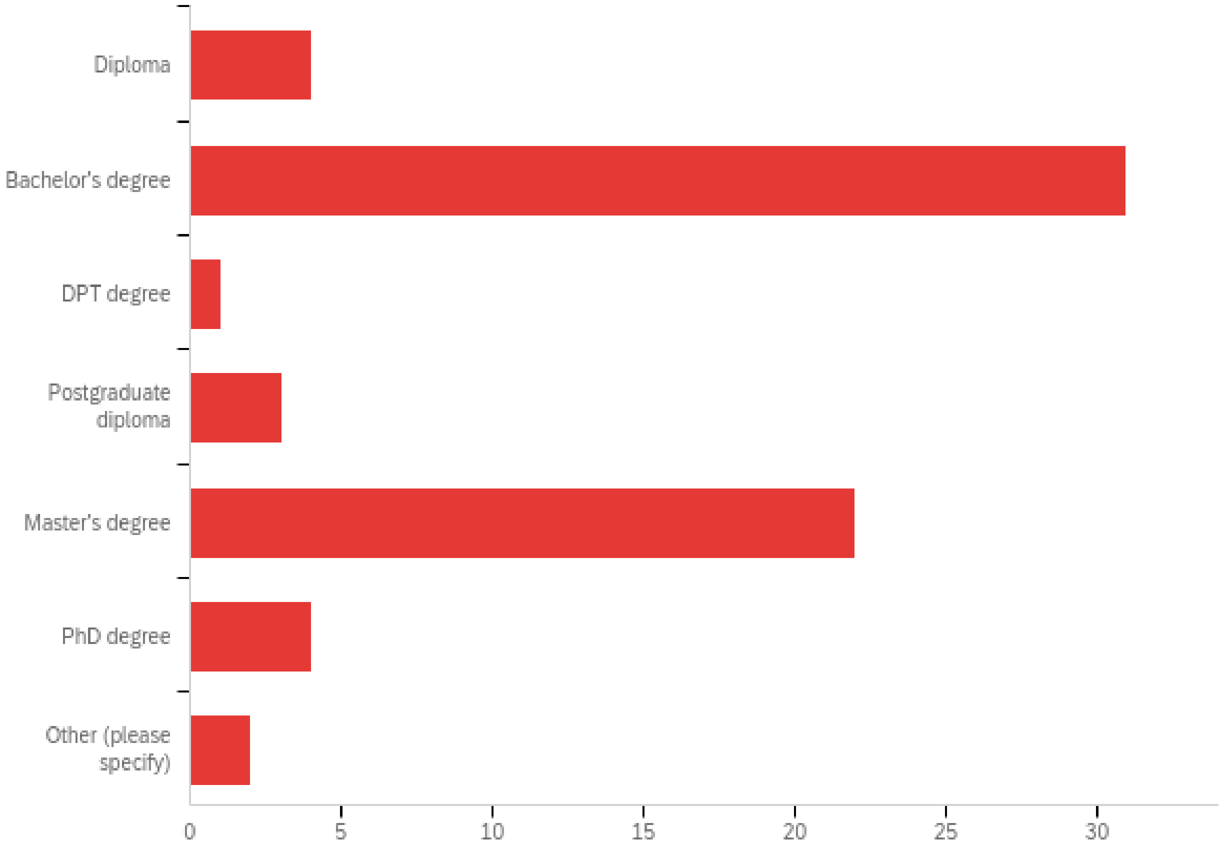
Q5 - What is your highest level of education?



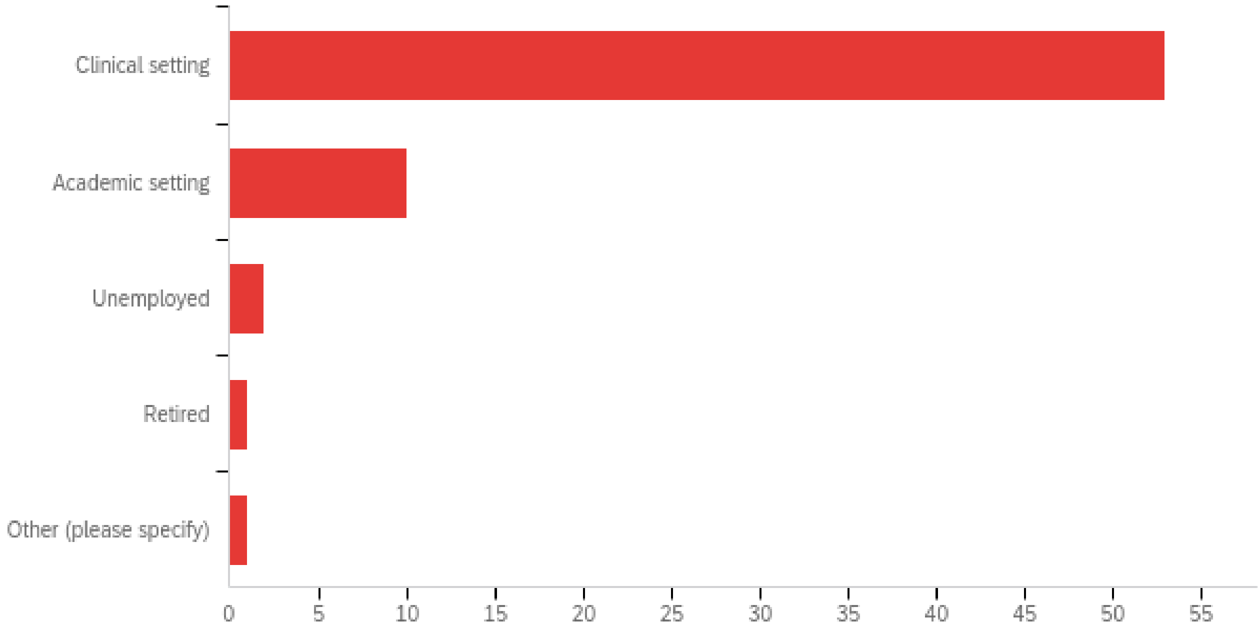
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is your highest level of education? - Selected Choice	1.00	7.00	3.42	1.70	2.90	67

#	Answer	%	Count
1	Diploma	5.97%	4
2	Bachelor's degree	46.27%	31
3	DPT degree	1.49%	1
4	Postgraduate diploma	4.48%	3
5	Master's degree	32.84%	22
6	PhD degree	5.97%	4
7	Other (please specify)	2.99%	2
	Total	100%	67

Q5_7_TEXT - Other (please specify)

Other (please specify) - Text
Plus 2 MSc modules
MCP

Q6 - What is your main work setting?



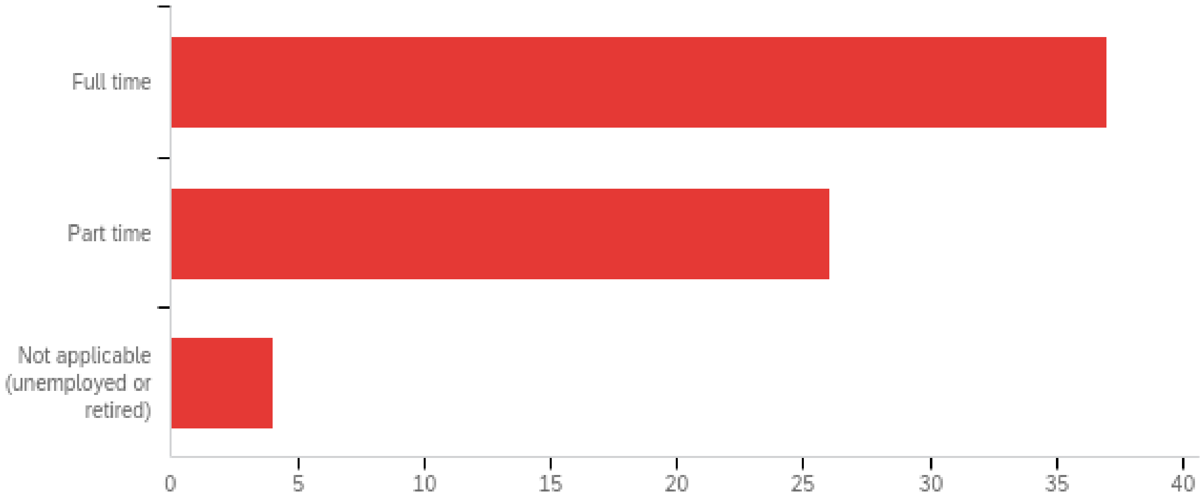
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is your main work setting? - Selected Choice	1.00	5.00	1.31	0.74	0.54	67

#	Answer	%	Count
1	Clinical setting	79.10%	53
2	Academic setting	14.93%	10
3	Unemployed	2.99%	2
4	Retired	1.49%	1
5	Other (please specify)	1.49%	1
	Total	100%	67

Q6_5_TEXT - Other (please specify)

Other (please specify) - Text
Student

Q7 - What is the type of your main work?

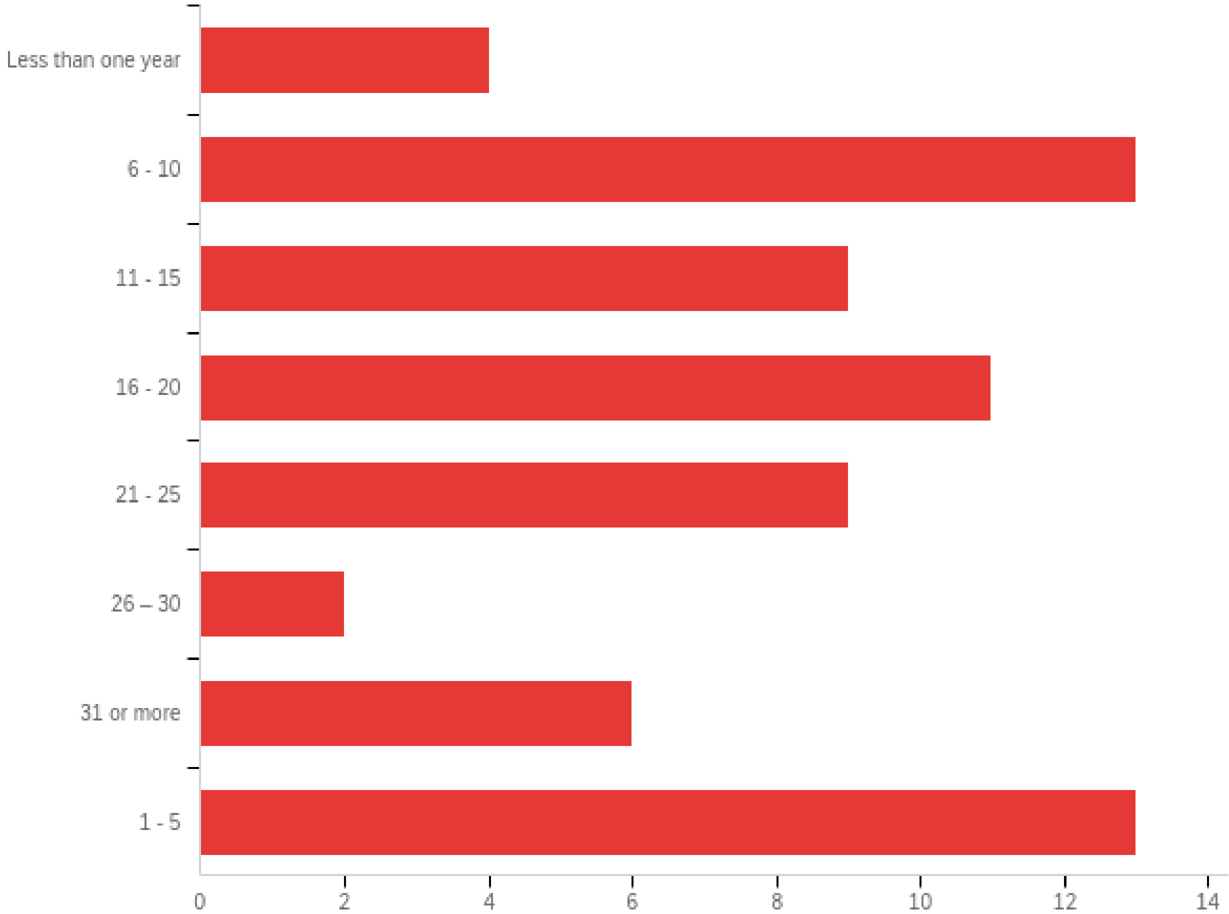


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is the type of your main work?	1.00	3.00	1.51	0.61	0.37	67

#	Answer	%	Count
1	Full time	55.22%	37
2	Part time	38.81%	26
3	Not applicable (unemployed or retired)	5.97%	4

		Total	100%	67

Q8 - What is your years of experience?

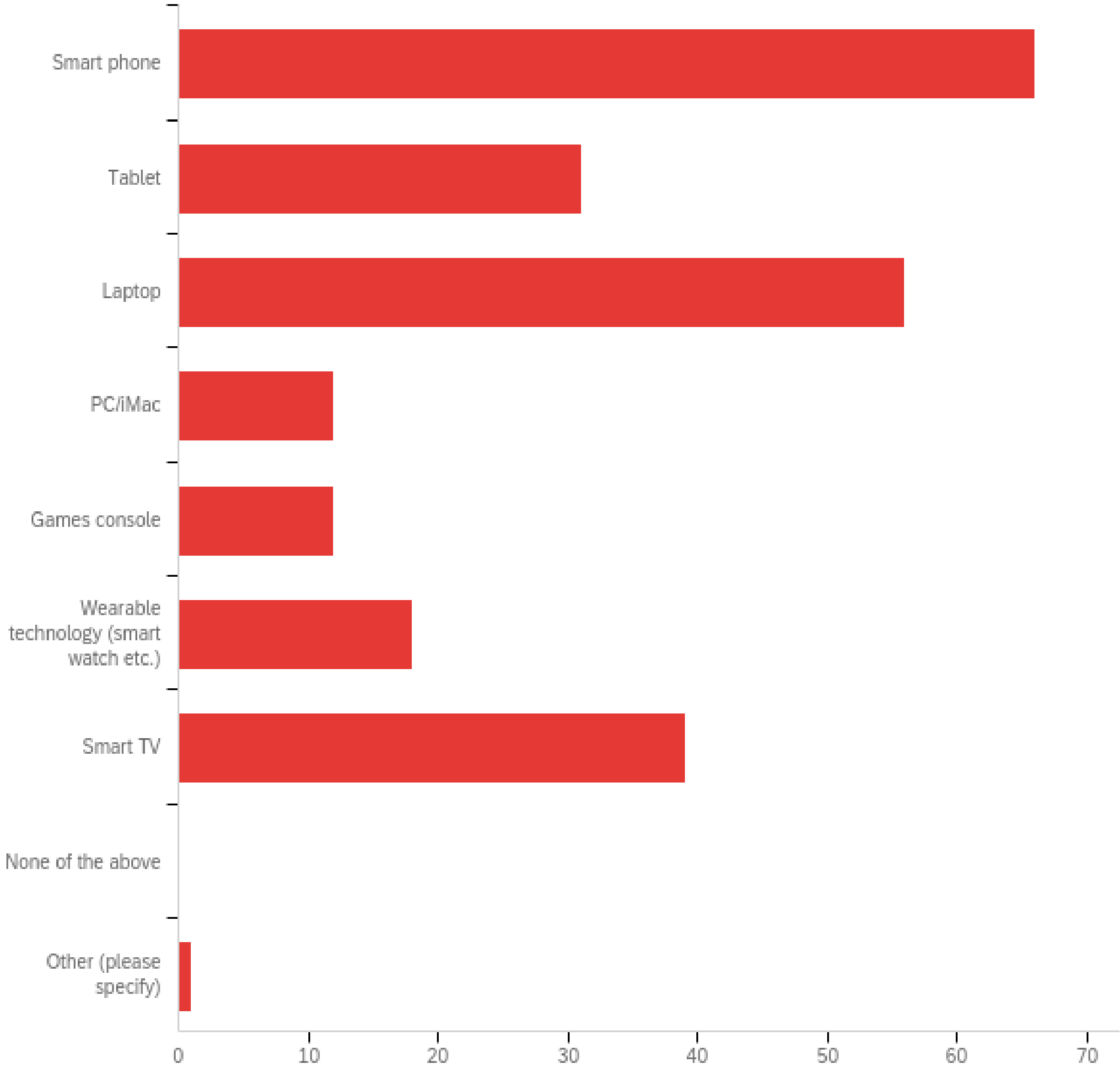


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is your years of experience?	1.00	11.00	6.61	2.82	7.94	67

#	Answer	%	Count
1	Less than one year	5.97%	4
4	6 - 10	19.40%	13
5	11 - 15	13.43%	9
6	16 - 20	16.42%	11
7	21 - 25	13.43%	9
8	26 – 30	2.99%	2
9	31 or more	8.96%	6

11	1 - 5	19.40%	13
	Total	100%	67

Q9 - Which, if any, of these devices do you own and use regularly? (You can select more than one response)



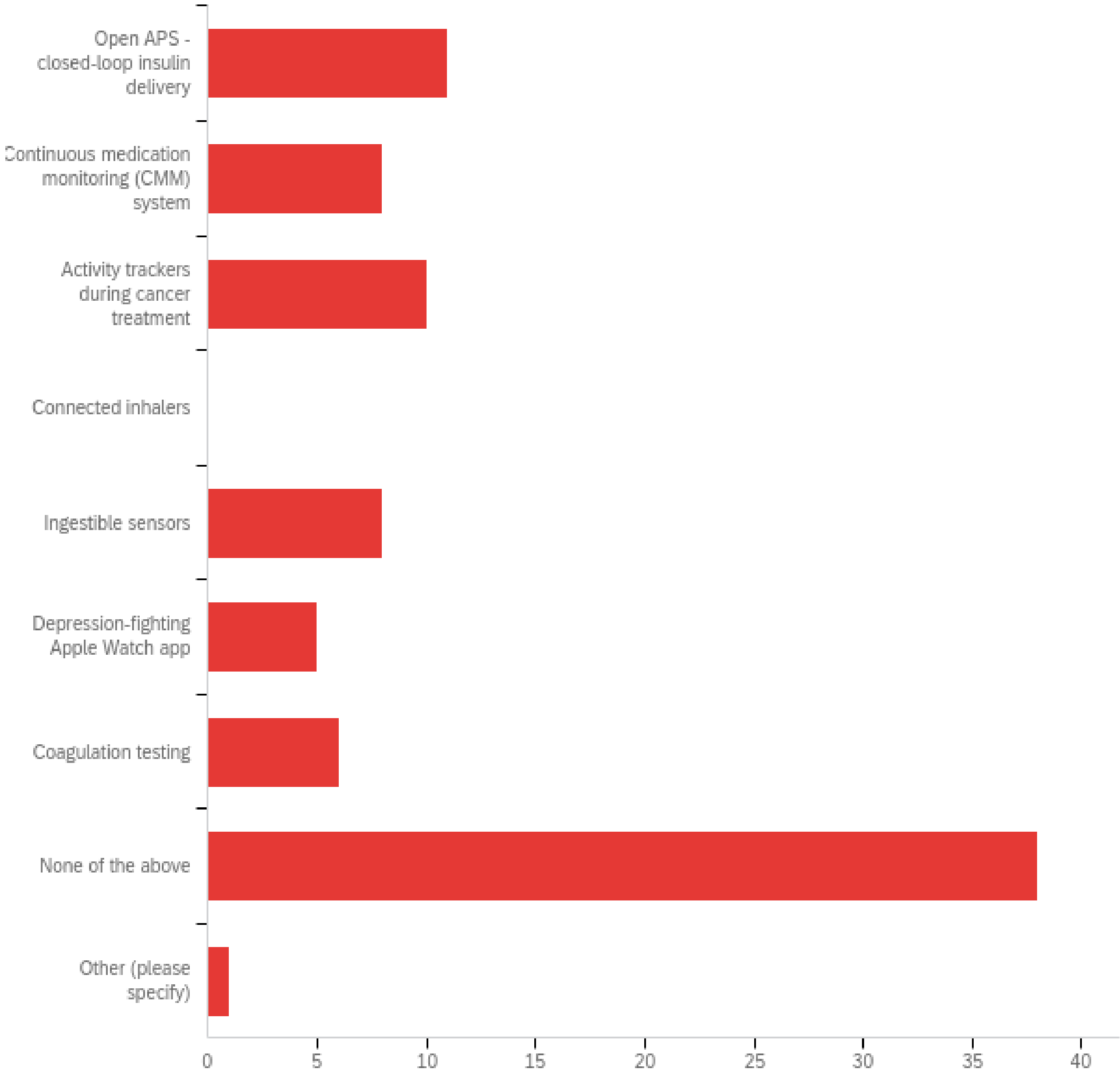
#	Answer	%	Count
1	Smart phone	28.09%	66
2	Tablet	13.19%	31
3	Laptop	23.83%	56
4	PC/iMac	5.11%	12
5	Games console	5.11%	12

6	Wearable technology (smart watch etc.)	7.66%	18
7	Smart TV	16.60%	39
8	None of the above	0.00%	0
9	Other (please specify)	0.43%	1
	Total	100%	235

Q9_9_TEXT - Other (please specify)

Other (please specify) - Text
Alexa speaker

Q10 - Which, if any, of these Internet of Things (IoT) or connected devices have you heard of? (You can select more than one response)



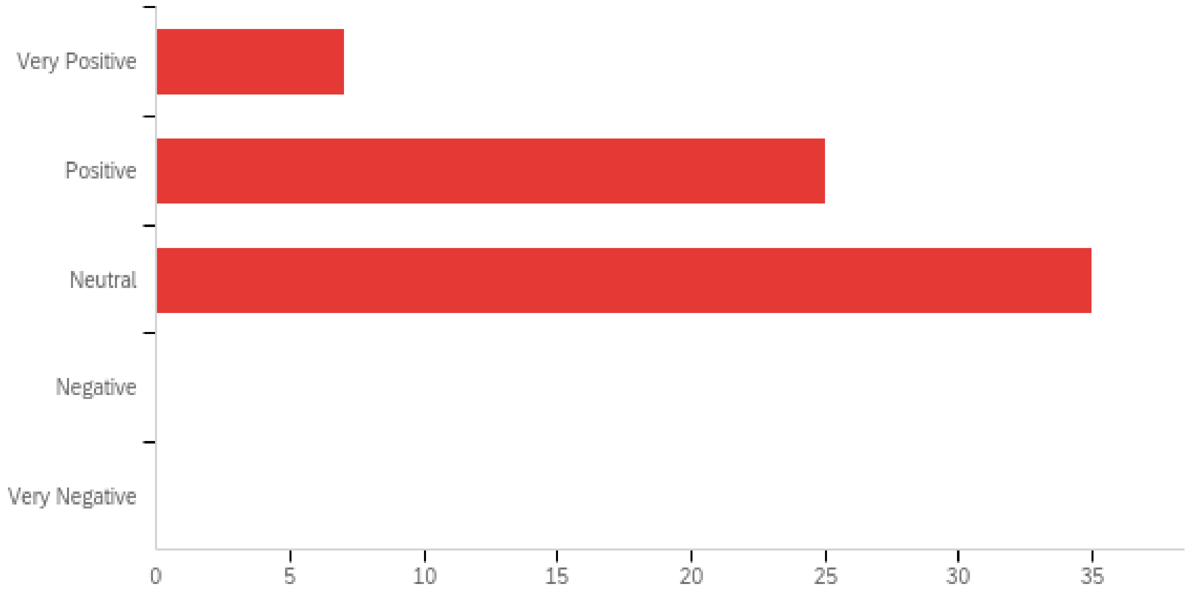
#	Answer	%	Count
1	Open APS - closed-loop insulin delivery	12.64%	11
2	Continuous medication monitoring (CMM) system	9.20%	8
3	Activity trackers during cancer treatment	11.49%	10
4	Connected inhalers	0.00%	0
5	Ingestible sensors	9.20%	8
6	Depression-fighting Apple Watch app	5.75%	5
7	Coagulation testing	6.90%	6
8	None of the above	43.68%	38

9	Other (please specify)	1.15%	1
	Total	100%	87

Q10_9_TEXT - Other (please specify)

Other (please specify) - Text
seizure monitors, sleep monitors

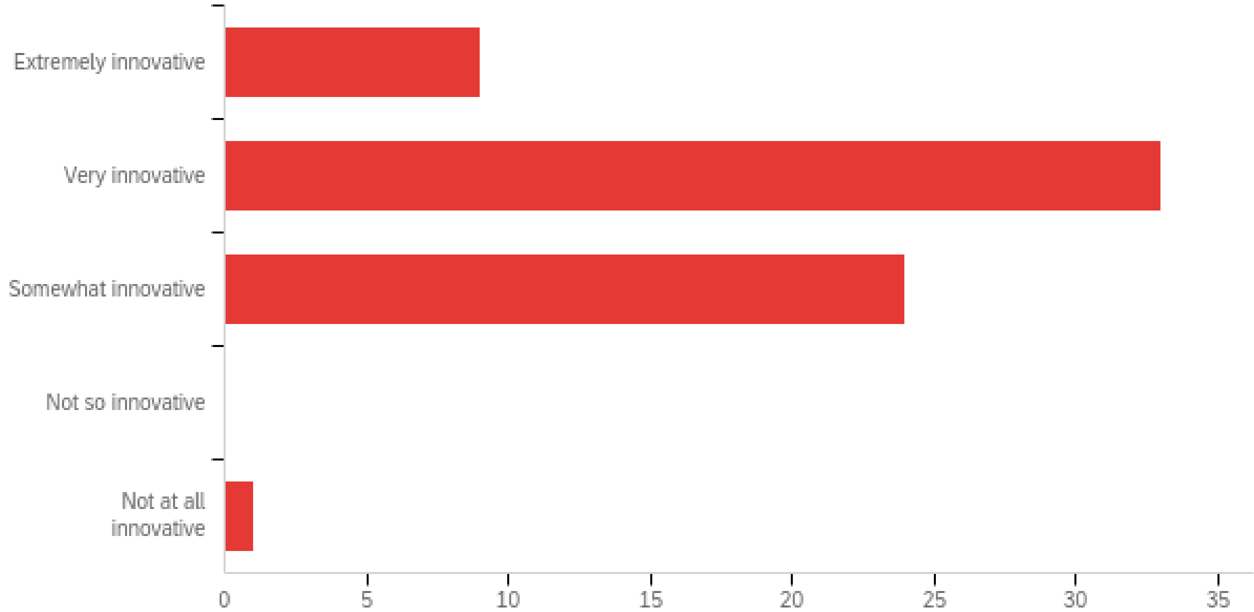
Q11 - What is your first impression of these connected devices?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	What is your first impression of these connected devices?	1.00	3.00	2.42	0.67	0.45	67

