

**Exploring Opportunities to Enhance Engagement in Home-Based  
Stroke Rehabilitation Through the Design of Instrumented Objects**

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## **Abstract**

This thesis explores opportunities to enhance patient engagement in stroke rehabilitation through the design of an instrumented object aimed at improving fine motor skills at home. Using a Research through Design approach, the study focuses on the development of MorlensRehab, a sensor-based device that incorporates occupational therapy exercises. The prototype was used in a co-creation workshop to identify and better understand the needs and experiences of a diverse group of stakeholders, including rehabilitation patients, caregivers, healthcare providers, and technology developers. A thematic analysis of the workshop data uncovered key themes such as motivation and engagement, monitoring health and wellness, and social connectedness, highlighting factors that influence the adoption of technology in rehabilitation. Insights from the workshop also provided recommendations for more user-friendly iterations of MorlensRehab and emphasized the importance of developing an ecosystem of supporting products that can enhance patient engagement and the adoption of rehabilitative technologies.

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## 1. Introduction

Stroke is a disease that is becoming more prevalent due to the increasing older population (Sanchetee, 2022). However, recent data indicates a concerning trend of stroke incidence among adults under 65 as well (Béjot et al., 2016). Stroke can be caused by the formation of blood clots or blocked blood vessels in the brain, abnormal accumulation of blood in the cranial cavity, or an insufficient supply of vital nutrients and oxygen to the brain (*About Stroke*, 2023). Approximately 30-50% of stroke survivors encounter an abrupt onset of neurological symptoms and physical disabilities (Beltrán-Rodríguez et al., 2022; Sanchetee, 2022). These complications may include a range of cognitive and motor impairments resulting in difficulties with speech, attention deficit, balance and gait, pain, weakness, or paralysis (Postolache et al., 2021). Stroke rehabilitation plays a crucial role in helping stroke patients improve or regain the functionality of affected extremities or cognitive impairments.

A stroke patient may encounter difficulties coordinating movements of their face, arm, and leg on one side of their body (Langhorne et al., 2009). Motor dysfunction and impairments of the upper limbs are the most commonly recognized impairment caused by stroke and affect approximately 80% of stroke patients (Kwakkel et al., 2015; Langhorne et al., 2009). Therefore, stroke rehabilitation is a critical process that can help restore these functions and help patients improve or adapt to lifestyle changes post-stroke. However, there are barriers associated with stroke rehabilitation, including a lack of resources and difficulties with transportation and access for those living in remote areas, as well as challenges with patient engagement and sustained motivation throughout the rehabilitation and recovery process (Jutai & Teasell, 2003; Mårtensson, 2023). As a result, there is interest in creating technical solutions that can address these limitations. The challenges in stroke rehabilitation highlight the need for innovative solutions that can improve accessibility and maintain patient engagement. Technical innovations offer promising opportunities to address these limitations while providing customizable approaches to rehabilitation.

Technical innovations introduced in the rehabilitation process, such as robotic devices and Virtual Reality (VR), can be highly customized and specific in use (Jones et al., 2010). Clinicians and developers are also repurposing mainstream technologies like smartphones, Nintendo, and Wii Fit to house platforms for rehabilitative games (Jones et al., 2010). These advancements in technology and telemedicine have created new opportunities for more

accessible stroke rehabilitation and are better able to adapt to new approaches to care (Gebreheat et al., 2024).

This thesis aims to investigate opportunities to develop an engaging sensor-based or instrumented stroke rehabilitation device for patients completing stroke rehabilitation at home. Home-based rehabilitation technologies provide the advantage of flexibility for both time and location and remote evaluation from clinicians (Chen et al., 2019). The project adopts a Research through Design approach, which employs reflective and iterative methods of design practice throughout the process of creating and critiquing artifacts to generate new knowledge (Zimmerman & Forlizzi, 2014). This thesis specifically oversees the development of a sensor-based device for stroke rehabilitation and gathers insights from a variety of stakeholders through a co-creation workshop. The artifact and workshop generate a deeper understanding of the varying experiences throughout rehabilitation as well as factors that influence the usability, motivation, and sustained use of rehabilitative technology, informing future prototype iterations. Additionally, the integration of technology in rehabilitation practices represents a shift from traditional approaches, requiring careful consideration of both technical capabilities and human factors that influence adoption and sustained use.

## **2. Literature Review and Context**

### **2.1. Stroke Rehabilitation Interventions Post-Stroke**

The primary purpose of stroke rehabilitation is to uphold the stroke patient's ability to function independently and improve their overall well-being (Beltrán-Rodríguez et al., 2022). Another goal of rehabilitation is to aid patients in adapting to new limitations and environments and providing the patient with support if recovery does not occur (Govender & Kalra, 2007). Stroke recovery is organized into clinical stages as follows: the acute phase covers the first two weeks following the stroke; the subacute phase spans the third to eleventh-week post-stroke; the early chronic stage spans the period from twelve to twenty-four weeks post-stroke; and the chronic stage includes any period following the initial twenty-four weeks (Wu et al., 2015). Different rehabilitative interventions occur throughout each phase post-stroke, including early mobilization of hands, arms, and legs in the acute phase and further motor and language recovery in the subacute and chronic phases.

The structures of care following a stroke are specific to each individual and involve a multidisciplinary approach that addresses different aspects of a stroke patient's recovery (Sancheete, 2022). There is a need for "sustained and coordinated effort" from a multidisciplinary team to deliver stroke rehabilitation and care (Winstein et al., 2016, p. 141). Communication and coordination between members of a rehabilitation team are critical to the effectiveness of rehabilitation. Members of a stroke patient's rehabilitation team, including physicians, occupational therapists, physiotherapists, speech therapists, nurses, social workers, nutritionists, friends, and family, help define the patient's rehabilitation goals and needs of care (Beltrán-Rodríguez et al., 2022; Winstein et al., 2016).

Stroke rehabilitation is a complex process tailored to a patient's individual needs and necessitates a multidisciplinary approach. It emphasizes collaborative efforts between physicians and other members of the rehabilitation team to work towards a stroke patient's recovery and independence throughout each of the phases post-stroke. Among the variety of rehabilitative interventions, physical and occupational therapy plays a critical role in recovery and addresses mobility, strength, and the ability to perform daily activities.

#### **2.1.1. Physical and Occupational Therapy**

Physical and occupational therapy are vital elements in stroke rehabilitation and entail the use of functional and purposeful activities to achieve attainable outcomes and develop,

improve, or sustain the “highest possible level of independence” (Legg et al., 2007, p. 1). These therapies begin during the acute phase of recovery within the first 24-48 hours and help determine areas of the body and brain that are affected to begin the recovery process (Beltrán-Rodríguez et al., 2022). Early intervention is crucial as the brain demonstrates heightened neuroplasticity in the initial weeks post-stroke, allowing for enhanced potential in neural repair and functional recovery (Cramer & Riley, 2008). The objective during the subacute phase of recovery is to regain functionality and adapt to deficits (Beltrán-Rodríguez et al., 2022). Rehabilitation involves a cyclical process where assessments are completed to identify the needs of patients, goals are set for improvement, interventions are prescribed to assist in achieving goals, and reassessment determines the progress made toward achieving the goals (Langhorne et al., 2011).

Physical therapy is a key discipline in stroke rehabilitation, and there is strong evidence that it favours intensive and repetitive task-oriented and task-specific physical therapy interventions and training in all phases following a stroke (Veerbeek et al., 2