#	Answer	%	Count
1	Very Positive	10.45%	7
2	Positive	37.31%	25
3	Neutral	52.24%	35
4	Negative	0.00%	0
5	Very Negative	0.00%	0
	Total	100%	67

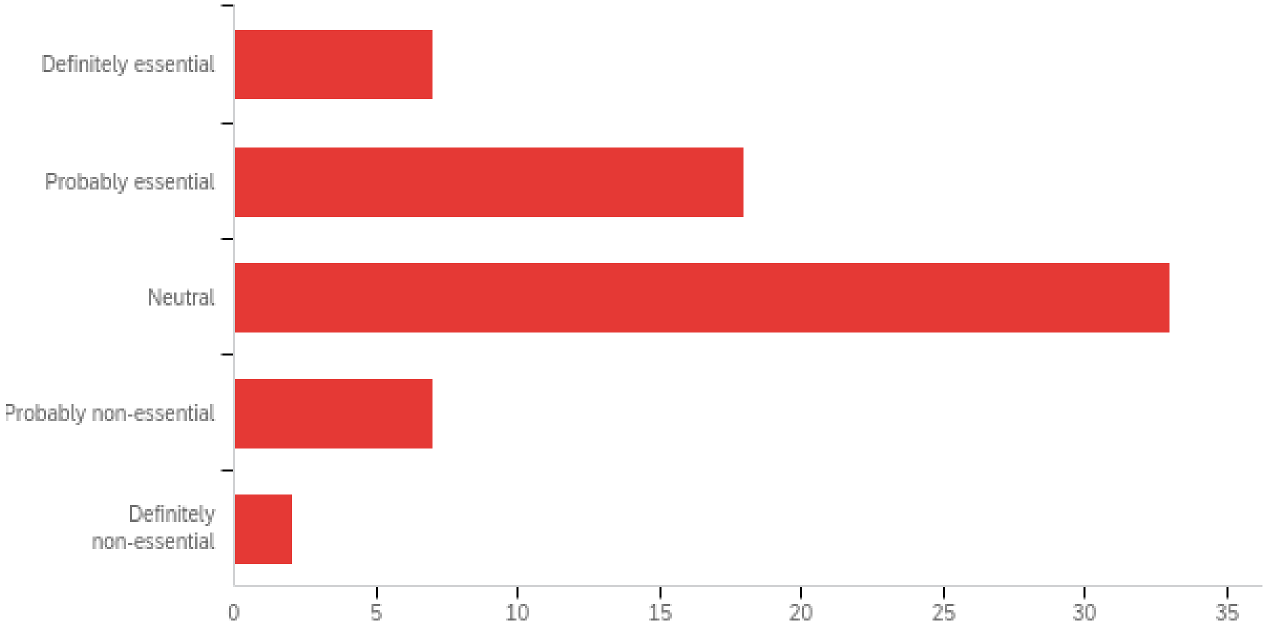
Q12 - how helpful is the technology of connected devices in monitoring patient recovery?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	how helpful is the technology of connected devices in monitoring patient recovery?	1.00	5.00	2.27	0.74	0.55	67

#	Answer	%	Count
1	Extremely innovative	13.43%	9
2	Very innovative	49.25%	33
3	Somewhat innovative	35.82%	24
4	Not so innovative	0.00%	0
5	Not at all innovative	1.49%	1
	Total	100%	67

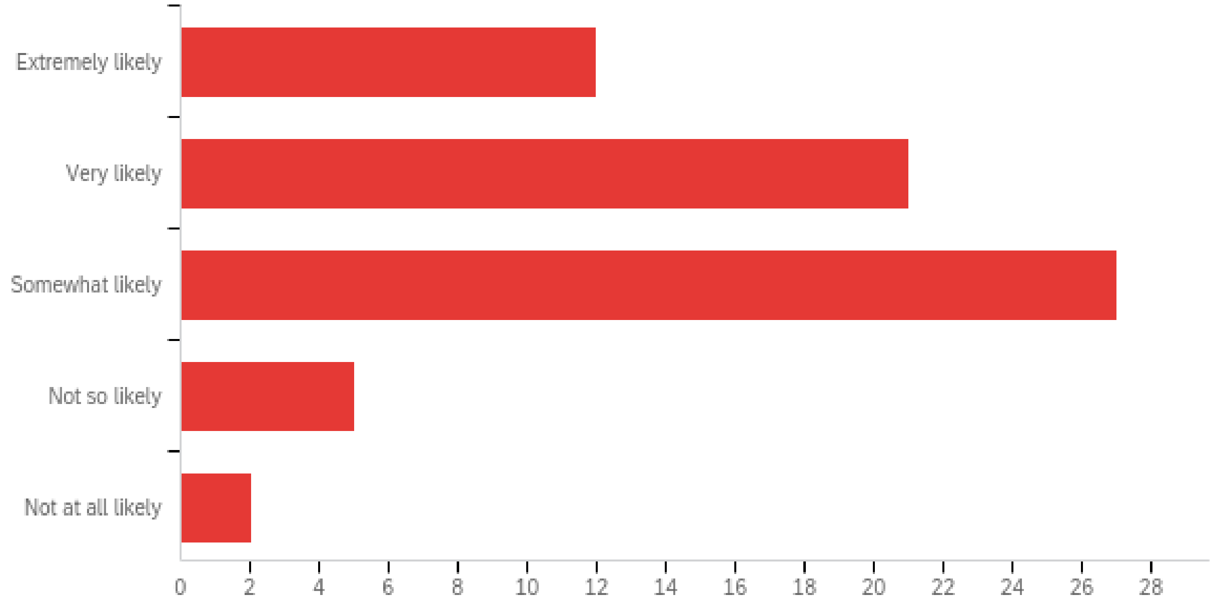
Q13 - When you think about these devices, do you think of them as something really essential or non-essential in your practice?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	When you think about these devices, do you think of them as something really essential or non-essential in your practice?	1.00	5.00	2.69	0.90	0.81	67

#	Answer	%	Count
1	Definitely essential	10.45%	7
2	Probably essential	26.87%	18
3	Neutral	49.25%	33
4	Probably non-essential	10.45%	7
5	Definitely non-essential	2.99%	2
	Total	100%	67

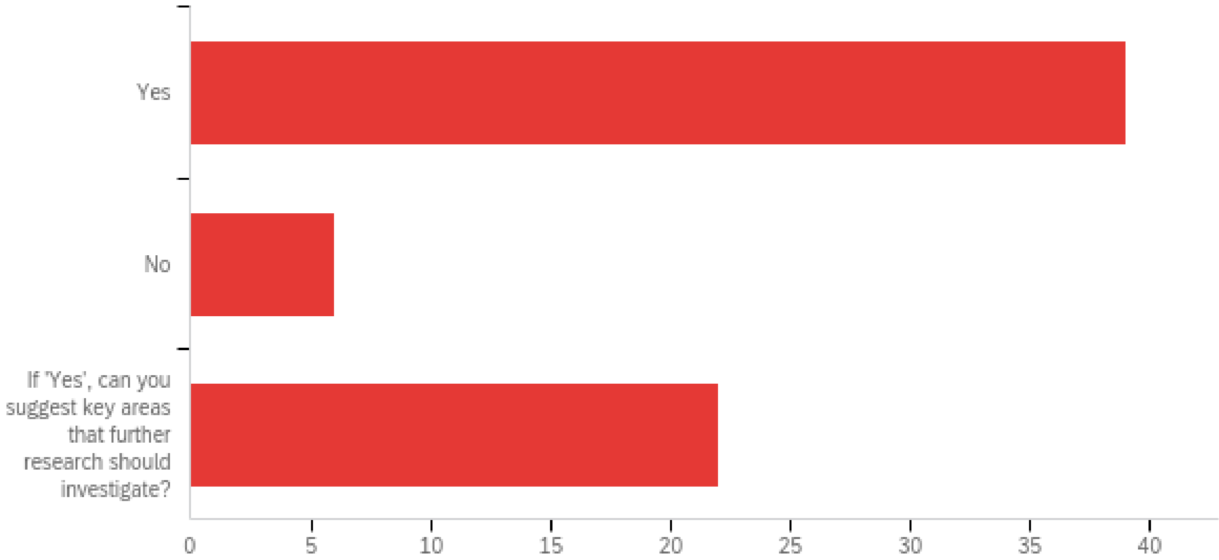
Q14 - If these devices were available today, how likely would you be to use them for stroke rehabilitation?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	If these devices were available today, how likely would you be to use them for stroke rehabilitation?	1.00	5.00	2.46	0.97	0.94	67

#	Answer	%	Count
1	Extremely likely	17.91%	12
2	Very likely	31.34%	21
3	Somewhat likely	40.30%	27
4	Not so likely	7.46%	5
5	Not at all likely	2.99%	2
	Total	100%	67

Q15 - Do you think that further research could benefit your practice with regard to use connected devices for stroke rehabilitation? If yes,where do you think further research is needed to benefit your practice in the use of new technologies, such as connected devices?



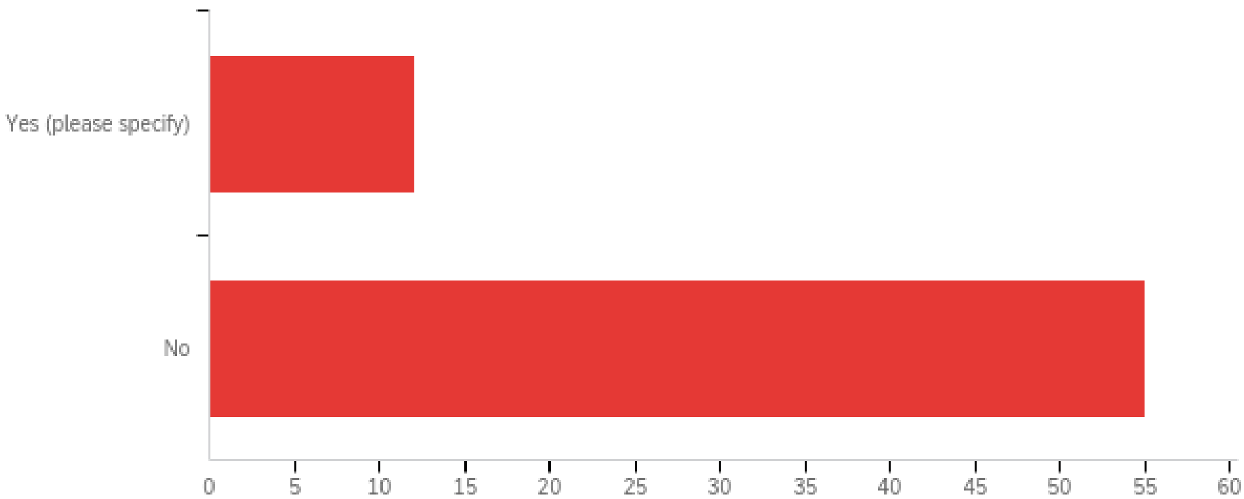
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do you think that further research could benefit your practice with regard to use connected devices for stroke rehabilitation? If yes,where do you think further research is needed to benefit your practice in the use of new technologies, such as connected devices? - Selected Choice	1.00	3.00	1.75	0.92	0.85	67

#	Answer	%	Count
1	Yes	58.21%	39
2	No	8.96%	6
3	If 'Yes', can you suggest key areas that further research should investigate?	32.84%	22
	Total	100%	67

Q15_3_TEXT - If 'Yes', can you suggest key areas that further research should investigat...

If 'Yes', can you suggest key areas that further research should investigate? - Text
ease of use, availability, affectiveness.
levels of cognition required to operate devices
Exercise Programme delivery
Cognitive cueing
Exercise prompting based on current behaviour, rather than just timed (i.e. just entered then kitchen so prompts balance exercises; cognitive cueing on voice activated devices, rather than just verbal prompting; step count verbalised periodically throughout the day via amazon echo etc; voive activated internet surfing; does auto prompting lead to less initiation from the patient; video door entry and remote door entry pro's and cons; video door bells to help prevent door to door caller fraud; nutrition and drinking goals verablised periodically with or without additional prompts; intuitive devices such as tablets for hand and dexterity based rehab;
Use within community setting, in community rehab teams. Particularly those that provide services to other patient cohorts as well as patients who have had a stroke. It feels much harder to implement specific recovery programmes when it is not being used for ALL patients.
Time of day optimum for more intense ex and if hourly get up and go. Fatiguability compared to none stroke pts. If HIIT can be put into place
Impact of cognition on technology use, Patient uptake and compliance, impact on outcomes
Visual aids e.g. smart eyewear for inattention and hemi-anopia
To assist with ways to increase intensity and aerobic training capacity of task specific therapy sessions
Fatigue and activity levels
EMG based activity monitors, pressure sensors in footwear connected ineteractive technology giving feedback about gait or upper limb movement when to encourage and when to rest when fatigue detected. Cognitive reminders programmed into an Alexa type technology and with permission alerts to main carers.
Activity trackers and 2 way exercise/activity programmes where client and therapist can communicate remotely
Activity levels
Speech, cognition and compliance with physiotherapy based exercises
timer and guide for home exercise prog
Hospitals who can afford it
accessibility
Hemispatial neglects
Activity profile
Smartphones companies , eg. Apple
Just testing the box and how much info it lets you write. This looks good!

Q16 - Have you ever used any connected devices in your practice?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Have you ever used any connected devices in your practice? - Selected Choice	1.00	2.00	1.82	0.38	0.15	67

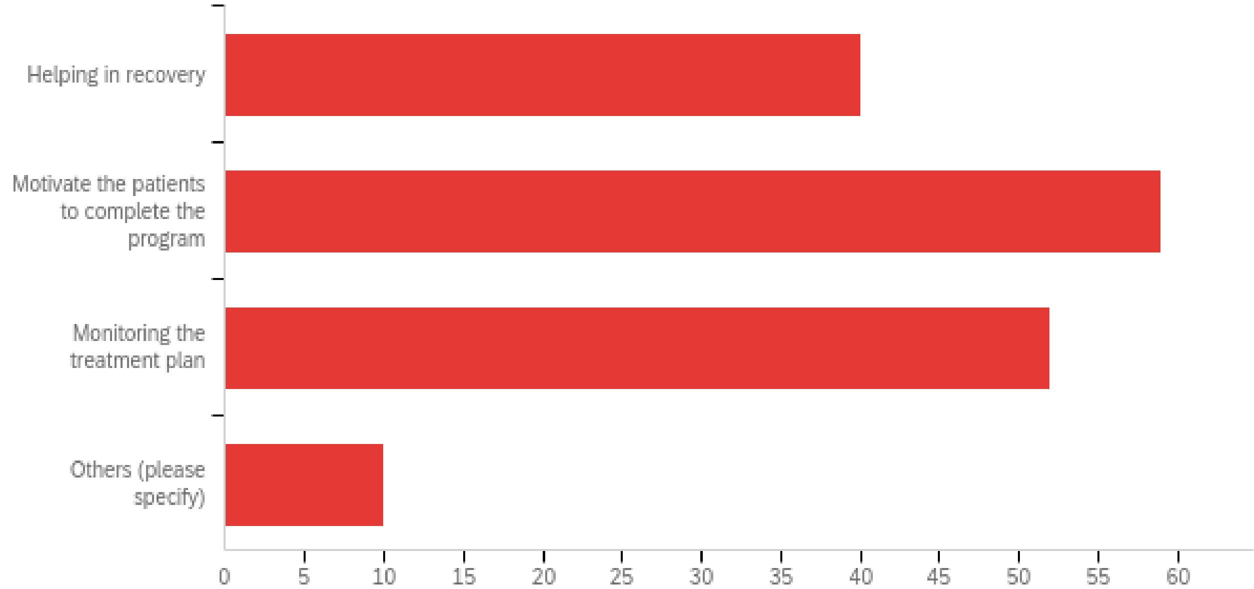
#	Answer	%	Count
1	Yes (please specify)	17.91%	12
2	No	82.09%	55
	Total	100%	67

Q16_1_TEXT - Yes (please specify)

Yes (please specify) - Text
tablet; voice control of phone;
Only use of ipads and varying apps in ESD stroke teams.
Apps
sleep app, alexa
Activity trackers
Ipad
Patients own smart watches
activity tracker/ heart rate monitors
Tablet

Repetition of exercise and movement or use of henipkegic arms and mobility.
Yes Apple Watch to record level of activity time
Monitor

Q17 - What do you see as the opportunities of using such connected devices in your practice? (You can select more than one response)



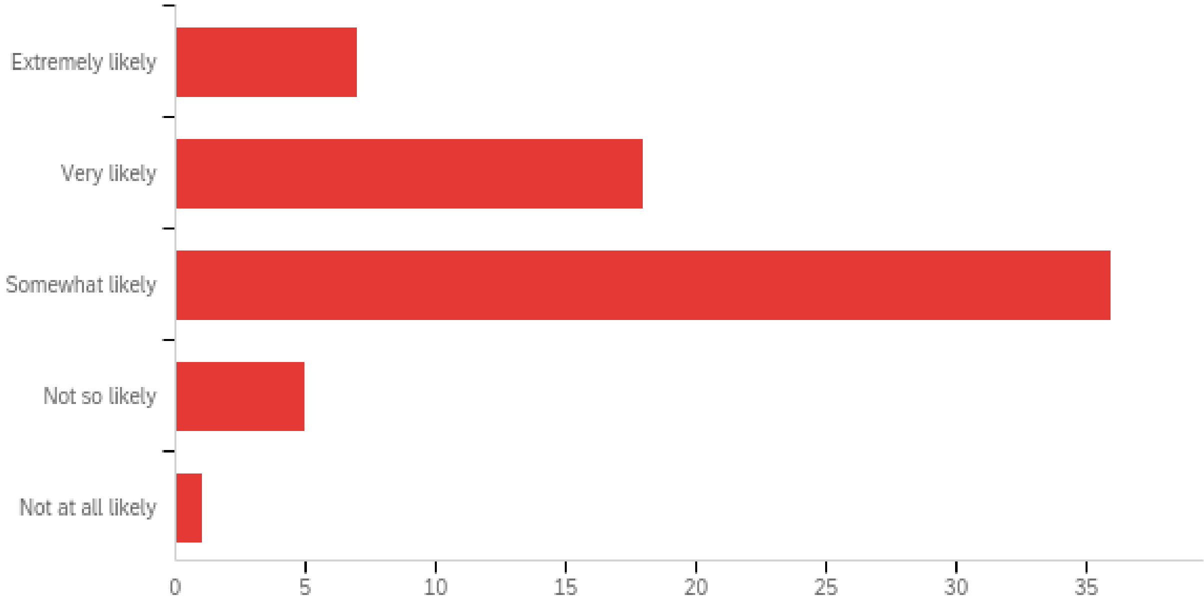
#	Answer	%	Count
1	Helping in recovery	24.84%	40
2	Motivate the patients to complete the program	36.65%	59
3	Monitoring the treatment plan	32.30%	52
4	Others (please specify)	6.21%	10
	Total	100%	161

Q17_4_TEXT - Others (please specify)

Others (please specify) - Text
more data for research; identifying more focussed direction for patient rehab plan based on behaviours; free up face to face resource so t can be undertaken for longer and with arger capture rate of patients, including high level one; better access to package of care as may not need so much input (particularly useful in rural settings with limited access);
self managment
Personal activity timings
Unsure

Measuring intensity and training potential of therapy
To establish routines to ensure carryover.
Able to give feedback remotely
Memory aid
I’ve not
Make things easier to explain

Q18 - How likely are you to augment your ways of treatment with using these devices?

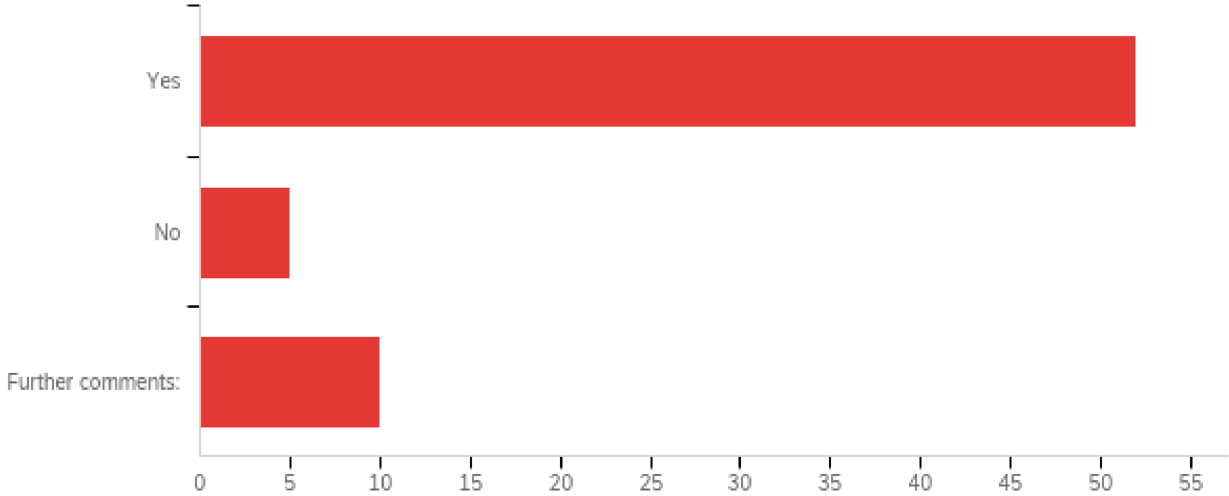


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How likely are you to augment your ways of treatment with using these devices?	1.00	5.00	2.63	0.83	0.68	67

#	Answer	%	Count
1	Extremely likely	10.45%	7
2	Very likely	26.87%	18
3	Somewhat likely	53.73%	36
4	Not so likely	7.46%	5
5	Not at all likely	1.49%	1

	Total	100%	67

Q19 - Based on your experience so far, do you think that the use of connected devices fit within the scope of rehabilitation?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Based on your experience so far, do you think that the use of connected devices fit within the scope of rehabilitation? - Selected Choice	1.00	3.00	1.37	0.73	0.53	67

#	Answer	%	Count
1	Yes	77.61%	52
2	No	7.46%	5
3	Further comments:	14.93%	10
	Total	100%	67

Q19_3_TEXT - Further comments:

Further comments: - Text
assists with self mnagement
no experience
I have had a long experience of working with people who have had a stroke. It is very important to help them understand what has happened and then give them hope and show them how to help themselves especially to move in bed safely, realise that lying in bed with good posture is the basis

of rehabilitation, followed by maintaining full range of movement, if possible, by teaching them to clasp their hands together. Then teaching them how to sit over the affected side to then sit with both hands flat on the bed to prevent spasticity. If the patient is unconscious then the patient should be turned every two hours alternating stretching one arm , flexing the opposite leg in alternate side lying every two hours. In my experience this reduces spasticity. Working on the bed to prepare for sitting balance and standing up to transfer onto a chair. When ever they have sitting balance .have b;adder control then I have had experience of running a self-help therapy group in an acute hospital. One patient was able to join three days after their stroke, thus they soon learnt how to help themselves encouraged by their fellow patients We used to run a group session from 10.30 am until 4pm socialising, moving to a table , where the programme included mobility of the upper limbs, working on perception and learning how to relax in normal ways which meant that they were learning how to stretch their elbow wrist and fingers. The day's programme included free sitting, standing and walking, eating lunch together with the therapists and maybe a nurse who had come to learn and watch so that the REHABILITATION PROCESS so that the rehabilitation process could continue in the ward, thus facilitating motor memory. I do not see how your connected devices have a relevance in their rehabilition which must include helping them to increase their confidence and self worth. Supporting the family members is integral in the rehab process.

Could be age specific if its suits the individual

a little

Unsure

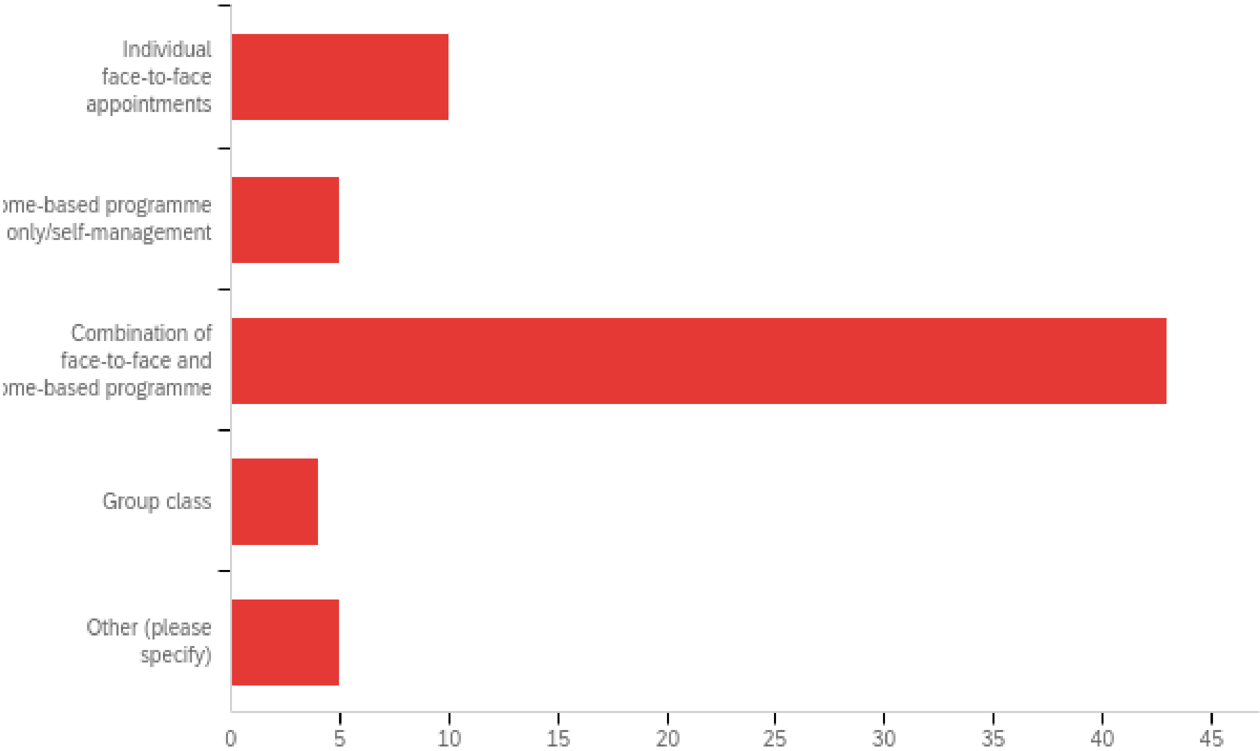
have no experience with connective devices c

The barrier is who will finance this technology.

Unsure as not used it in clinical practice

I think, not sure due to lack of clear info. About it

Q20 - According to your experience, how can you provide these new types of treatment to patients?



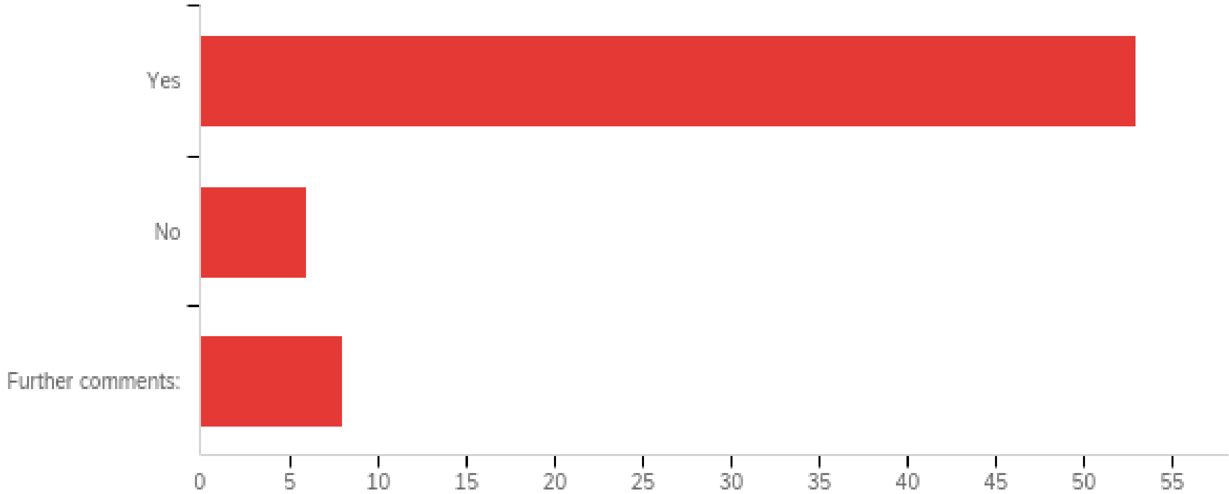
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	According to your experience, how can you provide these new types of treatment to patients? - Selected Choice	1.00	5.00	2.84	1.00	1.00	67

#	Answer	%	Count
1	Individual face-to-face appointments	14.93%	10
2	Home-based programme only/self-management	7.46%	5
3	Combination of face-to-face and home-based programme	64.18%	43
4	Group class	5.97%	4
5	Other (please specify)	7.46%	5
	Total	100%	67

Q20_5_TEXT - Other (please specify)

Other (please specify) - Text
Bespoke to each patient using initial face to face and then mixture of face to face and remote f/u. Start behvaiours early with acute inpatients so behaviours are already set before d/c (much easier to monitor initial progress and compliance).
All of above
Not available in our service
I don't know (see below)
Combination and depends on technology

Q21 - Do you think that using connected devices could motivate patients to complete their program compared to traditional methods of treatment?



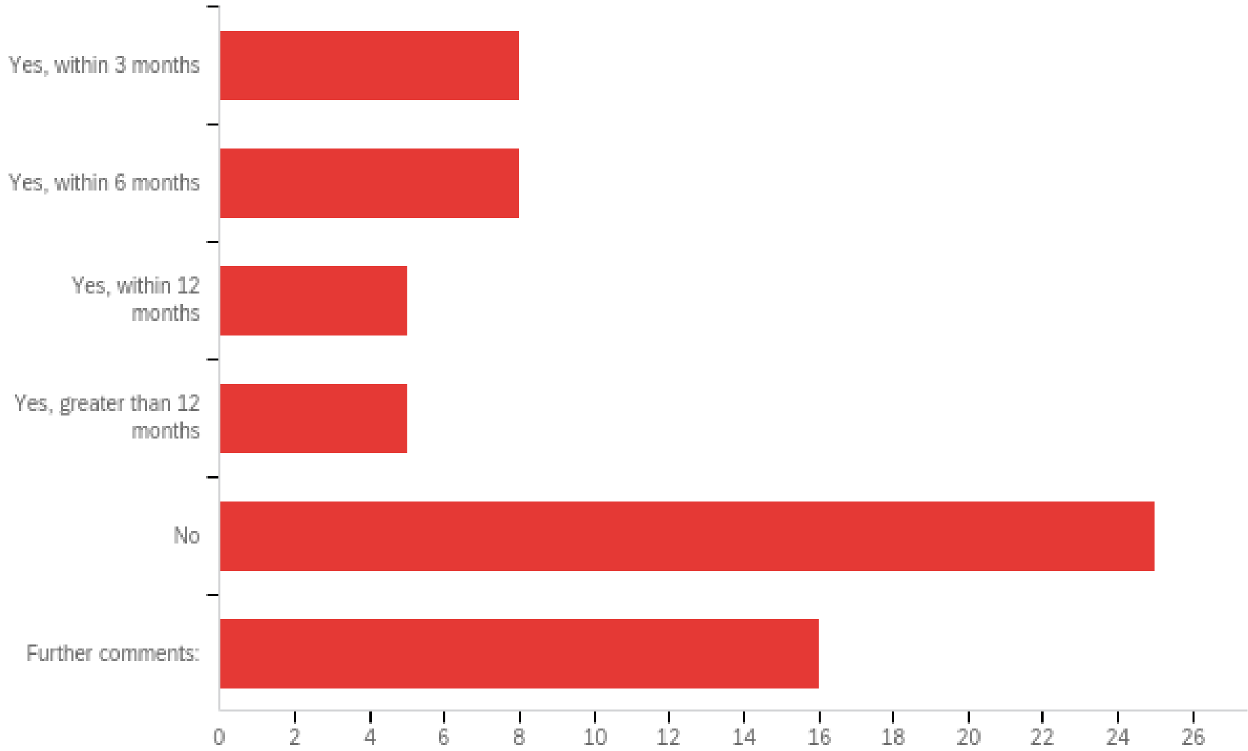
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do you think that using connected devices could motivate patients to complete their program compared to traditional methods of treatment? - Selected Choice	1.00	3.00	1.33	0.68	0.46	67

#	Answer	%	Count
1	Yes	79.10%	53
2	No	8.96%	6
3	Further comments:	11.94%	8
	Total	100%	67

Q21_3_TEXT - Further comments:

Further comments: - Text
maybe
Giving ex prompts and being able to explain to patients about ex levels and fatigue for them to be and take
Depending on if the individual is interested in tecnology
Yes if they are already familiar with and engaged in using the technology
Sometimes
There are always a few who would find them annoying or cognitive/ communication impaired to utilise them independently
Dependent on individual - IT comfortable; cognitive ability; ease of use
Gentle reminder and if tracked probable increased compliance

Q22 - Would you expect that using connected devices would shorten the patient recovery compared to traditional methods of treatment?



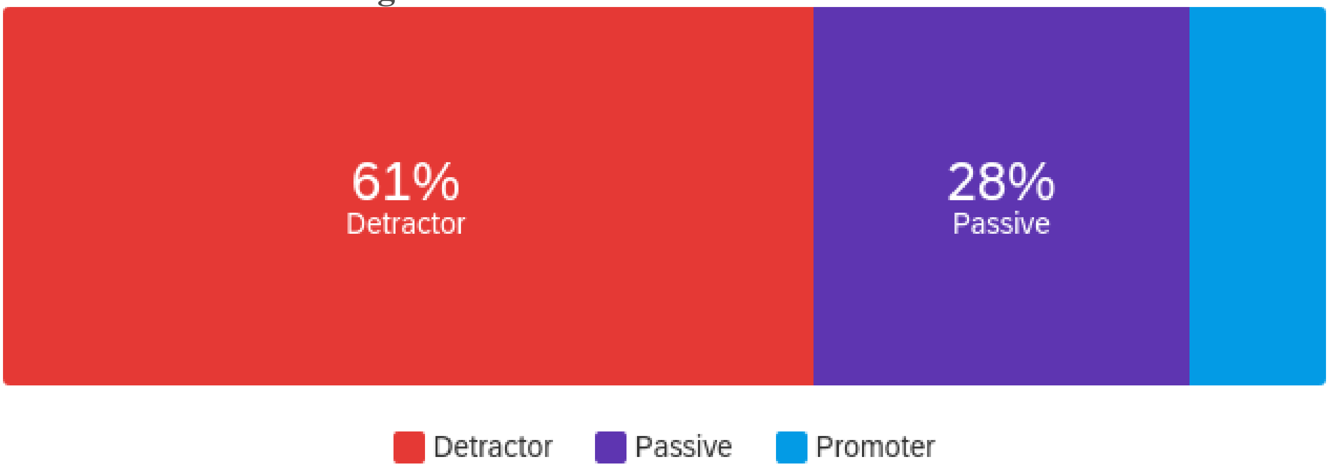
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Would you expect that using connected devices would shorten the patient recovery compared to traditional methods of treatment? - Selected Choice	1.00	6.00	4.18	1.71	2.92	67

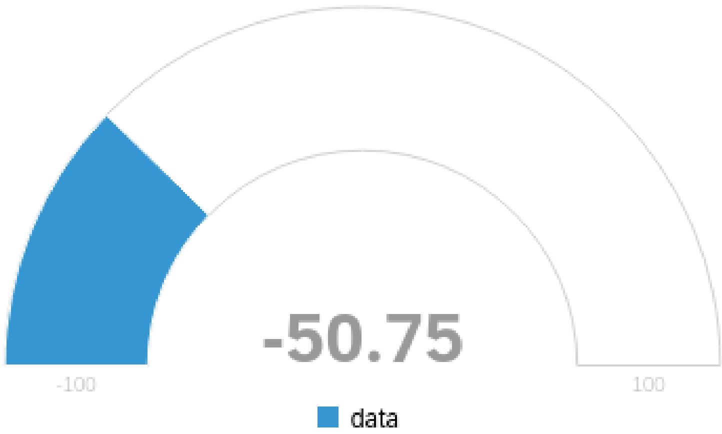
#	Answer	%	Count
1	Yes, within 3 months	11.94%	8
2	Yes, within 6 months	11.94%	8
3	Yes, within 12 months	7.46%	5
4	Yes, greater than 12 months	7.46%	5
5	No	37.31%	25
6	Further comments:	23.88%	16
	Total	100%	67

Q22_6_TEXT - Further comments:

Further comments: - Text
dont know enough to answer
Maybe just as adjunct to increase self management and increase adherence to exercise
I'm not convinced of this. There may be a better outcome overall in the cohort, but I imagine the enhanced outcomes would be secondary to resource availability as clinicians are freer to pick up less impaired patients and be able to carry patients on their caseload for longer.
Uncertain!
Depends on what is meant by recovery - more rapid recovery in a shorter time more effective and efficient
yes, depends what it is
Possibly but unable to put time frame on it
don't know
Needs research and deepens on impairment s.
Recovery time for a neurological event will not be shortened but use of such technology may maximise recovery timescale and aid self management
I don’t know, but would love to find out
Depends on compliance of patients to use technology?
If get patient/carer buy-in and its relevant
Maybe
Yes, no specific time
Depends on the case

Q23 - On a scale from 0-10, how likely is it that you would recommend these devices to a colleague?





Q24 - In your own words, what are the things that you like most about these devices?

In your own words, what are the things that you like most about these devices?
accountability, independence, able to monitor progress without patient coming into hospital
I would need to know more information about the device
I've not had the opportunity to use these devices so unable to say
can set reminders on phone
option to self monitor and manage
I know very little about them and so unable to answer this
i dont know enough to comment
Monitoring and motivation
To give patient feedback, to provide reminds/rewards to encouragement of exercise. Any apps/devices need to be tailorable to individual patients
Better monitoring and motivation of patients; allows more effective use of the team's resource
Engagement, ability to demonstrate progress, positively reinforcement.
Helping patients take control of their recovery / maintenance
Ease of use
Reduce repeating why need to be active. As already on board with bring part of activity programme.
Gives the patient more insight and control.
monitoring an d self efficacy
Increasingly user friendly, promoting patient autonomy in rehab, enhanceing motivation.
Personalised, independence, innovative
I don’t know anything about them so couldn’t recommend
The use of gadgets/technology that are available on nainstrwam narket such as alexa/google assist/smart watch help patients without them feeling it is a specially adapted piece of kit for disabled people, helping withcompl8ance particularly in younger stroke population
Modern
Monitoring to help give patients feedback or provide reminders
I have never heard of these devices before this survey but they are intriguing
6
Most people have a tablet or smart phone. Can provide video exercises and text chat with the client or video call.

Real time monitoring opportunity, ability to feedback and discuss with clients what they are really doing
Motivation; monitoring
Opportunity for exercises to be more interactive and fun
Time reminder, visual prompt
Ease of use
A new way could be benefit for humanity
I don't know because I have never seen them
Connection
Easy to use by young and old patients.
Less demanding
Engaging technology in rehabilitation
Make the patient more independant
Time saver
Monitoring and motivate the patient
continue to recovering and follow up
Efficiency and accuracy
Making ADL easy to handle
Arrangements
That it could help patients to live better and to improve better
Technology always make things easier
Test

Q25 - In your own words, what are the things that you would most like to see included in these devices?

In your own words, what are the things that you would most like to see included in these devices?
I don't know enough about the devices
Ways to check in on patient progress and give advice/input from therapist to patient directly
?
option to view and update goals
An ability to monitor amount of movement, activity a pt does
dont know enough to answer

If exercise done correctly

Ease of use and application particularly as many stroke survivors are elderly and possibly not very familiar with connected devices.

as above

user interface design flexibility to be more specific to patient's needs (eg, don't have 10 options on a screen when a patient only needs 3), colour choices of background (to aid in dementia and mild LD); open ended connectivity with less end user license limitations; easy data extraction and analysis for clinicians to help re-tailor the set up for patients more specifically.

AS I am not familiar with the devices I cannot comment. They don't seem very practical

Encouragement to reach goals

Very easy to use app for patient or carer and therapist reference.

Not appropriate for use by all (patients with cognitive problems / elderly patients that do not like technology).

simple set up and use

Ongoing development of interfaces that are user friendly for those with cognitive impairment, visual/ multi sensory impairment.

Reasonable price, robust, re-usable

More information

Activity monitoring, method of feedback, access to apps that can be personalised to support rehab program

Easy to use

Reminders, set parameters that motivate patient

I'm not sure

See above

Video call option included in whatever app is used

Not sure

Ease of use and don and doff one handed; adapted for control with sound; mouth etc

More user friendly for patients with reduced cognition and slower processing

Visual prompt, timer

Encouragement

.

Ease of access

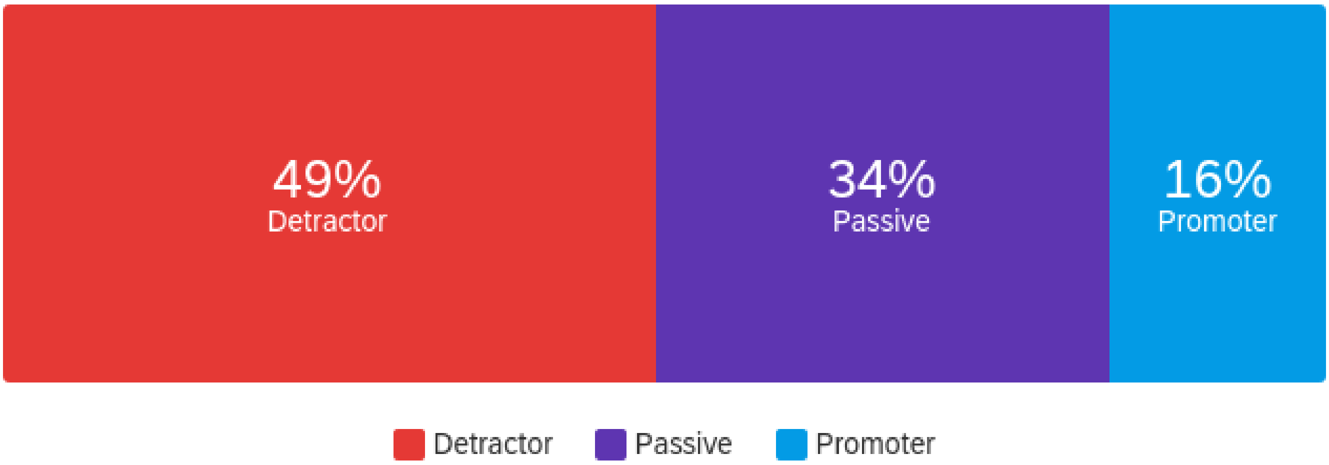
Applications

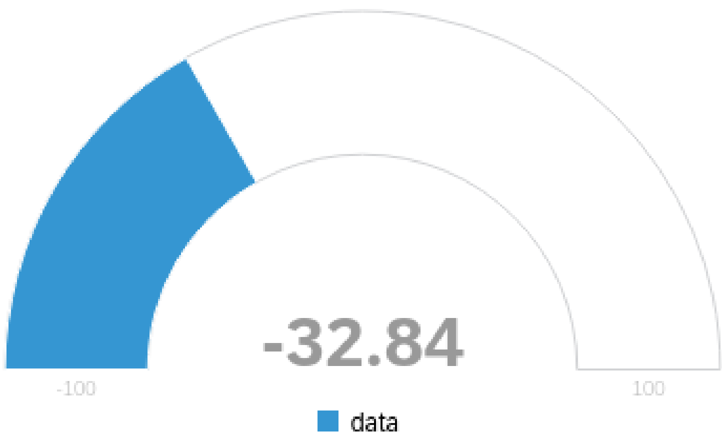
Records directly to the system where the PT can monitor

Monitoring patient's performance

Activity tracker that only control TV or games etc after the required level of activity achieved
More options
Level of activity, duration, intensity of exercise
to see that patient is applying an information that I told him
Availability with reasonable price
Motivation
Test

Q26 - On a scale from 0-10, how likely are you to use these devices in the future?





Q27 - If you have any additional comments please insert them below

If you have any additional comments please insert them below
Would be helpful to understand how the device in question aids ADl achievement
difficult survey to answer for people who don't have experience or knowledge of these devices
Unlikely to use due to where I work
I think devices such as this should be included in trust mandatory training and emphasised more at educational institutions. NHS trusts are usually retcient to purchase these devices due to limited evidence base and limited functionality or communication with the software installed within the trusts. Tackling this difficulty will be key in gaining increased clinician buy in.
I feel it is very exciting but does depend on the individual and if they wish to engage with technology so could be age specific as would be more welcmoed by people who are already interesed in technology
please note, that 'innovative' is very different to 'helpful'. Also where you refer to 'these devices' it is unclear if you are only referring to those you listed. Those participants that took your question to be referring to the technology listed, will have given you very different answers to those that took it to be technology in general - eg those listed will not help those specifically who have had a stroke, however internet technology in general will. i am suprised that this potential squewing of results was not picked up in your pilots.
Likely to Use more as general population become increasingly engaged with technology pre strokes and therefore likely to have and be more familiar with the tech already- improving likelihood of it being used correctly and efficiently.
Funding difficult
Do not have access to these devices in our NHS stroke service
This survey was not very good-not enough information about internet of things...myself and colleagues have never heard of this therefore couldn’t answer a lot of the questions.
I work love to use more devices but always face issues with funding and lack of specialist team support
It fills me with dread to have to learn yet another technology tool. They can be good but don’t replace human interaction
As I don't know about the devices I cant be of much help. Explanation of what they are and do would be helpful. Finance may be an issue; would patients have to buy their own?
your survey does not take in to account if we have no experience of these devices so it was not very clear how to answer
They sound great, haven’t actually used them in practice so hard to comment on some of the questions
In fact, I didn't understanding your title, but I think that you mean there are divorces that can physician can follow and seen if the patient applying your plane in home. If that what do you mean, I think it an amazing idea.

B. Workshop 1 Materials

B.1 Participant information sheet and consent form (English Language)

Internet of things based training system for improving activities of daily living after stroke

Participant information sheet

I am a PhD student (*Fayez Namnaqani*) at Lancaster University and I would like to invite you to take part in a research study about an Internet of things based training system for improving activities of daily living after stroke.

Please take time to read the following information carefully before you decide whether or not you wish to take part.

Background

Performing activities of daily living, like washing, dressing or making a meal can be difficult after a stroke. I want to see if we can help improve these sorts of activities using a technology called the internet of things. The internet of things is about connecting everyday objects in your home via the internet for the purposes of greater ease of use(e.g. the Amazon Echo). I would like to run some workshops to get your opinions and ideas to help with this.

We intend to run 1-2 workshops with you and stroke survivors from the same organisation. Each workshop will last 3 hours and it will include coffee/tea, biscuits and several breaks. The workshops will take place where your group normally meets. The workshops will involve activities, such as talking about your experiences and completing, with the help of the facilitator, a visual journey of your typical day, interspersed with the exploration of daily routines. We may also bring examples of this type of technology for you to comment on. You do not need to know about the internet or technology to participate.

I have approached you because you have experience in stroke and could therefore help me to design a new set of exercises or tasks using the internet and technology which helps people in their rehabilitation from stroke.

I would be very grateful if you would agree to take part in this study.

Your participation in the research project

If you decide to take part in the workshop, your participation is voluntary and you are free to withdraw at any time and leave the workshop, without giving a reason. The workshops will be audio recorded. If you decide to withdraw from the study you will not be able to withdraw your contribution to the discussion once recording has started. The audio recording data will not be made publicly available but the information will be anonymised when used for transcription purposes and data analysis. Some photographs will be taken of activities. The photographs will be of the activities, so it is anticipated that only the backs of people's heads will be visible. However, it may be possible to identify those in the photographs and therefore we cannot guarantee anonymity. Therefore you will be able to choose not to be in the photographs. If you feel uncomfortable thinking about a stroke in the workshop and it may remind you of activities that they can no longer do, we will let you taking a break from the workshop and you can leave if necessary with moral support in order to motivate and restore activity. After the end of the study a summary of the key findings may be submitted for publication in an academic/professional journal or at conferences and will form part of my PhD thesis. Any findings or quotes from the workshop to be used for this will be anonymised (i.e. your name will not be attached to them). The audio recordings, transcripts and photographs will be stored securely on a password protected computer at Lancaster University for 10 years.

Sources of support

We hope that you will enjoy participating in the workshop. If you experience any difficulty or distress on the day, please inform the facilitator.

If you experience any distress following the workshop, the following organisations may be helpful

Stroke Association Phone number: 03033033100 or email: supportercare@stroke.org.uk
Different Strokes Phone number: 03451307172 or email: info@differentstrokes.co.uk

If you are concerned about your health, please contact your GP for advice.

Thank you for your involvement.

If you are interested in the study and/or if you have any questions about this project, please contact:

Name: Fayez Namnaqani,

Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW

Telephone: 07466328533

Email: **f.namnaqani@lancaster.ac.uk**

If you have any concerns or complaints about the research, you can also contact the Head of Department:

Name: Prof Judith Motrram,

Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW

Telephone: 01524- 594395

Email: judith.mottram@lancaster.ac.uk

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.

Thank you for considering your participation in this project.

Lancaster University

CONSENT FORM

Project Title: Internet of things based training system for improving activities of daily living after stroke

Name of Researchers: Fayez Namnaqani

Email: **f.namnaqani@lancaster.ac.uk**

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 had 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, without giving any reason. If I am involved in the workshop and then withdraw my data will remain part of the study.	☐
3. If I am participating in the workshop I understand that any information disclosed within the workshop remains confidential to the group, and I will not discuss the workshop with or in front of anyone who was not involved unless I have the relevant person's express permission	☐
4. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included and every attempt will be made to ensure I will not be identifiable.	☐
5. I understand that if I am in the photographs, there is a possibility I might be identified and I can choose not to appear in the photographs	☐
6. I understand that the workshops will be audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure.	☐
7. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study and all data will be deleted after 10 years.	☐
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 ___________ Day/month/year

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

B2. Participant information sheet and consent form (Arabic Language)

نظام علاجي قائم على إنترنت الأشياء لتحسين أنشطة الحياة اليومية بعد السكتة الدماغية

ورقة معلومات المشروع

أنا طالب دكتوراه (فايز نمنقاني) بجامعة لانكستر وأود أن أدعوكم للمشاركة في دراسة بحثية حول نظام علاجي قائم على إنترنت الاطلاع على المعلومات التالية بعناية قبل أن تقرر ما إذا كنت ترغب في المشاركة أم لا .

المقدمة

قد يكون أداء أنشطة الحياة اليومية مثل الاغتسال وارتداء الملابس أو إعداد وجبة أمرًا صعبًا بعد السكتة الدماغية. أريد أن أرى ما إذا كان بإمكاننا المساعدة في تحسين هذه الأنواع من الأنشطة باستخدام تقنية تسمى إنترنت الأشياء. تدور فكرة إنترنت الأشياء حول توصيل الأشياء اليومية في منزلك عبر الإنترنت لغرض تسهيل الاستخدام (مثل امازون ايكو). أود أن اقوم ببعض ورش العمل للحصول على آرائك وأفكارك للمساعدة في ذلك.

ارغب بإجراء ورش عمل معك و التي قد تستمر كل ورشة ل ٤٥ دقيقة وستتضمن القهوة / الشاي والبسكويت والعديد من فترات الراحة. ستقام ورش العمل في مكان مجتمعي. سوف نتأكد من أن المكان مناسب لك. ستشمل ورش العمل أنشطة ، مثل التحدث عن تجاربك واستكمال رحلة مرئية ليومك المعتاد تتخللها استكشاف الروتين اليومي. قد نقدم أيضًا أمثلة على هذا النوع من التكنولوجيا لتعلق عليها. لا تحتاج إلى معرفة مسبقة عن الإنترنت أو التكنولوجيا للمشاركة.

لقد تواصلت معك لأني اؤمن بانه يمكنك أن تساعدني في تصميم مجموعة جديدة من التمارين أو المهام العلاجية باستخدام الإنترنت والتكنولوجيا التي تساعد الناس في إعادة تأهيلهم من السكتة الدماغية.
سأكون ممتنًا جدًا لو وافقت على المشاركة في هذه الدراسة.

تفاصيل مشاركتك في مشروع البحث

إذا قررت المشاركة في ورشة العمل ، فستكون مشاركتك تطوعية ولك مطلق الحرية في الانسحاب في أي وقت ومغادرة ورشة العمل من دون إبداء أسباب. سيتم تسجيل ورش العمل بالصوت. إذا قررت الانسحاب من الدراسة ، فلن تتمكن من سحب مساهمتك في المناقشة بمجرد بدء التسجيل.

لن يتم الكشف عن بيانات التسجيل الصوتي للجميع ولكن سيتم إخفاء هويتها عند استخدامها لأغراض النسخ وتحليل البيانات. سيتم التقاط بعض الصور للأنشطة. الصور ستكون من الأنشطة ، لذلك من المتوقع أن تظهر فقط ظهور رؤوس الناس. ومع ذلك ، قد يكون من الممكن تحديد و تمييز أولئك الموجودين في الصور ، وبالتالي لا يمكننا ضمان عدم الكشف عن هويتهم. لذلك ستتمكن من اختيار عدم الظهور في الصور. إذا كنت تشعر بعدم الارتياح عند التفكير بالسكتة الدماغية خلال ورشة العمل وقد تشعر بعدم الارتياح في الموقف ، فسنسمح لك بأخذ استراحة من ورشة العمل ويمكنك المغادرة إذا لزم الأمر من أجل التحفيز والاستعادة النشاط. بعد انتهاء الدراسة ، يمكن تقديم ملخص للنتائج الرئيسية للنشر في مجلة أكاديمية / مهنية أو في مؤتمرات وستشكل جزءًا من أطروحة الدكتوراه الخاصة بي. سيتم إخفاء هويتك أو أي نتائج أو اقتباسات من ورش العمل لاستخدامها لهذا الغرض (أي لن يتم إرفاق اسمك بها). سيتم تخزين التسجيلات الصوتية والنصوص والصور بشكل آمن على جهاز كمبيوتر محمي بكلمة مرور في جامعة لانكستر لمدة 10 سنوات.

الدعم النفسي و المعنوي

أتمنى أن تستمتعوا بالمشاركة في الورشة. إذا واجهت أي صعوبة أو مشكلة خلال اليوم ، يرجى إبلاغي مباشرة.
إذا كنت قلقًا بشأن صحتك ، فيرجى الاتصال بطبيبك للحصول على المشورة.

أشكركم على مشاركتكم.

إذا كنت مهتمًا بالدراسة و / أو إذا كان لديك أي أسئلة حول هذا المشروع ، فيرجى الاتصال بـ**:**

الاسم: فايز نمنقاني

العنوان: مبنى **LICA** ، جامعة لانكستر ، بيلريج ، **LA1 4YW**

هاتف: ٠٥٩٠١٨٨٢٨٩

بريد إلكتروني **f.namnaqani@lancaster.ac.uk**

إذا كانت لديك أي مخاوف أو شكاوى بشأن البحث ، يمكنك أيضًا الاتصال برئيس القسم**:**

الاسم: أ/ جوديث موترام

العنوان: مبنى **LICA** ، جامعة لانكستر ، بيلريج ، **LA1 4YW**

التليفون: 594395 -01524

البريد الإلكتروني **judith.mottram@lancaster.ac.uk**

لمزيد من المعلومات حول كيفية ادارة جامعة لانكستر للبيانات الشخصية لأغراض البحث وحقوق البيانات الخاصة بك ، يرجى زيارة صفحة الويب الخاصة بنا www.lancaster.ac.uk/research/data-protection

شكرا لك على اهتمامك بالمشاركة في هذا المشروع.

Lancaster University

نموذج الموافقة

عنوان المشروع: نظام علاجي قائم على إنترنت الأشياء لتحسين أنشطة الحياة اليومية بعد السكتة الدماغية

اسم الباحث: فايز نمنقاني

بريد إلكتروني : **f.namnaqani@lancaster.ac.uk**

يرجى وضع علامة في كل خانة

.9 أؤكد أنني قد قرأت وفهمت ورقة المعلومات الخاصة بالدراسة أعلاه. لقد أتيحت لي الفرصة للنظر في المعلومات وطرح الأسئلة وتمت الإجابة على هذه الأسئلة بشكل مرضي.	☐
.10 أفهم أن مشاركتي تطوعية وأنني حر في الانسحاب في أي وقت أثناء مشاركتي في هذه الدراسة ، دون إبداء أي سبب. إذا بدأت المشاركة في ورشة العمل ثم انسحبت ، فستظل بياناتك جزءًا من الدراسة.	☐
.11 إذا كنت مشارك في ورشة العمل ، فأنا أفهم أن أي معلومات يتم الكشف عنها في ورشة العمل تظل سرية للمجموعة ، ولن أناقش ورشة العمل مع أو أمام أي شخص غير مشارك ما لم يكن لدي إذن صريح من الشخص المعني.	☐
.12 أفهم أن أي معلومات قدمتها قد يتم استخدامها في التقارير المستقبلية أو المقالات الأكاديمية أو المنشورات أو العروض التقديمية من قبل الباحث / الباحثين ، ولكن لن يتم تضمين معلوماتي الشخصية وسيتم بذل كل محاولة للتأكد من أن لن يتم التعرف علي هويتي.	☐
.13 أفهم أنه إذا كنت في الصور ، فهناك احتمال أن يتم التعرف عليّ ويمكنني اختيار عدم الظهور في الصور.	☐
.14 أدرك أن ورش العمل سيتم تسجيلها ونسخها بالصوت وأن البيانات ستتم حمايتها على الأجهزة المشفرة والحفاظ عليها آمنة.	☐
.15 أفهم أنه سيتم الاحتفاظ بالبيانات وفقًا لإرشادات الجامعة لمدة لا تقل عن 10 سنوات بعد انتهاء الدراسة وسيتم حذف جميع البيانات بعد 10 سنوات.	☐
.16 أوافق على المشاركة في الدراسة أعلاه.	☐

التوقيع ________________ التاريخ ________________ اسم المشترك ________________

اود ان أؤكد أنه تم منح المشارك فرصة لطرح أسئلة حول الدراسة ، وتم الرد على جميع الأسئلة التي طرحها المشارك بشكل صحيح وبقدر ما أستطيع. أؤكد أن الشخص لم يُجبر على إعطاء الموافقة ، وأن الموافقة تم منحها بحرية وتطوعية

توقيع الباحث / الشخص الذي أخذ الموافقة ________________

التاريخ ____________ يوم/ شهر/ سنة

سيتم تسليم نسخة واحدة من هذا النموذج إلى المشارك وسيتم الاحتفاظ بالأصل في ملفات الباحث في جامعة لانكستر

B3. Workshop 1 process and responses

Research process

This research contributes to the body of knowledge on evidence-based practice by synthesizing the expertise and experiences of stroke participants to achieve optimal outcomes. The workshops approach was selected for this study as it enables a systematic gathering of information on current techniques for performing activities of daily living after stroke. It is worth noting that the workshops were conducted at the Abdullatif Rehabilitation Centre, which provided an ideal setting for the collection of data from stroke participants.

Before watching videos:

1.What is your impression about using IOT?

2.Do you think that the IOT could help you?

3.How do you think these IOT might help in taking care of ADLs?

4.Explain to us how easy or difficult these IOT devices were to help in doing your tasks?

After watching videos:

5.Explain to us how easy or difficult these connected devices were to use?

6.How do you think these Internet of Things (IoT) or connected devices might help you to take care of your health? (Why? Why not?)

7.What features of these connected devices did you like? What features did you not like?

8.What is your impression about the exercise section of these Internet of Things (IoT) or connected devices?

9.Which, if any, of these Internet of Things (IoT) or connected devices have you heard of?

- Connected inhalers
- Depression-fighting Apple Watch app
- Ingestible sensors
- Open APS - closed-loop insulin delivery
- Continuous medication monitoring (CMM) system
- Activity trackers
- Coagulation testing
- Others (examples)

10. What do you like focusing on the most?

11.Challenges of Doing ADLs with Time Line

12.How easy or difficult was project was to understand?

13.Was there anything you didn't like or didn't understand in the workshop?

Table 1:

Participant A	Participant B	Participant C	Name of participant	
CVA left hemiplegia	CVA left hemiplegia	Right ischemic hemiplegia	Diagnosis	
68	71	62	Age	
I need help to use it	It's perfect	I like it	Q.1	Questions
Control diabetes & blood pressure	A good helper	Reduce the time of management	Q.2	
Moving around without help	Could help in walking & doing activities	I hope it helps me	Q.3	
I need help to use it	Easy to use	I need help from my family to use it	Q.4	
I think it's easy to use	Easy to use	Easy to use	Q.5	
Simplify doing task	Can use it any where	Can take it any where	Q.6	
*Saving traveling cost *Could be hard to use because it's technology	*I Can take it any where because I have caregiver all time *Difficult to use if no one with me.	No need for appointments	Q.7	
Feeling excited to do tasks	Enjoying the time & don't lose their time	Similar to games	Q.8	
Smart watches	Nothing	Open APS - closed-loop insulin delivery	Q.9	
Focus on controlling diabetes & blood pressure	Focus on walking	Focus on upper limb more than lower limb	Q.10	
*Moving from bed to toilet	*Moving around *Missing to be with his family	*Moving from bed to toilet Morning	Q.11	

*Checking blood sugar & pressure		*Doing the rehab programme *Moving around			
Setting on chair or lying in bed for long time	Sleeping discomfort	*Sleeping discomfort *Moving around	Noon		
*Moving around *Sleeping discomfort	*Missing the social life *Moving around *Sleeping discomfort	*Setting on chair for long time *Moving around *Sleeping discomfort	Evening		
Good idea	Easy to understand	Easy project		Q.12	
-	Everything was clear	-		Q.13	

Table 2:

Participant D	**Participant E**	**Participant F**	**Name of participant**
CVA left hemiplegia	CVA left hemiplegia	Right ischemic hemiplegia	Diagnosis

70	76	62		Age	
Help me in my life	I dream to be better	Sure will help me		Q.1	
Control blood pressure	Simplify the life	A good helper		Q.2	
*Easily to follow up *Saving time	Could help in walking & to be independent	I hope it to be independent		Q.3	
Easy to use	Needs to be more accessible & more clarification	Could not help me because I'm lazy person		Q.4	
Easy to use	Easy to use	Easy to use		Q.5	
Good idea to simplify people life	Can use & take it any where	*Simplify people life *Can take it any where		Q.6	
*Easy to apply *Saving traveling cost	*Focus on affected side *Difficult to use if no one with me.	*Could be hard to use because it's technology		Q.7	
Keep improving progress	It will improve ADL	Prefer rehab centres more than devices		Q.8	
Nothing	*Smart phones *Robotic exoskeletons	Nothing		Q.9	Questions
	*Focus on walking *To be independent	Focus on walking		Q.10	
Moving from bed to toilet	*Sleeping discomfort * Using the toilet	*Moving from bed to chair *Changing the nappy	Morning		
I'm lazy to do rehab program	*Missing social life	*Being independent in everything *Moving around	Noon	Q.11	
*Moving around *Sleeping discomfort *Getting tired	*Moving around *Sleeping discomfort	*Being independent in everything	Evening		

		*Sleeping discomfort			
Easy project	Easy to understand	Easy to understand		Q.12	
-	Everything was clear	-		Q.13	

Table 3:

Participant G	**Participant H**	**Participant I**	**Name of participant**	
CVA left hemiplegia	Left ischemic hemiplegia	CVA right hemiplegia	Diagnosis	
65	58	79	Age	
I hope it helps me	It's perfect	It's like a dream	Q.1	Questions
*Restoring activities *Control diabetes & blood pressure	*A good helper *Enhance muscles power	*Management of restoring activities *Control diabetes & blood pressure	Q.2	
Saving time & effort	Could help in walking & doing activities	To be independent	Q.3	
I need help to use it	Easy to use	I need help to use it	Q.4	
It's a bit complicated	Easy to use	It's a bit complicated	Q.5	
Simplify doing task	Can use it any where	Help me in doing task	Q.6	
*Saving traveling cost *Could be hard to use because it's technology	I Can take it & use it any where	*I Can take it any where because I have caregiver all time *Difficult to use if no one with me.	Q.7	
Keep improving progress with need of rehab centre	Enjoying the time in dong tasks	Give me motivation to do tasks	Q.8	

Smart watches	Smart watches	Open APS - closed-loop insulin delivery		Q.9	
Focus on controlling diabetes & blood pressure *Focus on restoring activities	*Focus on walking *Enhance muscle power	Focus on restoring activities		Q.10	
*Moving from bed to toilet *Checking blood sugar & pressure	*Moving from bed to toilet *Feeling weak & lazy	*Moving from bed to toilet *Doing the rehab programme	Morning	Q.11	
*Setting on chair or lying in bed for long time *Missing the social life *Moving around	*Missing the social life *Moving around	*Setting on chair or lying in bed for long time	Noon		
Sleeping discomfort	Sleeping discomfort	*Setting on chair for long time *Sleeping discomfort	Evening		
Good idea & easy project	Easy to understand	Easy project		Q.12	
-	Everything was clear	-		Q.13	

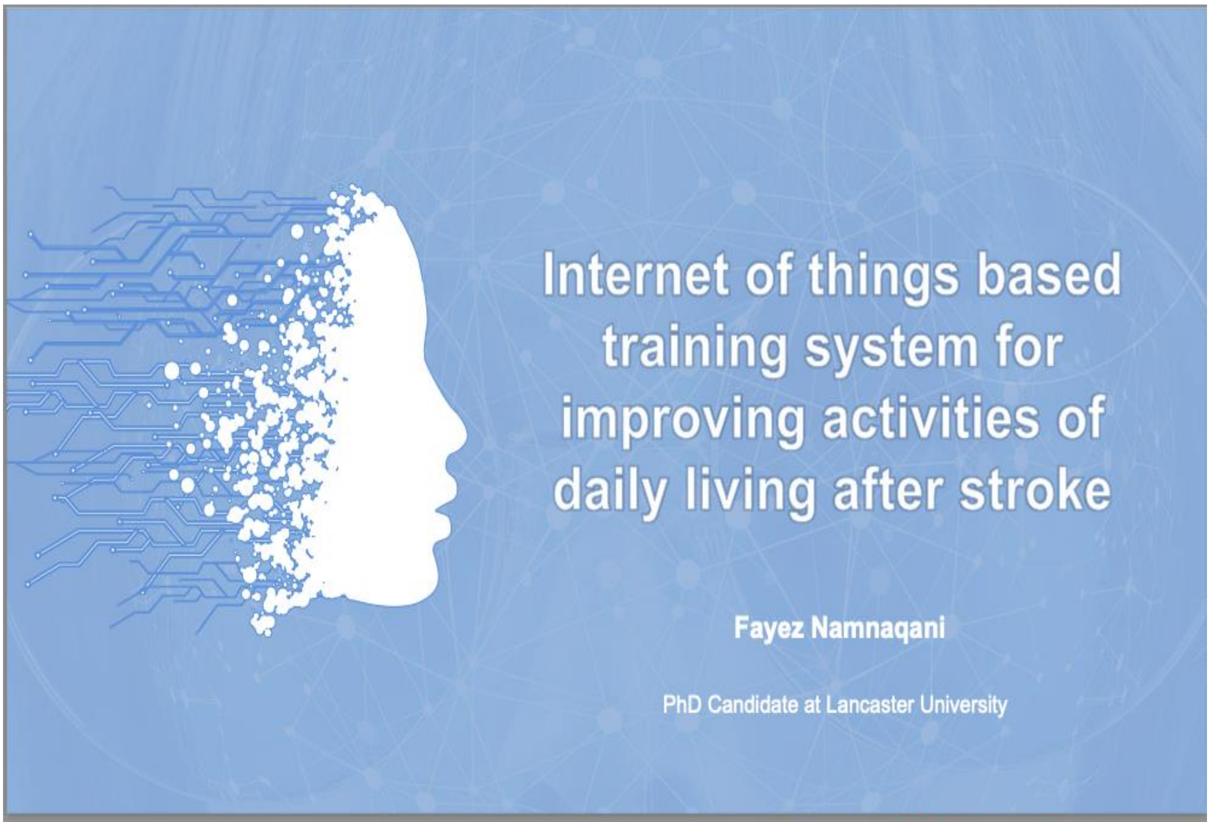
Table 4:

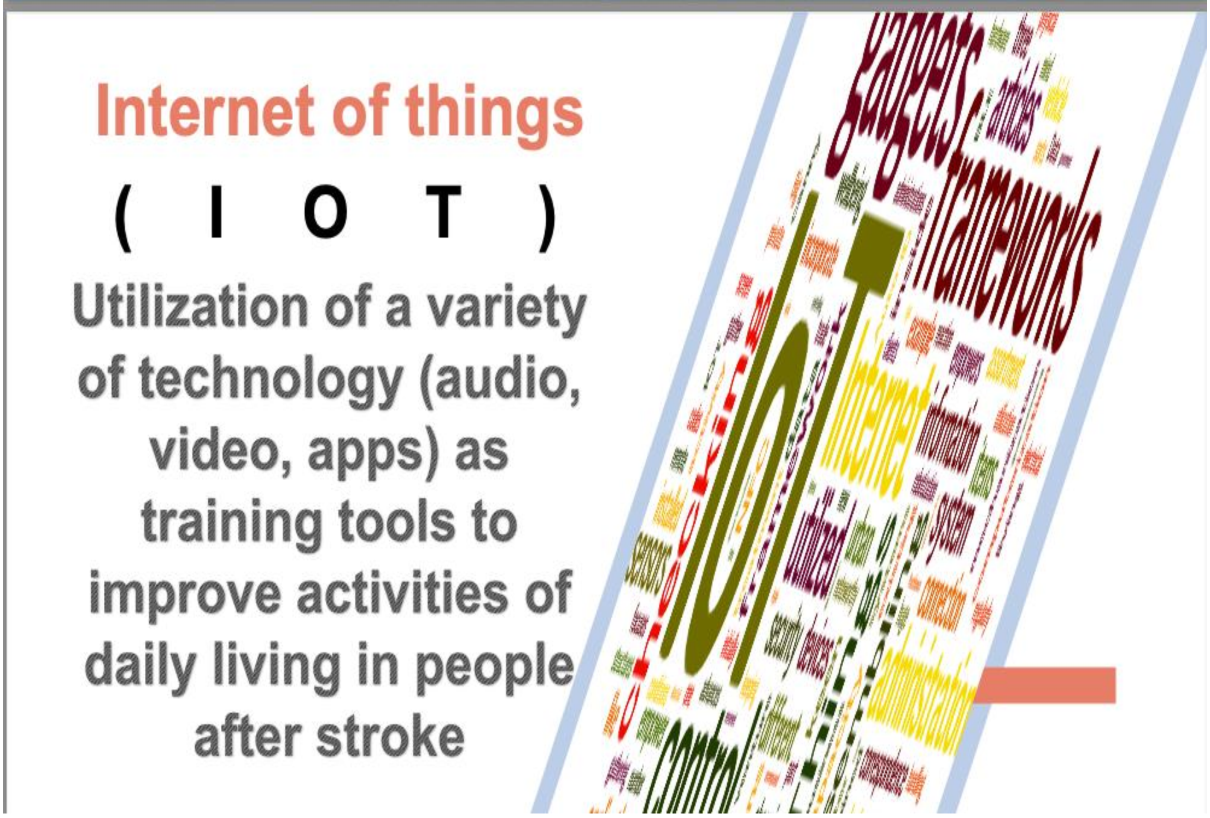
Participant J	Participant K	Participant L	Name of participant
CVA left hemiplegia	CVA left hemiplegia	CVA right hemiplegia	Diagnosis
51	88	73	Age

Sure will help me	Help me in my life	I hope it helps me		Q.1	Questions
Control blood pressure & sugar Enhance muscle power & mobility	Control blood pressure & sugar	Control blood pressure		Q.2	
*Easily to follow up *Saving time	To be independent with the help of these devices	I hope to be independent		Q.3	
Easy to use	I need help to use it	Make it easier		Q.4	
Easy to use	It's a bit complicated	It's a bit complicated		Q.5	
Good idea to simplify people life	Can take it & use it any where with help of others	*Simplify people life *Can take it any where with help of others		Q.6	
*Easy to apply *Saving time & effort	*Focus on restoring ADL *Difficult to use if no one with me.	*Could be hard to use because it's technology		Q.7	
*Keep improving progress *Similar to games	It will improve ADL	Can combine with rehab centres program		Q.8	
Smart watches	Nothing	Nothing		Q.9	
*Focus on walking *Enhance muscle power	*Focus on walking *To be independent	*Focus on walking *To be independent		Q.10	
Moving from bed to toilet	*Moving from bed to chair *Changing the nappy	*Moving from bed to chair *Changing the nappy	Morning	Q.11	
*I'm lazy to do rehab program *Missing social life *Moving around	*Missing social life	*Being independent in everything *Moving around	Noon		
*Moving around *Sleeping discomfort *Getting tired	*Moving around *Sleeping discomfort	*Missing social life *Sleeping discomfort	Evening		

Easy project	Easy to understand	Easy to understand	Q.12	
Everything was clear	Everything was clear	-	Q.13	

B4. Workshop 1 Presentation





GOALS

Improve health status

Increase access to health care

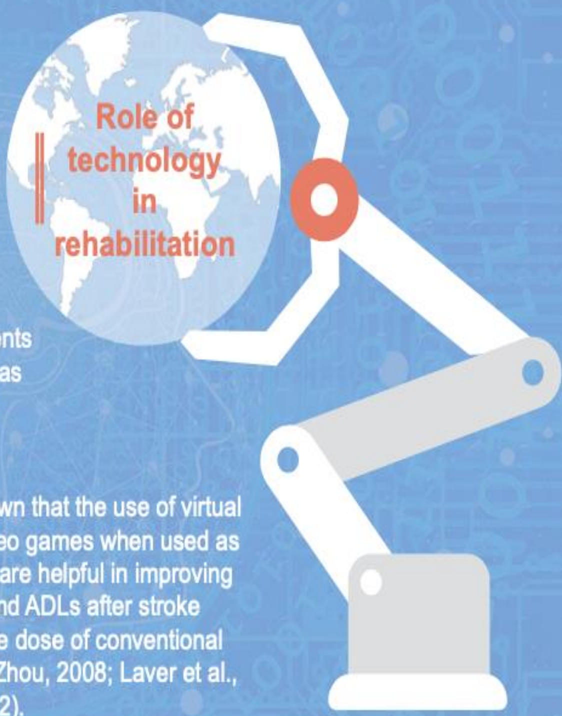
Reduce health disparities

Improve health care delivery

Role of rehabilitation

- Physical functions and activities of daily living (ADLs) are often affected by stroke, which is major cause of chronic impaired physical function.
- In order to improve basic mobility functions and ADL performance, an intensive rehabilitation plan must be developed during the stroke recovery period.
- only 5% to 20% of people reach full recovery (Nakayama et al., 1994).

Role of technology in rehabilitation



Recently, motion capture systems have expanded their scope in the development of numerous medical applications. For example, increased attention to human movement tracking systems for patients and elderly in hospitals and at home for obtaining more efficient rehabilitation treatments and the construction of remote monitoring networks (Masuda et al., 2005).

Recently, the use of video games for the patients rehabilitation with a wide range of ailments has made rehabilitation tasks more enjoyable.

Several studies have shown that the use of virtual reality and interactive video games when used as an adjunct to usual care are helpful in improving upper limb function and ADLs after stroke compared with the same dose of conventional therapy (Zhang, Hu and Zhou, 2008; Laver et al., 2012).

Examples of IOT devices in the health field

There is a need around the world for transforming healthcare from a hospital-centered system to a person-centered environment, with a focus on disease management among citizens due to ***the rising of health care costs***, ***the increase in elderly population, and the spread of many chronic diseases***.

Robotic exoskeletons

They are wearable, battery-powered robots attached to user's clothing, enabling people to achieve mobility, strength and / or endurance.

Smart socks

This technique helps to monitor walking activity even when it requires slow pace, short steps or walking aids.

Jolt Concussion Sensor

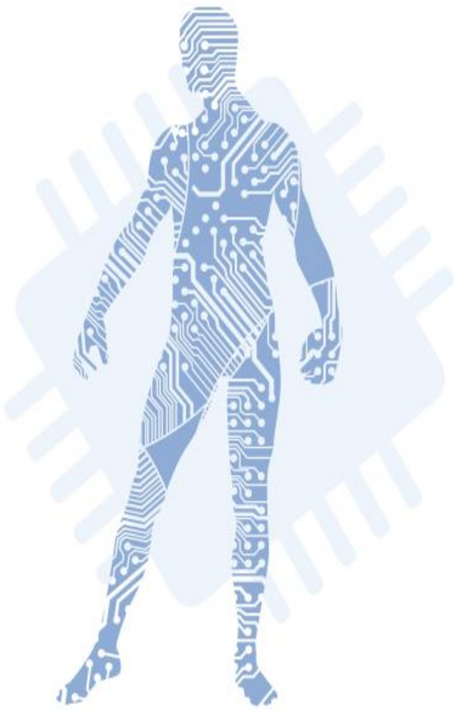
it detects a significant impact that might cause a concussion which vibrates to alert the player.

Withings

it is responsible for measuring the blood pressure and sending measurement data to the remote server and inform the patient with the progress of measurements.

Aims and Research Objectives

The aim of this PhD Thesis is to see the effectiveness of Internet of things (IOT) as training tools for improving activities of daily living in people after stroke.

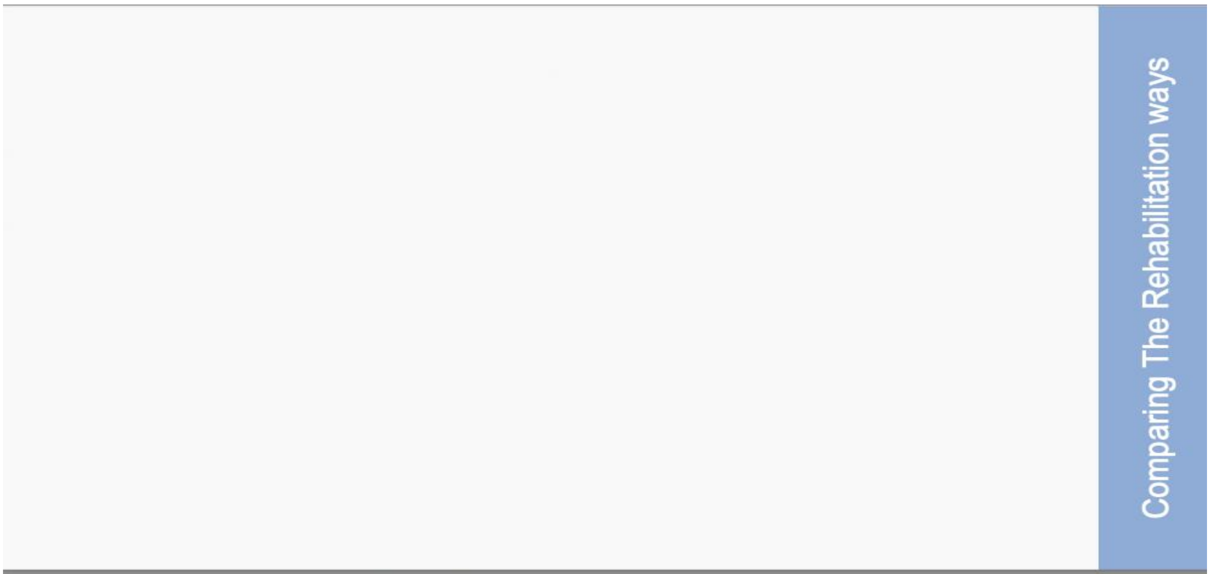


01 What is your impression about using IOT?

02 Do you think that the IOT could help you?

03 How do you think these IOT might help in taking care of ADLs?

04 Explain to us how easy or difficult these IOT devices were to help in doing your tasks?

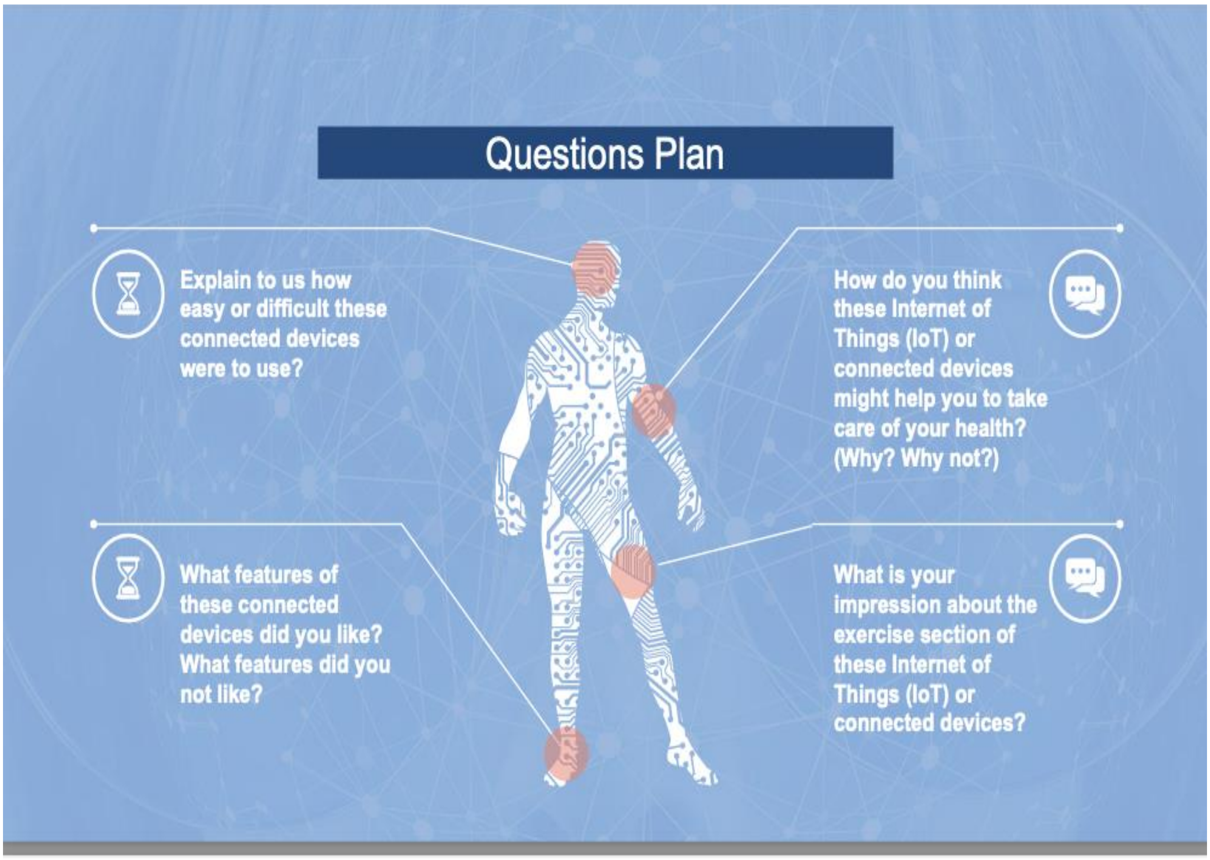


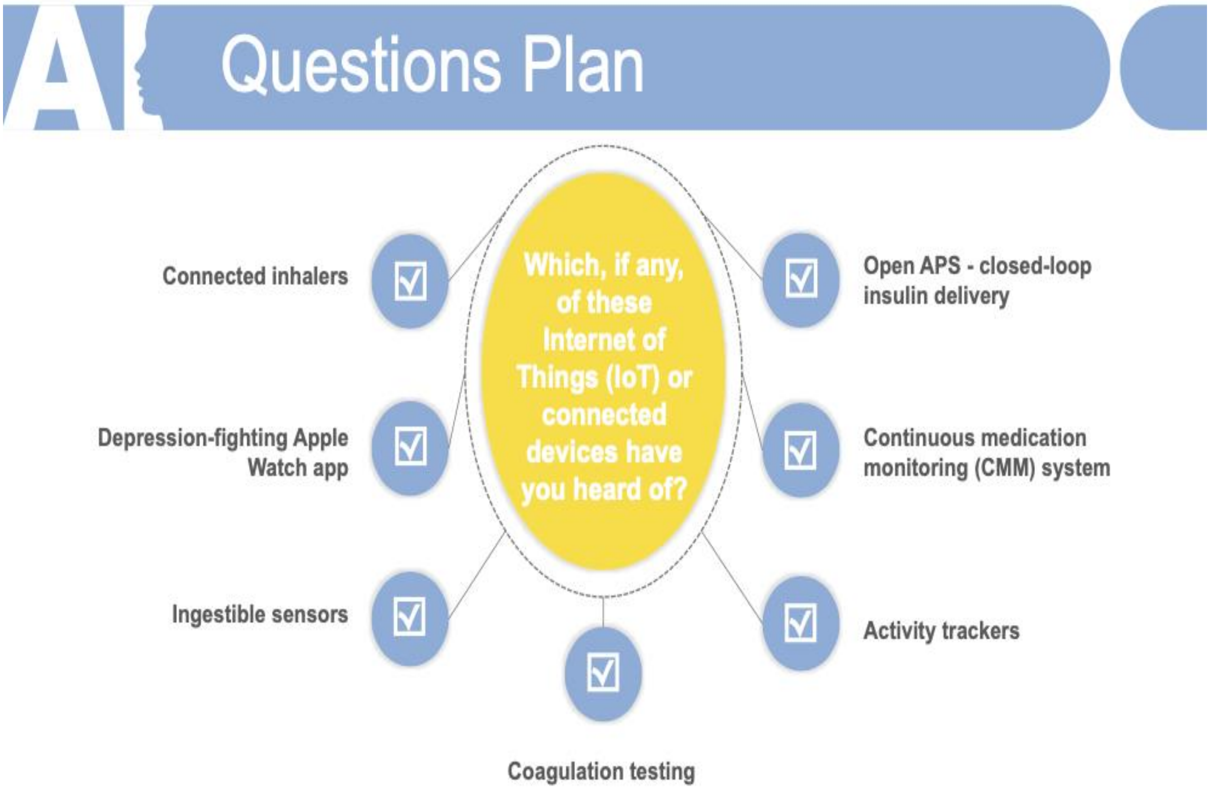
Video Clips on Rehabilitation Techniques
Video Clip 1: Comparing Rehabilitation Approaches
This video demonstrates a comparative analysis of various rehabilitation methods, highlighting their strengths and limitations in stroke recovery.

- Access the video here: [https://youtu.be/p9iK9_kmsf4]

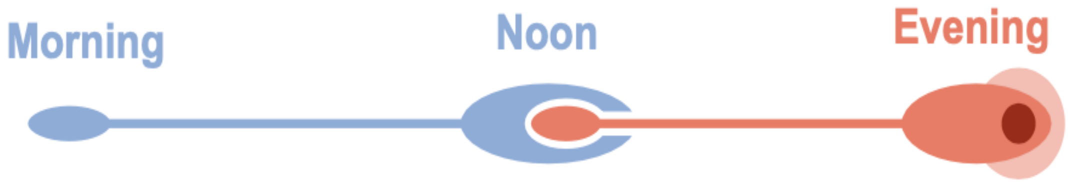
Video Clip 2: Rehabilitation Techniques
This video explores specific rehabilitation techniques utilized in stroke recovery, focusing on their practical applications and effectiveness.

- Access the video here: [https://youtu.be/vGHKT28uDNs]


Questions Plan
Explain to us how easy or difficult these connected devices were to use?
How do you think these Internet of Things (IoT) or connected devices might help you to take care of your health? (Why? Why not?)
What features of these connected devices did you like? What features did you not like?
What is your impression about the exercise section of these Internet of Things (IoT) or connected devices?

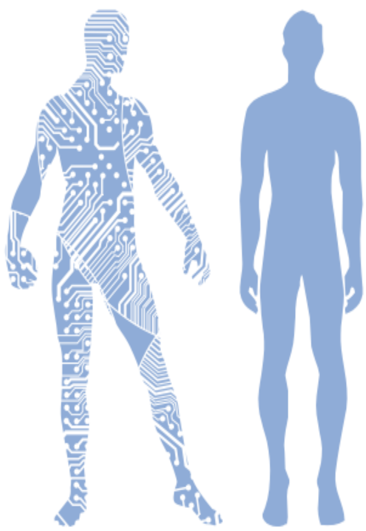

Questions Plan
Which, if any, of these Internet of Things (IoT) or connected devices have you heard of?
Connected inhalers
Open APS - closed-loop insulin delivery
Depression-fighting Apple Watch app
Continuous medication monitoring (CMM) system
Ingestible sensors
Activity trackers
Coagulation testing

Challenges of Doing ADLs with Time Line



AI Project assessment

How easy or difficult was project was to understand?



Was there anything you didn't like or didn't understand in the workshop?

C. Workshop 2 Materials

C1. Participant information sheet and consent form (English Language)

Internet of things based training system for improving activities of daily living after stroke

Participant information sheet

I am a PhD student (*Fayez Namnaqani*) at Lancaster University and I would like to invite you to take part in a research study about an Internet of things based training system for improving activities of daily living after stroke.

Please take time to read the following information carefully before you decide whether or not you wish to take part.

Background

Performing activities of daily living, like washing, dressing or making a meal can be difficult after a stroke. I want to see if we can help improve these sorts of activities using a technology called the internet of things. The internet of things is about connecting everyday objects in your home via the internet for the purposes of greater ease of use(e.g. the Amazon Echo). I would like to run some workshops to get your opinions and ideas to help with this.

We intend to run 1-2 workshops with you and stroke survivors from the same organisation. Each workshop will last 3 hours and it will include coffee/tea, biscuits and several breaks. The workshops will take place where your group normally meets. The workshops will involve activities, such as talking about your experiences and completing, with the help of the facilitator, a visual journey of your typical day, interspersed with the exploration of daily routines. We may also bring examples of this type of technology for you to comment on. You do not need to know about the internet or technology to participate.

I have approached you because you have experience in stroke and could therefore help me to design a new set of exercises or tasks using the internet and technology which helps people in their rehabilitation from stroke.

I would be very grateful if you would agree to take part in this study.

Your participation in the research project

If you decide to take part in the workshop, your participation is voluntary and you are free to withdraw at any time and leave the workshop, without giving a reason. The workshops will be audio recorded. If you decide to withdraw from the study you will not be able to withdraw your contribution to the discussion once recording has started. The audio recording data will not be made publicly available but the information will be anonymised when used for transcription purposes and data analysis. Some photographs will be taken of activities. The photographs will be of the activities, so it is anticipated that only the backs of people's heads will be visible. However, it may be possible to identify those in the photographs and therefore we cannot guarantee anonymity. Therefore you will be able to choose not to be in the photographs. If you feel uncomfortable thinking about a stroke in the workshop and it may remind you of activities that they can no longer do, we will let you taking a break from the workshop and you can leave if necessary with moral support in order to motivate and restore activity. After the end of the study a summary of the key findings may be submitted for publication in an academic/professional journal or at conferences and will form part of my PhD thesis. Any findings or quotes from the workshop to be used for this will be anonymised (i.e. your name will not be attached to them). The audio recordings, transcripts and photographs will be stored securely on a password protected computer at Lancaster University for 10 years.

Sources of support

We hope that you will enjoy participating in the workshop. If you experience any difficulty or distress on the day, please inform the facilitator.

If you experience any distress following the workshop, the following organisations may be helpful

Stroke Association Phone number: 03033033100 or email: supportercare@stroke.org.uk
Different Strokes Phone number: 03451307172 or email: info@differentstrokes.co.uk

If you are concerned about your health, please contact your GP for advice.

Thank you for your involvement.

If you are interested in the study and/or if you have any questions about this project, please contact:

Name: Fayez Namnaqani,

Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW

Telephone: 07466328533

Email: **f.namnaqani@lancaster.ac.uk**

If you have any concerns or complaints about the research, you can also contact the Head of Department:

Name: Prof Judith Motrram,

Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW

Telephone: 01524- 594395

Email: judith.mottram@lancaster.ac.uk

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.

Thank you for considering your participation in this project.

Lancaster University

CONSENT FORM

Project Title: Internet of things based training system for improving activities of daily living after stroke

Name of Researchers: Fayez Namnaqani

Email: **f.namnaqani@lancaster.ac.uk**

Please tick each box

17. 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 had these answered satisfactorily	☐
18. I understand that my participation is voluntary and that I am free to withdraw at any time during my participation in this study, without giving any reason. If I am involved in the workshop and then withdraw my data will remain part of the study.	☐
19. If I am participating in the workshop I understand that any information disclosed within the workshop remains confidential to the group, and I will not discuss the workshop with or in front of anyone who was not involved unless I have the relevant person's express permission	☐
20. I understand that any information given by me may be used in future reports, academic articles, publications or presentations by the researcher/s, but my personal information will not be included and every attempt will be made to ensure I will not be identifiable.	☐
21. I understand that if I am in the photographs, there is a possibility I might be identified and I can choose not to appear in the photographs	☐
22. I understand that the workshops will be audio-recorded and transcribed and that data will be protected on encrypted devices and kept secure.	☐
23. I understand that data will be kept according to University guidelines for a minimum of 10 years after the end of the study and all data will be deleted after 10 years.	☐
24. 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 ___________ Day/month/year

One copy of this form will be given to the participant and the original kept in the files of the researcher at Lancaster University

C2. Participant information sheet and consent form (Arabic Language)

نظام علاجي قائم على إنترنت الأشياء لتحسين أنشطة الحياة اليومية بعد السكتة الدماغية

ورقة معلومات المشروع

أنا طالب دكتوراه (فايز نمنقاني) بجامعة لانكستر وأود أن أدعوكم للمشاركة في دراسة بحثية حول نظام علاجي قائم على إنترنت الاطلاع على المعلومات التالية بعناية قبل أن تقرر ما إذا كنت ترغب في المشاركة أم لا .

المقدمة

قد يكون أداء أنشطة الحياة اليومية مثل الاغتسال وارتداء الملابس أو إعداد وجبة أمرًا صعبًا بعد السكتة الدماغية. أريد أن أرى ما إذا كان بإمكاننا المساعدة في تحسين هذه الأنواع من الأنشطة باستخدام تقنية تسمى إنترنت الأشياء. تدور فكرة إنترنت الأشياء حول توصيل الأشياء اليومية في منزلك عبر الإنترنت لغرض تسهيل الاستخدام (مثل امازون ايكو). أود أن اقوم ببعض ورش العمل للحصول على آرائك وأفكارك للمساعدة في ذلك.

ارغب بإجراء ورش عمل معك و التي قد تستمر كل ورشة ل ٤٥ دقيقة وستتضمن القهوة / الشاي والبسكويت والعديد من فترات الراحة. ستقام ورش العمل في مكان مجتمعي. سوف نتأكد من أن المكان مناسب لك. ستشمل ورش العمل أنشطة ، مثل التحدث عن تجاربك واستكمال رحلة مرئية ليومك المعتاد تتخللها استكشاف الروتين اليومي. قد نقدم أيضًا أمثلة على هذا النوع من التكنولوجيا لتعلق عليها. لا تحتاج إلى معرفة مسبقة عن الإنترنت أو التكنولوجيا للمشاركة.

لقد تواصلت معك لأني اؤمن بانه يمكنك أن تساعدني في تصميم مجموعة جديدة من التمارين أو المهام العلاجية باستخدام الإنترنت والتكنولوجيا التي تساعد الناس في إعادة تأهيلهم من السكتة الدماغية.
سأكون ممتنًا جدًا لو وافقت على المشاركة في هذه الدراسة.

تفاصيل مشاركتك في مشروع البحث

إذا قررت المشاركة في ورشة العمل ، فستكون مشاركتك تطوعية ولك مطلق الحرية في الانسحاب في أي وقت ومغادرة ورشة العمل من دون إبداء أسباب. سيتم تسجيل ورش العمل بالصوت. إذا قررت الانسحاب من الدراسة ، فلن تتمكن من سحب مساهمتك في المناقشة بمجرد بدء التسجيل.

لن يتم الكشف عن بيانات التسجيل الصوتي للجميع ولكن سيتم إخفاء هويتها عند استخدامها لأغراض النسخ وتحليل البيانات. سيتم التقاط بعض الصور للأنشطة. الصور ستكون من الأنشطة ، لذلك من المتوقع أن تظهر فقط ظهور رؤوس الناس. ومع ذلك ، قد يكون من الممكن تحديد و تمييز أولئك الموجودين في الصور ، وبالتالي لا يمكننا ضمان عدم الكشف عن هويتهم. لذلك ستتمكن من اختيار عدم الظهور في الصور. إذا كنت تشعر بعدم الارتياح عند التفكير بالسكتة الدماغية خلال ورشة العمل وقد تشعر بعدم الارتياح في الموقف ، فسنسمح لك بأخذ استراحة من ورشة العمل ويمكنك المغادرة إذا لزم الأمر من أجل التحفيز والاستعادة النشاط. بعد انتهاء الدراسة ، يمكن تقديم ملخص للنتائج الرئيسية للنشر في مجلة أكاديمية / مهنية أو في مؤتمرات وستشكل جزءًا من أطروحة الدكتوراه الخاصة بي. سيتم إخفاء هويتك أو أي نتائج أو اقتباسات من ورش العمل لاستخدامها لهذا الغرض (أي لن يتم إرفاق اسمك بها). سيتم تخزين التسجيلات الصوتية والنصوص والصور بشكل آمن على جهاز كمبيوتر محمي بكلمة مرور في جامعة لانكستر لمدة 10 سنوات.

الدعم النفسي و المعنوي

أتمنى أن تستمتعوا بالمشاركة في الورشة. إذا واجهت أي صعوبة أو مشكلة خلال اليوم ، يرجى إبلاغي مباشرة.
إذا كنت قلقًا بشأن صحتك ، فيرجى الاتصال بطبيبك للحصول على المشورة.

أشكركم على مشاركتكم.

إذا كنت مهتمًا بالدراسة و / أو إذا كان لديك أي أسئلة حول هذا المشروع ، فيرجى الاتصال بـ:

الاسم: فايز نمنقاني

العنوان: مبنى **LICA** ، جامعة لانكستر ، بيلريج ، **LA1 4YW**

هاتف: ٠٥٩٠١٨٨٢٨٩

بريد إلكتروني **f.namnaqani@lancaster.ac.uk**

إذا كانت لديك أي مخاوف أو شكاوى بشأن البحث ، يمكنك أيضًا الاتصال برئيس القسم:

الاسم: أ/ جوديث موترام

العنوان: مبنى **LICA** ، جامعة لانكستر ، بيلريج ، **LA1 4YW**

التليفون: 01524- 594395

البريد الإلكتروني **judith.mottram@lancaster.ac.uk**

لمزيد من المعلومات حول كيفية ادارة جامعة لانكستر للبيانات الشخصية لأغراض البحث وحقوق البيانات الخاصة بك ، يرجى زيارة صفحة الويب الخاصة بنا www.lancaster.ac.uk/research/data-protection

شكرا لك على اهتمامك بالمشاركة في هذا المشروع.

نموذج الموافقة

عنوان المشروع: نظام علاجي قائم على إنترنت الأشياء لتحسين أنشطة الحياة اليومية بعد السكتة الدماغية

اسم الباحث: فايز نمنقاني

بريد إلكتروني : **f.namnaqani@lancaster.ac.uk**

يرجى وضع علامة في كل خانة

25. أؤكد أنني قد قرأت وفهمت ورقة المعلومات الخاصة بالدراسة أعلاه. لقد أتيحت لي الفرصة للنظر في المعلومات وطرح الأسئلة وتمت الإجابة على هذه الأسئلة بشكل مرضي.	☐
26. أفهم أن مشاركتي تطوعية وأنني حر في الانسحاب في أي وقت أثناء مشاركتي في هذه الدراسة ، دون إبداء أي سبب. إذا بدأت المشاركة في ورشة العمل ثم انسحبت ، فستظل بياناتك جزءًا من الدراسة.	☐
27. إذا كنت مشارك في ورشة العمل ، فأنا أفهم أن أي معلومات يتم الكشف عنها في ورشة العمل تظل سرية للمجموعة ، ولن أناقش ورشة العمل مع أو أمام أي شخص غير مشارك ما لم يكن لدي إذن صريح من الشخص المعني.	☐
28. أفهم أن أي معلومات قدمتها قد يتم استخدامها في التقارير المستقبلية أو المقالات الأكاديمية أو المنشورات أو العروض التقديمية من قبل الباحث / الباحثين ، ولكن لن يتم تضمين معلوماتي الشخصية وسيتم بذل كل محاولة للتأكد من أن لن يتم التعرف علي هويتي.	☐
29. أفهم أنه إذا كنت في الصور ، فهناك احتمال أن يتم التعرف عليّ ويمكنني اختيار عدم الظهور في الصور.	☐
30. أدرك أن ورش العمل سيتم تسجيلها ونسخها بالصوت وأن البيانات ستتم حمايتها على الأجهزة المشفرة والحفاظ عليها آمنة.	☐
31. أفهم أنه سيتم الاحتفاظ بالبيانات وفقًا لإرشادات الجامعة لمدة لا تقل عن 10 سنوات بعد انتهاء الدراسة وسيتم حذف جميع البيانات بعد 10 سنوات.	☐
32. أوافق على المشاركة في الدراسة أعلاه.	☐

التوقيع ____________ التاريخ ____________ اسم المشترك ____________

اود ان أؤكد أنه تم منح المشارك فرصة لطرح أسئلة حول الدراسة ، وتم الرد على جميع الأسئلة التي طرحها المشارك بشكل صحيح وبقدر ما أستطيع. أؤكد أن الشخص لم يُجبر على إعطاء الموافقة ، وأن الموافقة تم منحها بحرية وتطوعية

توقيع الباحث / الشخص الذي أخذ الموافقة ____________

التاريخ ____________ يوم/ شهر/ سنة

سيتم تسليم نسخة واحدة من هذا النموذج إلى المشارك وسيتم الاحتفاظ بالأصل في ملفات الباحث في جامعة لانكستر

C3. Workshop 2 process and responses

Research process

This research significantly advances the understanding of evidence-based practices in stroke rehabilitation by integrating the insights and experiences of stroke survivors, aiming to enhance recovery outcomes. By employing a workshop methodology, this study methodically collected detailed information on the current strategies employed in performing daily activities post-stroke. These workshops were strategically held at the Abdullatif Rehabilitation Centre, providing a conducive environment for gathering valuable insights from individuals who have experienced a stroke. The study is structured in two distinct phases to ensure a comprehensive understanding of the participants' experiences and responses to technological interventions. Initially, participants were asked about their experiences with stroke and their familiarity with existing Internet of Things (IoT) devices before being introduced to specific examples and a detailed presentation. This initial phase aimed to establish a baseline understanding of the participants' knowledge and experiences. Following this, the second phase introduced the participants to various examples of IoT devices and a presentation that elucidated the usage of these devices in the context of medical rehabilitation for stroke survivors. Notably, I demonstrated the application of these devices personally, ensuring that the participants could directly observe their potential benefits. The responses collected from the participants, both before and after the presentation and demonstrations, were meticulously recorded and are presented in the tables. This dual-phase approach not only allowed for the assessment of the immediate impact of the presentation and device demonstrations on participants' perceptions and knowledge but also provided a structured framework for understanding the potential of IoT devices in enhancing stroke rehabilitation practices. The inclusion of personal demonstrations further enriched the participants' learning experience, offering a practical perspective on how technology can be leveraged to improve quality of life post-stroke.

Before watching the show:

1.Could you please share your thoughts on the utilization of IoT (Internet of Things) technology?

2.Could the Internet of Things (IoT) be beneficial in your opinion?

3.In your opinion, how do you believe the Internet of Things (IoT) could assist in managing Activities of Daily Living (ADLs)?

4.Please provide an explanation of the ease or difficulty you experienced in utilizing these Internet of Things (IoT) devices to assist with your tasks.

After watching the show:

5.Please provide an explanation regarding the ease or difficulty you encountered in utilizing these interconnected devices.

6.What are your perceptions regarding the potential benefits of Internet of Things (IoT) or connected devices in managing your health? Please provide reasons supporting your viewpoint, including any potential advantages or disadvantages you foresee.

7. Could you please identify the features of these connected devices that you found favourable? Additionally, are there any features that you did not find satisfactory or appealing? Your insights into both the positive and negative aspects of these devices would be greatly appreciated.

8. What are your thoughts regarding the exercise features available on these Internet of Things (IoT) or connected devices? Your insights into the exercise functionalities provided by these devices would be greatly appreciated.

9.What specific aspect do you prefer to concentrate on the most?

10.Challenges in Performing Activities of Daily Living (ADLs) over Time

11.How comprehensible was the project?

12.Did you encounter any aspects of the workshop that you found challenging or unclear?

Table 1:

Participant A	Participant B	Participant C	Name of participant
ISCHEMIC CVA LEFT HEMIPLEGIA	CVA ISCHEMIC INFARCTION RIGHT HEMIPLEGIA	Right ischemic hemiplegia	Diagnosis
74	67	62	Age
Female	Female	Male	Gender

I require assistance in utilizing it	It meets all expectations	I find it helpful		Q.1	Questions
An effective assistant	Manage diabetes and blood pressure	Minimize management time		Q.2	
Could assist with ambulation and daily tasks	Independent mobility	I am optimistic that it will be beneficial to me		Q.3	
I require assistance in utilizing it	Simple to operate	I require assistance from my family to utilize it		Q.4	
I find it straightforward to use	Simple to operate	Simple to operate		Q.5	
Simplify doing task	Can use it any where	Can take it any where		Q.6	
Potential challenges may arise due to its technological nature	*I can bring it anywhere because I always have a caregiver with me. *It becomes challenging to use when I am alone.	Appointments are unnecessary		Q.7	
Excited to perform tasks	Utilizing time wisely and enjoying the moment	Resembling gaming experiences		Q.8	
Prioritize walking as the main focus	Concentrate on managing diabetes and blood pressure	Emphasize the importance of upper limb exercises over lower limb exercises		Q.9	
*Performing tasks like moving from bed to toilet *Monitoring blood sugar and blood pressure	*Moving around independently *Missing to be with his family	*Transferring from bed to the toilet. *Engaging in the rehabilitation program. *Moving around independently.	Morning	Q.10	

Prolonged sitting in a chair or lying in bed for an extended period	Experiencing discomfort during sleep	* Experiencing discomfort while sleeping *Difficulty moving around	Noon		
*Experiencing difficulty moving around *Discomfort while sleeping	*Feeling isolated from social life *Experiencing difficulty moving around *Discomfort while sleeping	*Experiencing discomfort from sitting for extended periods *Difficulty moving around *Discomfort while sleeping	Evening		
Good idea	Easy to understand	Easy project		Q.11	
-	Everything was clear	-		Q.12	

Table 2:

Participant D	Participant E	Participant F	Name of participant	
CVA left hemiplegia	CVA left hemiplegia	Right ischemic hemiplegia	Diagnosis	
70	76	62	Age	
Male	Male	Male	Gender	
Assist me in my daily life	I dream to improve myself	Definitely, it will help me	Q.1	Questions
Manage blood pressure	Simplify daily activities	An effective assistant	Q.2	
*Convenient to track *Time-saving	Assistance with walking and promoting independence	I aspire for independence	Q.3	

Simple and user-friendly	Requires increased accessibility and further clarification	I was unable to benefit from it due to my own lack of motivation		Q.4
Simple to operate	Simple to operate	Simple to operate		Q.5
It's a great idea to make life easier for people	You can use and take it anywhere	*Simplifies life *Portable		Q.6
*Simple to use *Saves travel expenses	*Concentrates on the affected side *Hard to use without assistance	* May be challenging due to its technological nature		Q.7
Continue making progress	It will enhance ADLs	I prefer rehabilitation centres over devices		Q.8
	*Prioritize walking *Aim for independence	Focus on walking		Q.9
Moving from bed to toilet	*Having trouble sleeping *Using the toilet	*Moving from bed to chair *Changing the nappy	Morning	Q.10
I lack motivation to engage in the rehabilitation program	* Feeling isolated from social activities	*Being independent in everything *Moving around	Noon	
*Moving around *Sleeping discomfort *Getting tired	*Moving around *Sleeping discomfort	*Being independent in everything *Sleeping discomfort	Evening	
Easy project	Easy to understand	Easy to understand		Q.11
-	Everything was clear	-		Q.12

Table 3:

Participant G	Participant H	Participant I	Name of participant	
LEFT HEMIPLEGIA CVA ISCHEMIA	left hemiplegia post recent ischemic stroke	CVA right hemiplegia	Diagnosis	
74	82	79	Age	
Male	Female	Male	Gender	
I hope it provides assistance to me	It's perfect	It feels like a dream	Q.1	Questions
*Restoring activities *Managing diabetes and blood pressure	*A helpful tool *Increases muscle strength	*Management of restoring activities *Managing diabetes and blood pressure	Q.2	
Conserves time and effort	Assisting with walking and daily activities	Achieving independence	Q.3	
Assistance required for usage	Easy to use	Assistance required for usage	Q.4	
It's a bit complicated	Easy to use	It's a bit complicated	Q.5	
Make tasks simpler	You can use it anywhere	Assist me in doing tasks	Q.6	
*Helps save on travel expenses *May pose challenges due to its technological nature	I can use and take it anywhere	*I can take it anywhere because I have a caregiver with me all the time *It's difficult to use if I'm alone	Q.7	
Progress is improving, but I still need the support of a rehab centre	I enjoy completing tasks and using my time effectively	Give me motivation to do tasks	Q.8	

*Focus on managing diabetes and blood pressure. *Emphasis on restoring activities.	*Emphasis on walking. *Aim to strengthen muscles.	Concentrate on regaining daily activities		Q.9
*Moving from bed to toilet. *Monitoring blood sugar and pressure.	*Moving from bed to toilet *Experiencing weakness and lethargy	*Moving from bed to toilet * Engaging in rehabilitation exercises	Morning	Q.10
*Spending long periods sitting in a chair or lying in bed *Missing out on social activities *Moving around	* Missing out on social activities *Moving around	* Spending long periods sitting in a chair or lying in bed	Noon	
Difficulty sleeping	Difficulty sleeping	* Spending long periods sitting in a chair or lying in bed * Difficulty sleeping	Evening	
Good idea & easy project	Easy to understand	Easy project		Q.11
-	Everything was clear	-		Q.12

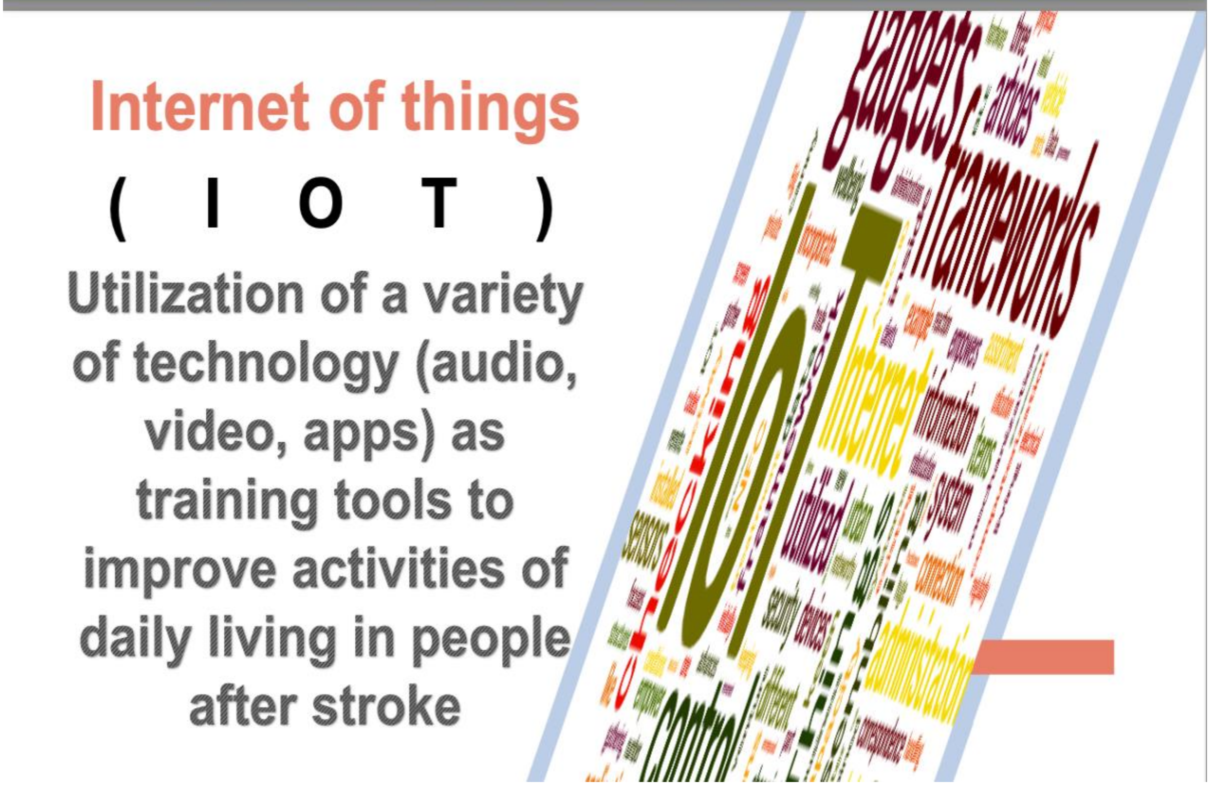
Table 4:

Participant J	Participant K	Participant L	Name of participant
Post Stroke Left Hemiplegia	CVA left hemiplegia	CVA right hemiplegia	Diagnosis

59	88	73		Age	
Male	Male	Male		Gender	
Certainly, it will assist me	Assist me in my daily life	I hope it provides assistance to me		Q.1	Questions
*Manage blood pressure and sugar levels. *Improve muscle strength and mobility.	Manage blood pressure and sugar levels	Manage sugar levels		Q.2	
Follow easily and save time	Achieving independence with the assistance of these devices	I aim to achieve independence		Q.3	
Easy to use	I need help to use it	Simplifying people's lives		Q.4	
Easy to use	It's a bit complicated	It's a bit complicated		Q.5	
Simplifying people's lives is a good idea	Use it anywhere with assistance	* Simplifying people's lives * Use it anywhere with assistance		Q.6	
*Easy to apply *Saving time & effort	*Focus on restoring ADL *Difficult to use if no one with me.	*Could be hard to use because it's technology		Q.7	
*Keep improving progress *Similar to games	It will improve ADL	Can combine with rehab centres program		Q.8	
*Focus on walking *Enhance muscle power	*Focus on walking *To be independent	*Focus on walking *To be independent		Q.9	
Moving from bed to toilet	*Moving from bed to chair *Changing the nappy	*Moving from bed to chair *Changing the nappy	Morning	Q.10	

*I'm lazy to do rehab program *Missing social life *Moving around	*Missing social life	*Being independent in everything *Moving around	Noon		
*Moving around *Sleeping discomfort *Getting tired	*Moving around *Sleeping discomfort	*Missing social life *Sleeping discomfort	Evening		
Easy project	Easy to understand	Easy to understand		Q.11	
Everything was clear	Everything was clear	-		Q.12	

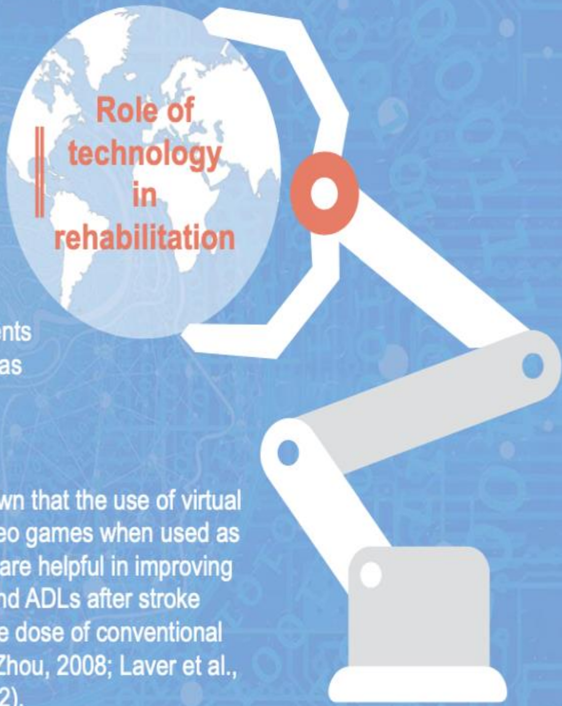
C4. Workshop 2 Presentation



GOALS

Role of rehabilitation

- Physical functions and activities of daily living (ADLs) are often affected by stroke, which is major cause of chronic impaired physical function.
- In order to improve basic mobility functions and ADL performance, an intensive rehabilitation plan must be developed during the stroke recovery period.
- only 5% to 20% of people reach full recovery (Nakayama et al., 1994).



Role of technology in rehabilitation

Recently, motion capture systems have expanded their scope in the development of numerous medical applications. For example, increased attention to human movement tracking systems for patients and elderly in hospitals and at home for obtaining more efficient rehabilitation treatments and the construction of remote monitoring networks (Masuda et al., 2005).

Recently, the use of video games for the patients rehabilitation with a wide range of ailments has made rehabilitation tasks more enjoyable.

Several studies have shown that the use of virtual reality and interactive video games when used as an adjunct to usual care are helpful in improving upper limb function and ADLs after stroke compared with the same dose of conventional therapy (Zhang, Hu and Zhou, 2008; Laver et al., 2012).

Examples of IOT devices in the health field

There is a need around the world for transforming healthcare from a hospital-centered system to a person-centered environment, with a focus on disease management among citizens due to ***the rising of health care costs***, ***the increase in elderly population, and the spread of many chronic diseases***.

Robotic exoskeletons

They are wearable, battery-powered robots attached to user's clothing, enabling people to achieve mobility, strength and / or endurance.

Smart socks

This technique helps to monitor walking activity even when it requires slow pace, short steps or walking aids.

Jolt Concussion Sensor

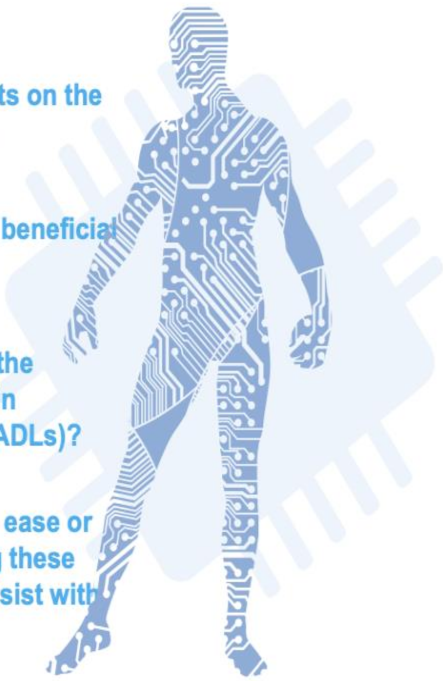
it detects a significant impact that might cause a concussion which vibrates to alert the player.

Withings

it is responsible for measuring the blood pressure and sending measurement data to the remote server and inform the patient with the progress of measurements.

Aims and Research Objectives

The aim of this PhD Thesis is to see the effectiveness of Internet of things (IOT) as training tools for improving activities of daily living in people after stroke.

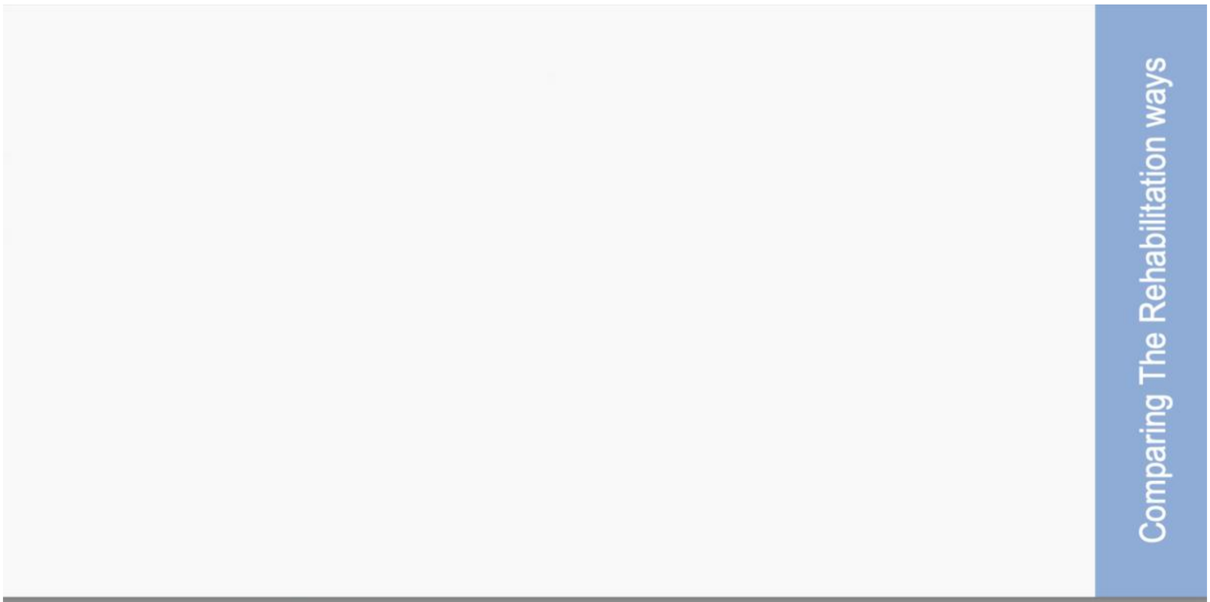


01 Could you please share your thoughts on the utilization of IoT (Internet of Things) technology?

02 Could the Internet of Things (IoT) be beneficial in your opinion?

03 In your opinion, how do you believe the Internet of Things (IoT) could assist in managing Activities of Daily Living (ADLs)?

04 Please provide an explanation of the ease or difficulty you experienced in utilizing these Internet of Things (IoT) devices to assist with your tasks

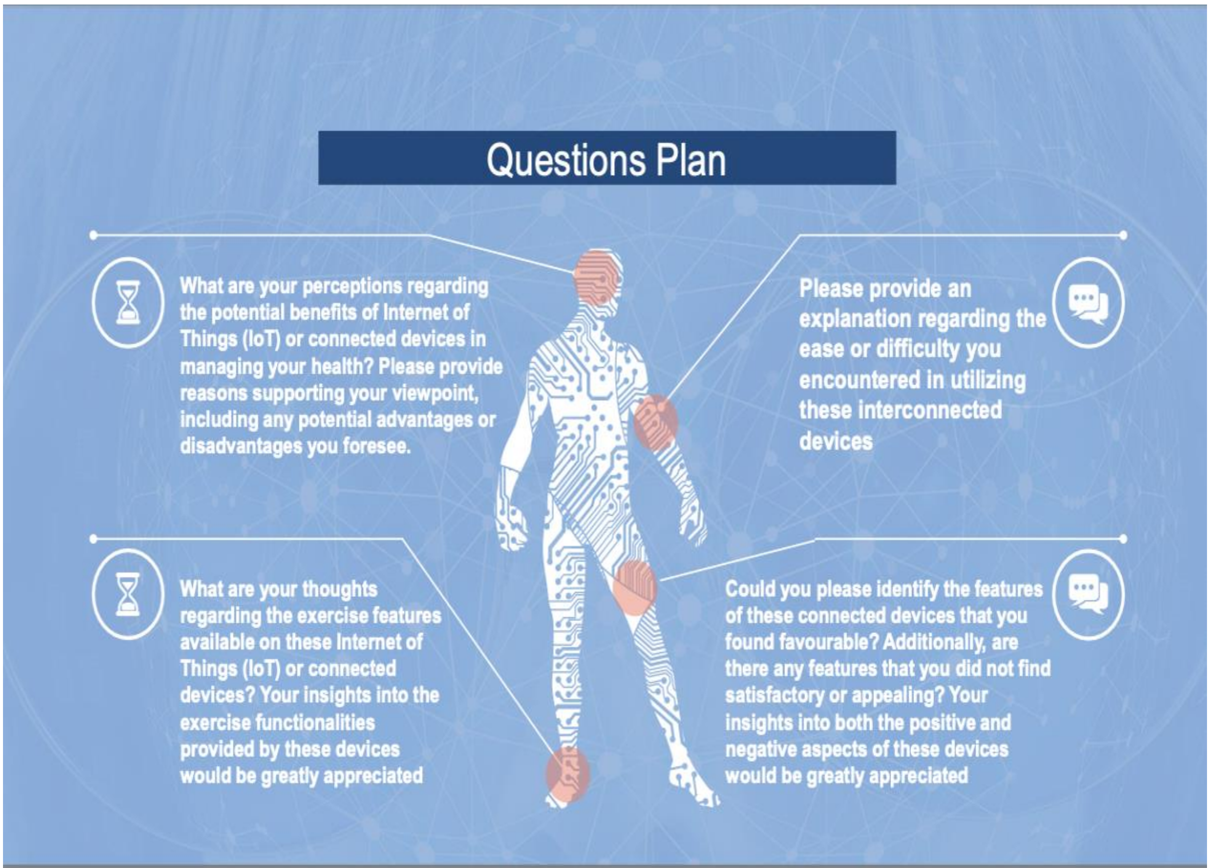


Video Clips on Rehabilitation Techniques
Video Clip 1: Comparing Rehabilitation Approaches
This video demonstrates a comparative analysis of various rehabilitation methods, highlighting their strengths and limitations in stroke recovery.

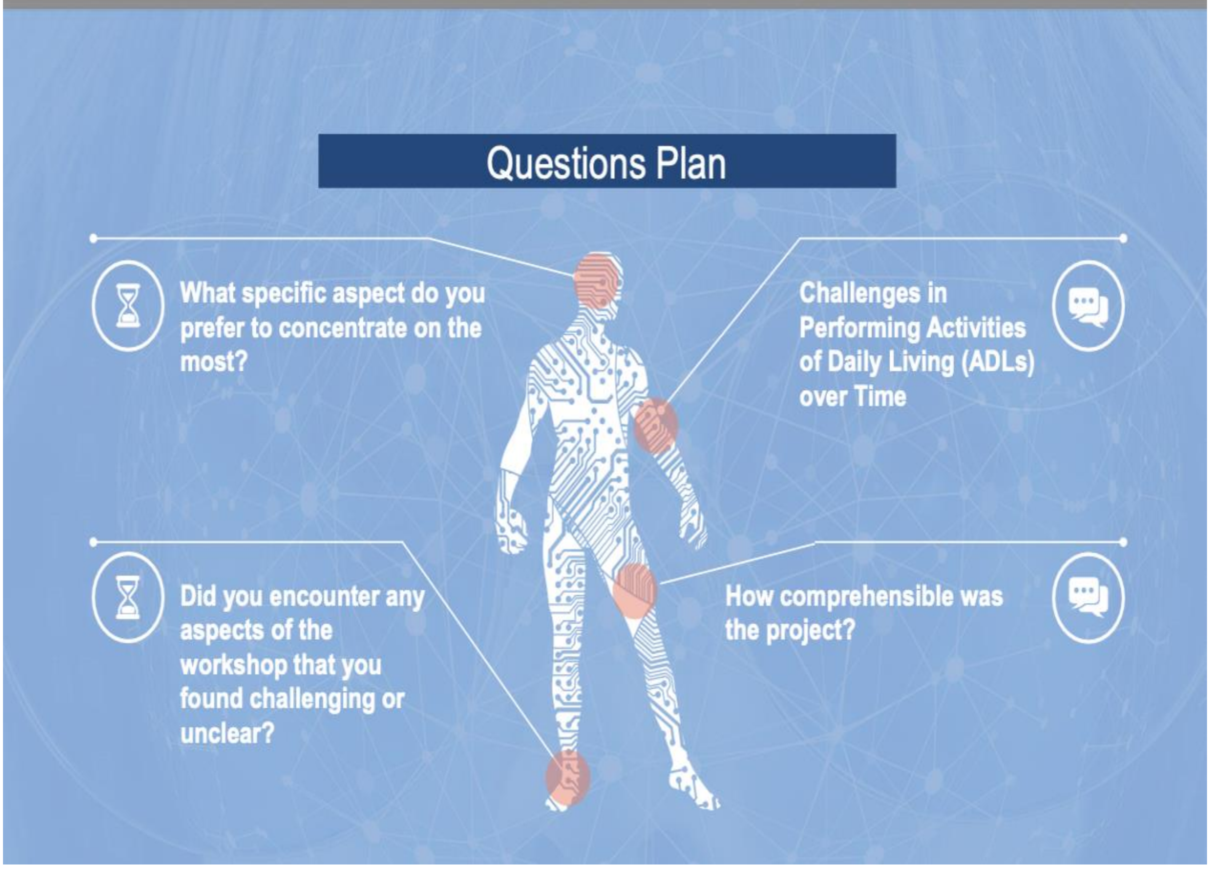
- Access the video here: [https://youtu.be/p9iK9_kmsf4]

Video Clip 2: Rehabilitation Techniques
This video explores specific rehabilitation techniques utilized in stroke recovery, focusing on their practical applications and effectiveness.

- Access the video here: [https://youtu.be/vGHKT28uDNs]



Questions Plan
What are your perceptions regarding the potential benefits of Internet of Things (IoT) or connected devices in managing your health? Please provide reasons supporting your viewpoint, including any potential advantages or disadvantages you foresee.
Please provide an explanation regarding the ease or difficulty you encountered in utilizing these interconnected devices
What are your thoughts regarding the exercise features available on these Internet of Things (IoT) or connected devices? Your insights into the exercise functionalities provided by these devices would be greatly appreciated
Could you please identify the features of these connected devices that you found favourable? Additionally, are there any features that you did not find satisfactory or appealing? Your insights into both the positive and negative aspects of these devices would be greatly appreciated



Questions Plan
What specific aspect do you prefer to concentrate on the most?
Challenges in Performing Activities of Daily Living (ADLs) over Time
Did you encounter any aspects of the workshop that you found challenging or unclear?
How comprehensible was the project?

C5. IoT Rehabilitation Technologies That Included During The Workshop 2 Presentation

- P1: IoT-Enabled Rehabilitation Glove for Stroke Recovery

This device is designed to track hand movements and provide real-time feedback during rehabilitation exercises.

- P2: IoT-Based Exercise Tracking Device

This technology offers customizable rehabilitation plans for stroke survivors.

- P3: Smart Assistant for Stroke Recovery

A device designed to assist stroke survivors by offering adaptive feedback and monitoring daily progress.

D. Validation Materials

D1. Validation information sheet, consent, process form and the questions

Introduction to the Recommendations for IoT-Based Rehabilitation Interventions

Welcome to this focused guide on using Internet of Things (IoT) technologies to help with stroke rehabilitation. This guide is made just for healthcare workers. I've gathered lots of feedback from workshops and surveys with stroke survivors, their families, and medical teams. Based on this information, I've created practical advice that you can use to improve how you care for and help people recover from strokes.

Research Program and Development of Recommendations

The research project has been working closely with stroke survivors and their families to figure out how IoT (Internet of Things) technologies can be used both during and after the rehabilitation process to really improve the lives of those who have survived a stroke. I've developed these suggestions through a detailed and step-by-step process that involved not just the stroke survivors and their families, but also doctors and other healthcare workers. I've used real quotes and situations from real people to make sure these recommendations are practical and based on what I've actually learned from the research.

For example, one of the people I talked to said:
"Having a device that changes with how I'm doing each day and gives me feedback right away would really help me get better."
This kind of feedback has really shaped our suggestions, especially in recommending technologies that can adapt to how a patient is doing over time. I've also made sure to improve how easy these technologies are to use, so that everyone, no matter how tech-savvy they are, can benefit from them.

The Role of IoT in Healthcare

IoT in healthcare means using a lot of different gadgets and systems that are connected over the internet to help make healthcare better. For people recovering from strokes, this includes things like wearable sensors, smart medical devices, and software that can keep an eye on patients all the time, gather their health data, and help doctors make decisions automatically. All these technologies work together to make sure that the health information is easy to get and use, which helps doctors and nurses provide very personalized care that really fits what each patient needs.

It's important to understand that these recommendations are not fixed; they will change as I learn more and as new technology is developed. This document is meant to show what I know right now and to help spark new ideas for better ways to help people recover from strokes. By really listening to what stroke survivors have experienced and bringing those insights into the plans, I hope to create a care system that is more caring, more connected, and uses technology to make people's lives better and more independent.

Overview of Recommendations:

1. **Personalization through Adaptive Technologies**

Recommendation: Healthcare professionals should use smart devices that adjust automatically to fit each stroke survivor's recovery needs. For instance, a special brace can change how much support it gives based on how well the patient can move each day, making the treatment more tailored and effective.

Rationale: Participants showed increased engagement and perceived benefits from IoT devices when these devices provided tailored rehabilitation exercises. Aligning technology with individual recovery profiles fosters a sense of control and progress, enhancing recovery outcomes.

Implementation Examples: Use of a smart wristband that monitors motor functions and adjusts the difficulty level of prescribed exercises in real-time, providing feedback directly to the healthcare team for further customization.

Benefits for Healthcare Professionals: Enables precise monitoring and tailoring of rehabilitation efforts, ensuring optimal patient progress and reduced recovery times.

Benefits for Patients: Personalized adjustments make rehabilitation more engaging and aligned with their specific recovery needs, enhancing overall effectiveness.

2. **Enhancing Accessibility and Usability**

Recommendation: It's important that the devices used by stroke survivors are easy to operate. They should have big screens that are easy to touch, respond to voice commands, and have clear, easy-to-use controls to fit their specific needs.

Rationale: Feedback indicated difficulties with complex interfaces. Simplifying interaction with IoT devices can reduce barriers to technology adoption, making it accessible to all users, irrespective of their tech-savviness or physical capabilities.

Implementation Examples: Tablets with customizable interfaces that allow the icons and text to be enlarged for patients with visual impairments or reduced motor skills, enabling easier access to telehealth services.

Benefits for Healthcare Professionals: Simplifies the process of training patients on technology use, enhancing efficiency and focus on rehabilitation.

Benefits for Patients: Makes technology more accessible, encouraging consistent use and promoting independence.

3. **Integration with Existing Healthcare Systems**

Recommendation: IoT devices need to work well with the systems already in place at healthcare facilities. This helps ensure that doctors and nurses can quickly get important information about patients, which helps them make better decisions about care.

Rationale: Seamless integration of IoT devices into healthcare systems allows healthcare professionals to access real-time data crucial for monitoring patient progress and adapting rehabilitation plans effectively. This integration helps in creating a more dynamic and responsive healthcare environment where decisions are data-driven and timely.

Implementation Examples: Create software for IoT devices that works with the health record systems already used in hospitals to update patient progress in real time.

Benefits for Healthcare Professionals: Streamlines patient data management and improves the accuracy of health records, facilitating better-informed clinical decisions.

Benefits for Patients: Ensures all health data is comprehensively managed and utilized, improving the continuity and personalization of care.

4. **Continuous Education and Support**

Recommendation: Develop ongoing education programs for healthcare providers to improve familiarity and confidence in using IoT technologies.

Rationale: As observed in workshop findings, initial unfamiliarity with IoT can hinder effective utilization. Sustained education efforts can enhance user competence and device integration into daily routines.

Implementation Examples: Offer regular webinars and hands-on workshops that train staff on new technologies and updates to existing systems, focusing on practical uses in patient care scenarios.

Benefits for Healthcare Professionals: Ongoing opportunities to enhance proficiency with IoT devices as technologies evolve. Support resources to resolve issues and optimize use of IoT for quality care.

Benefits for Patients: Proper onboarding increases ability to successfully use IoT devices for rehabilitation. Continued training allows patients to take full advantage of advanced device capabilities over time.

5. **Robust Support and Maintenance for Healthcare Staff**

Recommendation: Hospitals should have dependable help for IoT devices to make sure they work well all the time, keeping patient care uninterrupted.

Rationale: Providing continuous, accessible support is crucial for healthcare professionals who rely on IoT devices to deliver patient care. Effective support systems not only build trust but also ensure that devices function seamlessly, preventing interruptions in patient care.

Implementation Examples: Create a specialized team within the hospital that regularly checks and fixes IoT devices quickly to ensure they work properly for patient care.

Benefits for Healthcare Professionals: Reduces downtime and maintains high standards of care delivery, enhancing trust in technology-driven treatments.

Benefits for Patients: Ensures that the devices are always functioning optimally, providing continuous support for their rehabilitation journey.

6. **Real-Time Data Analytics and Decision Support**

Recommendation: Use advanced tools that analyse data from smart devices to give healthcare professionals helpful insights and support for making decisions quickly.

Rationale: Remote monitoring allows continuous care and monitoring without the need for physical travel, which is particularly beneficial for patients with mobility issues and reduces the burden on healthcare systems.

Implementation Examples: Create a simple dashboard that shows patient information live as it comes from different smart devices. This helps healthcare professionals quickly change treatments as needed. Also, use software that looks at past and present data to guess how patients might do in the future, helping doctors plan care more effectively.

Benefits for Healthcare Professionals: Improved decision-making ability with access to real-time, data-driven insights.

Benefits for Patients: More timely and precise adjustments to treatment plans, enhancing recovery rates and personal satisfaction.

7. **Remote Patient Monitoring Systems**

Recommendation: These systems let doctors watch over patients’ health from far away using smart devices. This means patients don’t have to visit the hospital as often, which is great for those who find it hard to get around. Doctors can check on their patients' health and get updates automatically, making it easier to take care of them without needing them to come in.

Rationale: Remote monitoring lets doctors care for and watch over patients without them having to travel, which is really helpful for patients who have trouble moving around. This also eases the workload on healthcare systems.

Implementation Examples: A mobile app lets healthcare professionals check patient health stats and track rehab exercises from anywhere. There's also a platform for video chats with patients, which automatically keeps doctors updated on the patient's condition.

Benefits for Healthcare Professionals: More efficient patient management and the ability to extend care to more patients.

Benefits for Patients: Less travel to healthcare facilities, providing convenience and reducing physical strain.

8. **Wearable Technology for Movement Tracking and Feedback**

Recommendation: Wearable technology, like smartwatches or fitness bands, tracks how much a patient moves and how they perform rehabilitation exercises. This technology provides instant feedback to both the patient and their healthcare provider, helping adjust exercises in real time to suit the patient’s current needs. This ensures exercises are done correctly and safely, enhancing recovery.

Rationale: Carefully monitoring how much a patient moves and giving quick feedback helps doctors make immediate changes to treatments, which is very important for successful rehabilitation.

Implementation Examples: Wearable devices can monitor how a patient moves and give feedback on their exercises through an app, helping both the patient and their therapist. Also, virtual reality (VR) equipment can mimic exercises and give instant feedback on the patient's movements.

Benefits for Healthcare Professionals: More accurate monitoring leads to better adherence to rehabilitation plans.

Benefits for Patients: Immediate feedback motivates and guides patients, enhancing their engagement and progress.

9. **IoT-Enabled Home Adaptation Tools**

Recommendation: These tools automatically adjust the home environment to make daily activities easier and safer for stroke survivors. For example, lights that turn on via voice command or appliances that are easier to operate can significantly enhance a patient's ability to manage independently, reducing the risk of accidents and improving their quality of life.

Rationale: Customizing home environments with IoT tools promotes recovery by making daily activities safer and more manageable for stroke survivors.

Implementation Examples: Systems can adjust lights, temperature, and devices in the home using voice commands or apps, making things easier for stroke survivors. Also, sensors can be installed to quickly alert doctors or family if a patient falls or needs immediate assistance.

Benefits for Healthcare Professionals: Reduced emergency calls and better management of patient care at home.

Benefits for Patients: Increased autonomy and safety, improving overall quality of life.

10. IoT Training Programs for Healthcare Staff

Recommendation: Training programs provide healthcare staff with the knowledge and skills they need to effectively use IoT technologies. By understanding how to use these technologies, staff can better support patients using IoT devices, leading to more effective treatments and better patient outcomes.

Rationale: The effectiveness of IoT in healthcare relies heavily on the skill and confidence of the staff using these technologies.

Implementation Examples: Offer courses designed for healthcare staff to help them understand how to use smart device technology in caring for patients. Also, hold regular workshops, either in person or online, where staff can practice using the latest smart devices.

Benefits for Healthcare Professionals: Well-trained staff are more efficient and can leverage IoT to deliver superior patient care.

Benefits for Patients: Better support from knowledgeable staff enhances treatment outcomes.

11. Patient-Cantered IoT Innovation Workshops

Recommendation: These workshops involve patients directly in the development and feedback process for IoT devices. By listening to patient experiences and suggestions, developers can create or adjust devices to better meet the actual needs of users. This approach not only makes the devices more user-friendly but also empowers patients by involving them in their own care solutions.

Implementation Examples: Set up regular meetings where patients can talk about their experiences with smart devices and suggest changes. Also, organize workshops where patients help developers create or adjust devices to better suit their needs.

Rationale: Involving patients directly in the design and feedback processes ensures that IoT solutions are truly user-friendly and effective.

Benefits for Healthcare Professionals: Direct insights into patient needs enhance care customization.

Benefits for Patients: Greater empowerment and satisfaction as they contribute to the development of technologies they use.

Questions

1. **Professional Background and Expertise:**

Could you please share your professional background and expertise in the field of post-stroke rehabilitation?

2. **Challenges in ADLs:**

Drawing from your experience, could you highlight the most prevalent challenges that stroke survivors encounter when performing activities of daily living (ADLs) at home?

3. **Familiarity with IoT:**

How well-acquainted are you with the concept of the Internet of Things (IoT) and its potential applications in healthcare, particularly within the realm of post-stroke rehabilitation?

4. **Feasibility and Impact of Guidelines:**

How feasible do you think the guidelines/recommendations we are developing for IoT devices in post-stroke rehabilitation are? What is your view on their potential impact?

5. **Gaps and Improvements:**

In your opinion, what aspects might be missing from our guidelines, or what would you consider changing to enhance their effectiveness in addressing post-stroke challenges?

6. **Importance and Benefits:**

From your experience, what do you consider the most important aspects of these guidelines, and why? What specific benefits do you think they can bring to stroke survivors?

7. **Examples of IoT Devices:**

Could you identify examples of IoT devices that could be pivotal in enhancing daily activity performance for stroke survivors? How do these devices align with the guidelines' objectives for supporting post-stroke rehabilitation?

8. **Concerns and Limitations:**

What concerns or limitations do you foresee in the practical application of IoT-based interventions in post-stroke rehabilitation? What strategies would you recommend to address these challenges within the framework of the guidelines?

9. **Integration and Acceptance:**

How do you assess the likelihood of healthcare professionals and stroke survivors integrating IoT devices into post-stroke rehabilitation regimens? Are there particular elements within the guidelines that could influence their willingness to accept or reject these technologies?

D2. Validation responses

Professional Background and Expertise:

1. I'm a physiotherapist with 10 years of experience, mainly working in neurorehabilitation. Stroke rehabilitation has been a core part of my work, especially in community settings.
2. I'm an occupational therapist with six years of experience. I specialize in helping stroke survivors regain their ability to perform everyday tasks, particularly at home.
3. I'm a newly qualified physiotherapist, having been in the field for just under a year. Most of my experience so far has been with stroke rehabilitation patients in a clinical setting.
4. I've been an occupational therapist for 15 years, focusing primarily on post-stroke rehabilitation in both clinical and home settings.
5. I'm a physiotherapist with over 20 years of experience in stroke rehabilitation. My focus is on helping patients regain mobility and independence.
6. I’ve been an occupational therapist for nearly five years, primarily working in community settings with stroke survivors.
7. I've been a physiotherapist for 12 years, working in both hospital and home care settings. Stroke rehabilitation has been a key focus of my career.
8. I’m an occupational therapist with 10 years of experience in stroke rehabilitation. I work mainly with older adults in a community setting.
9. I’m a newly qualified occupational therapist, and I’ve been working in stroke rehabilitation for about a year now. My experience is mainly with home care patients.
10. I’ve been working as a physiotherapist for 14 years, focusing primarily on stroke rehabilitation in both acute and community settings.
11. I’m an occupational therapist with 7 years of experience working with stroke survivors, primarily in their homes. I focus on helping them regain independence in daily activities.
12. I’m a physiotherapist with 18 years of experience, mainly in stroke rehabilitation. My focus has been on helping stroke survivors regain their mobility and independence in daily life.

13. I've been an occupational therapist for over 12 years, working mainly with stroke survivors in a rehabilitation centre. My focus is on helping patients regain their ability to perform everyday tasks independently.
14. I’ve been a physiotherapist for 5 years, working primarily with stroke survivors in both hospital and community settings.
15. I've been an occupational therapist for 8 years, focusing on stroke rehabilitation in a home care setting. I work closely with patients to help them regain their independence in daily activities.
16. I’ve been a physiotherapist for 6 years, working mainly in hospital settings with stroke survivors. My focus is on helping patients regain their strength and mobility.
17. I've been an occupational therapist for 9 years, working primarily with stroke survivors in a community setting. My focus is on helping patients regain their independence in daily activities.
18. I’m a newly qualified physiotherapist, having been in the field for just over a year. Most of my experience so far has been with stroke rehabilitation patients in a clinical setting.

Challenges in ADLs:

1. One major challenge I've seen is patients struggling with basic mobility. Things like getting dressed or walking around the house become monumental tasks.
2. Fatigue is a major issue for stroke survivors, which makes tasks like cooking or cleaning incredibly difficult.
3. Coordination is a big issue. Stroke survivors often struggle with simple tasks like buttoning a shirt or using utensils.
4. Patients often struggle with fine motor skills, which makes tasks like writing or using their phones very challenging.
5. One of the biggest challenges is regaining balance and coordination, which affects tasks like walking or standing up from a chair.
6. Cognitive impairments are a major challenge, especially when it comes to tasks that require planning and execution, like cooking or cleaning.
7. Fatigue is a significant challenge for many stroke survivors, especially when trying to perform activities like bathing or dressing.
8. Cognitive challenges like memory loss and problem-solving difficulties are a huge barrier for stroke survivors, particularly when it comes to managing medications or following routines.

9. Many of my patients struggle with basic coordination, which makes everyday tasks like making a cup of tea or brushing their teeth quite difficult.
10. One of the biggest challenges I see is with fine motor control. Simple tasks like tying shoelaces or writing can be extremely difficult for stroke survivors.
11. Many stroke survivors struggle with balance and mobility, making it difficult for them to move around the house or perform tasks like cooking or cleaning.
12. Stroke survivors often face challenges with coordination and strength, making simple tasks like standing or walking long distances difficult.
13. Many of my patients struggle with fine motor skills, which makes activities like dressing, eating, and writing incredibly difficult.
14. Balance and mobility are the biggest challenges my patients face. Many of them are at a high risk of falling, which makes everyday tasks like walking or standing dangerous.
15. Cognitive impairments are a major challenge for stroke survivors, particularly when it comes to tasks that require memory and problem-solving, like managing medications or following a routine.
16. Many stroke survivors struggle with basic mobility, making it difficult for them to walk or perform tasks like getting out of bed or standing up.
17. One of the biggest challenges I see is with fine motor skills. Tasks like dressing, eating, and writing can be extremely difficult for stroke survivors.
18. Coordination is a big issue for many of my patients. Tasks like using utensils, brushing their teeth, or tying their shoes can be very challenging.

Familiarity with IoT:

1. I’m relatively new to the concept of IoT in healthcare. I've heard about it in passing, but I haven't yet used it in practice.
2. I’ve been reading up on IoT and its applications in healthcare, but I haven’t had the opportunity to use it in my practice yet.
3. I’ve only recently learned about IoT, but I see its potential, especially for remote patient monitoring.
4. I’m very familiar with IoT in healthcare and have used some basic devices, like smartwatches, to track patient progress.
5. I’ve been hearing more about IoT recently, especially in terms of wearable devices that monitor movement.

6. I’m somewhat familiar with IoT through workshops and professional development courses. I haven’t used it extensively, though.
7. I’ve used basic IoT devices like fitness trackers with my patients, but I’m still exploring more advanced applications.
8. I’m aware of IoT, and I’ve seen it discussed in professional forums, but I haven’t had much practical experience with it yet.
9. I’ve only recently started learning about IoT, but I’m excited by the potential it holds for enhancing rehabilitation.
10. I’ve been using wearable devices like smartwatches in my practice for a while now, and I’ve found them useful for tracking patient progress.
11. I’ve attended several workshops on IoT and its applications in healthcare, but I haven’t had the chance to implement it in my practice yet.
12. I’ve used basic IoT devices such as movement trackers and wearable sensors in my practice, and they’ve been very helpful in monitoring patient progress.
13. I’ve read about IoT in professional journals, but I haven’t had much practical experience with it yet. I’m excited to see how it can be applied in stroke rehabilitation.
14. I’ve started to use IoT devices like wearable fitness trackers to monitor patient activity levels, and I’m keen to explore more advanced applications.
15. I’m aware of IoT and its potential applications in healthcare, but I haven’t had the opportunity to use it in my practice yet.
16. I’ve been using IoT devices like smartwatches to monitor patient progress, and I’ve found them to be incredibly helpful in tracking rehabilitation.
17. I’ve been hearing more about IoT recently, particularly in terms of wearable devices that monitor patient progress. I’m excited to see how they can be applied in stroke rehabilitation.
18. I’m relatively new to IoT, but I’m eager to learn more about how it can be applied in stroke rehabilitation. I see its potential for improving patient outcomes.

Feasibility and Impact of Guidelines:

1. The guidelines seem feasible but may require more resources than some clinics have. The potential impact could be profound if the devices are easy to use and accessible.
2. The guidelines seem quite practical, especially for larger rehabilitation centres. The potential for real-time data could revolutionize the way we monitor patient progress.

3. The guidelines are ambitious but realistic. I think they could make a significant difference, particularly in terms of reducing recovery times.
4. These guidelines are definitely feasible, particularly in a hospital setting where there are resources to support new technologies.
5. I think the guidelines are feasible but might require significant investment upfront. However, the long-term benefits could outweigh the costs.
6. The guidelines seem achievable, but I'm concerned about the learning curve for both therapists and patients.
7. These guidelines are certainly feasible, but more funding will be required to make IoT devices available to all patients.
8. The guidelines are promising but will require training and resources to implement effectively. The impact could be huge if the right support is in place.
9. The guidelines are ambitious, but they seem achievable with the right resources and support. The potential impact could be life-changing for stroke survivors.
10. The guidelines are feasible, but implementation will depend on having the right training and support in place for both healthcare professionals and patients.
11. The guidelines are very feasible, but there will need to be a focus on providing proper training for healthcare staff to ensure they're used effectively.
12. The guidelines seem feasible, but there needs to be a strong focus on training healthcare providers to ensure the effective use of IoT devices.
13. The guidelines are practical, but the main challenge will be ensuring that all healthcare providers are trained to use these devices effectively.
14. The guidelines are definitely feasible, but they will require significant training and ongoing support for healthcare providers to be implemented successfully.
15. The guidelines are practical, but there needs to be a strong focus on providing proper training for both healthcare providers and patients to ensure they're used effectively.
16. The guidelines are feasible, but implementation will depend on having the right training and support in place for both healthcare professionals and patients.
17. The guidelines are very feasible, but there will need to be a strong focus on training healthcare professionals to use these devices effectively.
18. The guidelines are ambitious but achievable with the right resources. I think they could significantly improve the quality of care we provide to stroke survivors.

Gaps and Improvements:

1. One area that could use improvement is the integration of training programs for both healthcare staff and patients. The guidelines should focus more on this aspect to ensure adoption.
2. I would suggest adding more focus on how these IoT devices can be made accessible for stroke survivors with severe cognitive impairments.
3. I'd like to see more emphasis on integrating these IoT solutions into existing rehabilitation practices without requiring a complete overhaul.
4. One improvement could be more guidance on how to handle data privacy concerns, which are a big issue for both patients and professionals.
5. I would suggest adding more focus on how to train healthcare professionals in using IoT devices effectively.
6. There should be more emphasis on the support needed to maintain these devices. If a device breaks down, it could interrupt the patient's rehabilitation process.
7. I would like to see more emphasis on patient education. Stroke survivors need to understand how to use IoT devices effectively.
8. I think the guidelines need to include a plan for how IoT devices can be adapted for patients with severe cognitive impairments.
9. I think more focus needs to be placed on making IoT devices user-friendly for both patients and therapists.
10. I would suggest adding more guidance on how to deal with potential technical failures. If a device malfunctions, it could disrupt the patient's rehabilitation process.
11. I think the guidelines could benefit from more focus on how to make IoT devices accessible to patients with severe physical limitations.
12. I think there should be more discussion on how to integrate IoT devices with existing healthcare systems. Many clinics may not have the infrastructure to support these technologies.
13. One area for improvement is ensuring that IoT devices are accessible to patients with limited financial resources. Cost could be a major barrier to widespread adoption.
14. I think more emphasis should be placed on integrating IoT devices into existing healthcare workflows to ensure a smooth transition.
15. I think the guidelines could benefit from more focus on how to make IoT devices accessible to patients with severe cognitive impairments.

16. I think the guidelines need to include more information on how to handle potential technical failures. If a device malfunctions, it could disrupt the patient's rehabilitation process.
17. I think the guidelines need to address the issue of technical support. If a device breaks down, it could interrupt the patient's rehabilitation process.
18. I think more focus needs to be placed on making IoT devices user-friendly for both patients and healthcare providers, particularly for those who are not familiar with technology.

Importance and Benefits:

1. The most important aspect is personalization. IoT devices that adapt to each patient's progress could significantly improve recovery outcomes.
2. I believe the biggest benefit lies in the real-time monitoring aspect. It allows healthcare providers to adjust treatment plans more quickly and accurately.
3. Personalization is key. Patients respond better when their treatment plans are tailored to their specific needs, and IoT can facilitate this.
4. The ability to monitor patients in real-time could drastically improve recovery times. Patients would feel more engaged knowing their progress is being tracked.
5. The most important aspect is accessibility. Ensuring that IoT devices are easy to use for both healthcare providers and patients is crucial.
6. The potential for IoT to offer real-time data is hugely beneficial. It could help us adjust treatment plans based on immediate feedback from the patient.
7. The real-time monitoring aspect of IoT is the most valuable. It allows healthcare providers to adjust treatments based on accurate, up-to-the-minute data.
8. The personalization of rehabilitation plans through IoT is the most important benefit. Every patient recovers differently, and IoT can help tailor their treatment to their specific needs.
9. The ability to track patient progress in real-time is invaluable. It allows for immediate adjustments to treatment plans, which can accelerate recovery.
10. Personalization is key. IoT allows us to tailor rehabilitation plans to each patient's unique needs, which can lead to better outcomes.
11. The ability to continuously monitor patient progress is the most valuable. This real-time data can help healthcare providers make more informed decisions about treatment plans.

12. The ability to tailor rehabilitation exercises to each patient's progress is the most valuable benefit of IoT. This kind of personalization can significantly improve recovery outcomes.
13. The ability to monitor patient progress remotely and make real-time adjustments to their treatment plans is the most important benefit of IoT.
14. The ability to provide personalized treatment plans based on real-time data is the most important benefit. This could significantly improve patient outcomes.
15. The ability to continuously monitor patient progress and adjust treatment plans in real-time is the most important benefit.
16. The ability to provide personalized rehabilitation plans based on real-time data is the most important benefit of IoT.
17. The ability to monitor patient progress remotely and adjust treatment plans in real-time is the most important benefit of IoT.
18. The ability to provide real-time feedback to patients and adjust their rehabilitation plans based on their progress is the most valuable benefit.

Examples of IoT Devices:

1. Smartwatches that track movement could be extremely helpful. These devices could provide real-time feedback, aligning with the guidelines' focus on continuous monitoring.
2. Voice-activated assistants could be very useful for stroke survivors, especially those with limited mobility. This aligns well with the guideline on adaptive home environments.
3. Wearable fitness trackers could help stroke survivors monitor their progress during rehabilitation exercises, which fits well with the guidelines.
4. Home automation systems could be a game-changer for stroke survivors, allowing them to control their environment with ease.
5. Wearable devices like smartwatches that track movement and provide feedback could be extremely beneficial for stroke survivors.
6. Smart home systems that adapt the environment, like lighting and temperature controls, would be a great help to stroke survivors.
7. Smartwatches that track movement and provide feedback during rehabilitation exercises are a perfect fit for the guidelines.
8. Voice-activated devices like smart speakers could help stroke survivors perform ADLs more independently, which aligns with the guidelines.

9. Wearable devices like fitness bands that monitor movement and provide feedback are perfect examples of how IoT can support rehabilitation.
10. Smartwatches that monitor movement and provide feedback are an excellent example of how IoT can support stroke survivors in their recovery.
11. Home automation systems that allow stroke survivors to control their environment with voice commands would be incredibly helpful.
12. Wearable sensors that monitor patient movement and provide feedback in real-time could help therapists adjust treatment plans more effectively.
13. Voice-activated home assistants could be a great help for stroke survivors who struggle with mobility, allowing them to control their environment more easily.
14. Wearable devices that monitor movement and provide feedback during rehabilitation exercises could help patients stay on track with their recovery.
15. Home automation systems that allow patients to control their environment with voice commands would be incredibly helpful for stroke survivors with limited mobility.
16. Wearable fitness trackers that monitor movement and provide feedback in real-time are a great example of how IoT can support stroke survivors in their recovery.
17. Voice-activated assistants could help stroke survivors control their environment more easily, which aligns well with the guidelines.
18. Wearable devices that monitor movement and provide feedback during rehabilitation exercises are a great fit for the guidelines.

Concerns and Limitations:

1. Cost is a big concern. Smaller clinics or individual therapists may struggle to afford these devices. There needs to be a focus on making IoT interventions cost-effective.
2. Privacy is a major concern. Patients and their families might worry about who has access to their health data.
3. A potential limitation is the lack of technical support. If a device malfunctions, it could disrupt the entire rehabilitation process.
4. The main concern I have is the reliability of the technology. What happens if the IoT device fails during a crucial moment of rehabilitation?
5. A potential limitation is the cost of these devices. Not all healthcare providers or patients may be able to afford them.
6. One concern is data privacy. Patients may feel uncomfortable with their health data being shared through IoT devices.

7. One concern is the potential over-reliance on technology. Human interaction is still a key part of rehabilitation, and we shouldn't lose sight of that.
8. A limitation could be that the technology could be too complex for older stroke survivors. Simplicity is key to ensure widespread adoption.
9. A limitation could be the initial cost of implementing these devices. Many patients and smaller clinics may not have the budget for this kind of technology.
10. A concern is that some patients may find the technology overwhelming, particularly older stroke survivors who are not familiar with digital devices.
11. A limitation could be the lack of technical support for IoT devices. If a device breaks down, it could disrupt the patient's rehabilitation process.
12. One concern is the reliability of these devices. If they malfunction or provide inaccurate data, it could negatively impact the rehabilitation process.
13. A limitation could be the initial cost of IoT devices. Many patients and smaller clinics may not have the budget for this kind of technology.
14. One concern is that some patients may feel overwhelmed by the technology, particularly older stroke survivors who are not familiar with digital devices.
15. A limitation could be the cost of IoT devices. Not all patients or healthcare providers may be able to afford them.
16. A concern is that some patients may find the technology overwhelming, particularly older stroke survivors who are less familiar with digital devices.
17. A limitation could be the initial cost of IoT devices. Many patients and smaller clinics may not have the budget for this kind of technology.
18. A limitation could be the learning curve for both patients and healthcare providers. If the technology is too complex, it may discourage adoption.

Integration and Acceptance:

1. I think IoT will be widely accepted once people see the benefits. However, there might be some initial resistance due to unfamiliarity with the technology.
2. IoT acceptance will depend on how well healthcare providers are trained to use it. If the learning curve is too steep, it could slow adoption.
3. I think stroke survivors will embrace IoT if they see clear benefits, but there may be resistance from older healthcare professionals who are less comfortable with new technology.
4. I think IoT integration will be widely accepted once the benefits are clear, but there needs to be ongoing support for both healthcare providers and patients.

5. I think IoT will be accepted more quickly by younger healthcare professionals, but older generations may take more time to adapt.
6. The success of IoT will depend on how well it's integrated into existing systems. If it's too complicated to use, it might not be widely accepted.
7. I think IoT will be accepted over time, but as more success stories emerge, IoT devices will likely become a standard part of stroke rehabilitation.
8. I think there will be some initial resistance, but as more success stories emerge, IoT devices will likely become a standard part of stroke rehabilitation.
9. IoT will likely be accepted by healthcare professionals, but patients may need time to get comfortable with using these devices.
10. I think IoT will be widely accepted, especially as more healthcare professionals see the benefits it brings to patient outcomes.
11. I think healthcare professionals will be quick to adopt IoT devices, but patients may need more time and support to feel comfortable using them.
12. I think IoT devices will be accepted by healthcare professionals as long as they are easy to use and provide clear benefits to both patients and providers.
13. I think IoT will be accepted over time, but there will need to be ongoing support and education for both healthcare providers and patients.
14. IoT will likely be accepted by healthcare providers, but patients may need more time to get comfortable using these devices.
15. I think IoT will be widely accepted, but there will need to be ongoing support and education for both healthcare providers and patients.
16. I think IoT will be widely accepted, especially as more healthcare professionals see the benefits it brings to patient outcomes.
17. I think IoT will be accepted by healthcare professionals, but patients may need more time to get comfortable using these devices.
18. I think IoT will be accepted over time, but there will need to be ongoing support and education for both patients and healthcare providers to ensure successful integration.

E. Ethics Approvals

E1. Online Survey Ethics

Ethics approval (reference FL21032) please quote this reference in all correspondence about this project

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From FASS and LUMS Research Ethics <fass.lumsethics@lancaster.ac.uk>

Date Tue 05/04/2022 10:17

To Namnaqani, Fayez (Postgraduate Researcher) <f.namnaqani@lancaster.ac.uk>

Cc Tsekleves, Emmanuel <e.tsekleves@lancaster.ac.uk>; Eccles, Fiona <f.eccles@lancaster.ac.uk>

Dear Fayez,

Thank you for submitting your application and additional information for *Designing an Internet of things based training system for improving activities of daily living after stroke.* The information you provided has been reviewed by members of the Faculty of Arts and Social Sciences and Lancaster Management School Research Ethics Committee and I can confirm that approval has been granted for this project.

As principal investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licenses and approvals have been obtained;
- reporting any ethics-related issues that occur during the course of the research or arising from the research (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress) to the Research Ethics Officer;
- submitting details of proposed substantive amendments to the protocol to the Research Ethics Officer for approval.

*** If you need to make an amendment to your application, including due to Covid-19 restrictions that may call for changes to data collection methods, before you submit your amendment application to the committee for review, we recommend that you refer to the university guidance here and ethics committee guidance here .**

Please do not hesitate to contact me if you require further information about this.

Kind regards,

Debbie

Debbie Knight I Research Ethics Officer
Secretary FASS & LUMS Research Ethics Committee & UREC I Research and Enterprise Services
Lancaster University I
Contact me on Teams
https://www.lancaster.ac.uk/Research Ethics

E2. Workshops Ethics

[External] FASSLUMS-2023-3495-RECR-1 Ethics Approval from FREC

From donotreply@infonetica.net <donotreply@infonetica.net>
Date Mon 13/03/2023 12:36
To Namnaqani, Fayez (Postgraduate Researcher) <f.namnaqani@lancaster.ac.uk>
Cc Tsekleves, Emmanuel <e.tsekleves@lancaster.ac.uk>; Eccles, Fiona <f.eccles@lancaster.ac.uk>

1 attachment (118 KB)
Letter.pdf;

This email originated outside the University. Check before clicking links or attachments.

Name: Fayez Namnaqani

Supervisor: Emmanuel Tsekleves

Department: Lancaster Institute for the Contemporary Arts

FASS LUMS **REC Reference:** FASSLUMS-2023-3495-RECR-1

Title: Designing an Internet of Things based training system for improving activities of daily living after stroke

Dear Mr. Fayez Namnaqani,

Thank you for submitting your ethics application in REAMS, Lancaster University's online ethics review system for research. The application was recommended for approval by the FASS LUMS Research Ethics Committee, and on behalf of the Committee, I can confirm that approval has been granted for this application.

As Principal Investigator/Co-Investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licences and approvals have been obtained.

- reporting any ethics-related issues that occur during the course of the research or arising from the research to the Research Ethics Officer at the email address below (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress).

- submitting any changes to your application, including in your participant facing materials (see attached amendment guidance).

Please keep a copy of this email for your records. Please contact me if you have any queries or

E3. Validation Ethics

[External] REAMS (Applicant Info) Ethics Approval from Faculty Research Ethics Committee FASSLUMS-2024-3630-RECR-3

donotreply@infonetica.net <donotreply@infonetica.net>

Wed 06/03/2024 14:11

To:Namnaqani, Fayez (Postgraduate Researcher) <f.namnaqani@lancaster.ac.uk>
Cc:Tsekleves, Emmanuel <e.tsekleves@lancaster.ac.uk>;Eccles, Fiona <f.eccles@lancaster.ac.uk>

1 attachments (118 KB)

Letter.pdf;

This email originated outside the University. Check before clicking links or attachments.

Dear Mr. Fayez Namnaqani,

Please note that this is an automated e-mail (Please do not reply to this e-mail).

Name: Fayez Namnaqani

Supervisor: Emmanuel Tsekleves

Department: Lancaster Institute for the Contemporary Arts

FASS LUMS **REC Reference:** FASSLUMS-2024-3630-RECR-3

Title: Validation of recommendations for using Internet of Things based training systems for improving activities of daily living after stroke

Thank you for submitting your ethics application in REAMS. The application was recommended for approval by the FASS LUMS Research Ethics Committee, and on behalf of the Committee, I can confirm that approval has been granted for this application.

As Principal Investigator/Co-Investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licences and approvals have been obtained.

- reporting any ethics-related issues that occur during the course of the research or arising from the research to the Research Ethics Officer at the email address below (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress).

- submitting any changes to your application, including in your participant facing materials (see attached amendment guidance).

Please keep a copy of this email for your records. Please contact me if you have any queries or require further information.

If you are experiencing any problems please contact your Research Ethics Officer.

E4. Design-Expert Ethics

Outlook

[External] REAMS (Applicant Info) Ethics Approval from Faculty Research Ethics Committee FASSLUMS-2025-5533-RECR-2

From donotreply@infonetica.net <donotreply@infonetica.net>
Date Wed 06/08/2025 14:47
To Namnaqani, Fayez (Postgraduate Researcher) <f.namnaqani@lancaster.ac.uk>
Cc Tsekleves, Emmanuel <e.tsekleves@lancaster.ac.uk>; Eccles, Fiona <f.eccles@lancaster.ac.uk>

1 attachment (147 KB)
Letter.pdf;

This email originated outside the University. Check before clicking links or attachments.

Dear Mr. Fayez Namnaqani,

Please note that this is an automated e-mail (Please do not reply to this e-mail).

Name: Fayez Namnaqani

Supervisor: Emmanuel Tsekleves

Department: Lancaster Institute for the Contemporary Arts

FASS LUMS **REC Reference:** FASSLUMS-2025-5533-RECR-2

Title: Gathering Design Perspectives on IoT-Based Stroke Rehabilitation Recommendations through Online Interviews

Thank you for submitting your ethics application in REAMS. The application was recommended for approval by the FASS LUMS Research Ethics Committee, and on behalf of the Committee, I can confirm that approval has been granted for this application.

As Principal Investigator/Co-Investigator your responsibilities include:

- ensuring that (where applicable) all the necessary legal and regulatory requirements in order to conduct the research are met, and the necessary licences and approvals have been obtained.

- reporting any ethics-related issues that occur during the course of the research or arising from the research to the Research Ethics Officer at the email address below (e.g. unforeseen ethical issues, complaints about the conduct of the research, adverse reactions such as extreme distress).

- submitting any changes to your application, including in your participant facing materials (see attached amendment guidance).

Please keep a copy of this email for your records. Please contact me if you have any queries or

F. Design-Expert Materials

F1. Design-Expert information sheet and consent form

Gathering Design Perspectives on IoT-Based Stroke Rehabilitation Recommendations through Online Interviews

Participant information sheet

Researcher: Fayez Namnaqani

Supervisors: Dr. Emmanuel Tsekleves, Dr. Fiona Eccles

Purpose of the Study:

You are invited to take part in a research study that aims to collect expert feedback on a set of 11 IoT-based design recommendations for stroke rehabilitation. Your insights will contribute to refining the design implications of this research.

What Participation Involves:

You will be invited to take part in a one-to-one semi-structured interview (30–45 minutes) via Microsoft Teams (the university's preferred platform) or Zoom. The discussion will be recorded (audio and/or video) for transcription and analysis purposes. If you do not wish to appear on video, you may choose to keep your camera turned off during the interview. Audio will still be recorded for transcription purposes.

Voluntary Participation and Confidentiality:

Participation is entirely voluntary and you can stop the interview any time.. You will be able to withdraw your data up to 4 weeks from the point of interview, without giving a reason. After this time anonymisation and data analysis will have begun, and it will no longer be possible to withdraw your data. Your responses will be anonymised, and all personal information will be handled securely.

Use of Data:

Data will be used for academic purposes including inclusion in the researcher's PhD thesis and potential publication. Anonymised quotes may be included.

Data Storage and Deletion:

Interview data will be stored securely on Lancaster University OneDrive. Video and audio recordings will be securely stored and used solely for transcription and analysis. These will be deleted after the PhD thesis has been examined. However, anonymised transcripts and signed consent forms will be retained for 10 years, in accordance with Lancaster University's data management policy.

Contact Information:

For any questions, you may contact the researcher at f.namnaqani@lancaster.ac.uk or supervisors Emmanuel Tsekleves (e.tsekleves@lancaster.ac.uk) and Fiona Eccles (f.eccles@lancaster.ac.uk).

If you have any concerns or complaints about the research, you can also contact the Head of Department:

Name: Professor Emma Rose,

Address: LICA Building, Lancaster University, Bailrigg, LA1 4YW

Tel: +441524524475

Email: e.rose@lancaster.ac.uk

This study has been reviewed and approved by the Faculty Research Ethics Committee at Lancaster University.

For concerns related to data protection and GDPR, please refer to Lancaster University's Privacy Policy for Research Participants: www.lancaster.ac.uk/research/data-protection.

Thank you for considering your participation in this project.

Lancaster University

CONSENT FORM

Project Title: Gathering Design Perspectives on IoT-Based Stroke Rehabilitation Recommendations through Online Interviews

Name of Researchers: Fayez Namnaqani

Email: **f.namnaqani@lancaster.ac.uk**

Please tick each box

33. I have read and understood the participant information sheet	☐
34. I have had the opportunity to ask questions and received satisfactory answers.	☐
35. I understand that participation is voluntary and I may withdraw from the study at any time up to 4 weeks after the interview without providing a reason. After this point anonymisation and analysis will have begun, it will not be possible to remove my data.	☐
36. I agree to the interview being recorded (audio and video).	☐
37. I understand that anonymised quotes may be used in the thesis or publications.	☐
38. I understand that anonymised transcripts and consent forms will be stored securely for 10 years in accordance with Lancaster University's data management policy.	☐
39. I agree to take part in this study.	☐

______________________________ ___________________ ____________________

Name of Participant Date Signature

F2. Design-Expert process form and the questions

Interview Schedule

Section A: Background and Expertise

1. Can you briefly describe your background and current role in design?
2. What experience do you have working with digital health, IoT, or assistive technology?
3. Have you previously contributed to healthcare-related design projects?

Section B: General Feedback on the Recommendations

4. What were your initial impressions after reviewing the 11 IoT-based recommendations?
5. Which recommendations align most with current trends in digital health and IoT design?
6. Are any recommendations unclear, unrealistic, or too broad?

Section C: Design Feasibility and Impact

7. Which recommendations seem most feasible from a design standpoint?
8. How might users (stroke survivors or clinicians) interact with technologies based on these recommendations?
9. Are there overlooked design opportunities or challenges?

Section D: Design Relevance and Contribution

10. Do the recommendations convey a clear design voice or ethos?
11. How would you improve or refine any recommendations for usability?
12. What additional considerations (e.g., accessibility, ethics) should be integrated?

Section E: Closing

13. Do you have any final comments or suggestions to enhance the design contribution?

Overview of Recommendations:

- **Personalization:** Tailoring rehabilitation to the unique recovery paths of stroke survivors using adaptable IoT devices.
- **Accessibility and Inclusivity:** Ensuring IoT devices are easy to use for all patients, regardless of their physical or cognitive abilities.
- **Interoperability:** Devices should integrate seamlessly with existing healthcare systems for efficient care coordination.
- **Privacy and Security:** Strict adherence to data privacy laws and ensuring the security of personal health information.
- **Support and Maintenance:** Providing robust support systems and easy maintenance for IoT devices.
- **Affordability and Availability:** Making IoT solutions cost-effective and widely available to ensure broad access.
- **Monitoring and Feedback Systems:** Incorporating real-time monitoring and feedback to adjust rehabilitation plans dynamically.
- **Continuous Improvement and Adaptation:** Ongoing enhancement of IoT devices based on the latest research and user feedback.
- **Social and Emotional Support:** Facilitating social connections and emotional health through IoT functionalities.
- **Economic and Policy Considerations:** Addressing economic and policy issues to support the implementation and scalability of IoT solutions.
- **Professional Education and Training:** Educating healthcare providers about the potential and use of IoT in rehabilitation to ensure effective deployment.

F3. Design-Expert responses

Theme	Participant D1	Participant D2	Participant D3	Participant D4
Professional Background	Lecturer in Design, IoT & digital health researcher.	Senior Lecturer in HCI & User-Centred Design.	Design Researcher focused on AI-driven IoT ethics.	UX Designer & Lecturer, healthcare app design.
Experience with IoT	Extensive personal and research use of connected devices.	Research on smart healthcare and tele-rehab.	Studies ethical and regulatory frameworks for IoT.	Designs patient-facing digital health tools.
General View of Recommendations	"Utopian but valuable" — ambitious, idealistic framework.	"Comprehensive and logical," though difficult to apply in clinical settings.	"Strong but lacks regulatory realism."	"Balanced and human-centered; emotionally resonant."
Feasibility / Realism	IoT moves faster than policy; current systems not ready.	Practical barriers: workload, digital literacy, and resource constraints.	Concern about gap between theory and deployment.	Supports gradual, user-informed implementation.
Privacy & Security	Major vulnerability — weak encryption, poor manufacturer practices.	Should include clearer data management roles.	Must address data ownership, certification, and compliance.	Supports transparency and patient control of data.
Training & Professional Education	Questions practicality — "Who delivers and monitors training?"	Important but needs scalable delivery (e-learning).	Advocates institutional responsibility for continuous updates.	Supports integrating user-friendly guidance for patients.
Maintenance & Ownership	Devices differ in lifespan; hardware vs software mismatch.	Emphasises cost of ongoing maintenance.	Suggests defining ownership and accountability models.	Highlights sustainability and affordability.
Affordability & Access	"Core issue — equity and cost must guide design."	Acknowledges socioeconomic barriers to adoption.	Notes digital divide; affordability impacts scalability.	"Even best tech fails if people can't afford or understand it."
Usability & Interface Design	Needs simplification and intuitive control systems.	Advocates co-design and clear visual feedback.	Stresses that usability links to	Prioritises empathy, accessibility, and user trust.

			privacy control.	
Regulation & Certification	Absent in recommendations; should reference standards.	Limited awareness of healthcare policy frameworks.	Demands inclusion of GDPR, NHS Data Security, ISO.	Suggests adding compliance section for designers.
Human & Emotional Support	Unclear definition; needs contextualisation.	Appreciates the inclusion of emotional factors.	Cautions not to overextend design goals.	Praises it as "humanising technology"; suggests tele-support networks.
Integration & Interoperability	"Devices act in silos—need cross-system design."	Recommends platform-agnostic design and system integration.	Suggests standard protocols and open APIs.	Supports multi-device compatibility for users.
Suggested Additions / Improvements	Economic models, device ownership, realistic tone.	Simplify recommendations; highlight patient usability.	Add governance, certification, and transparency clauses.	Add co-design, emotional intelligence, and affordability notes.
Overall Evaluation	"Excellent ideals, not grounded in real-world complexity."	"Useful and well-structured; must reflect clinical constraints."	"Ethically sound but incomplete without regulation."	"Inspiring and empathetic; balances tech and humanity."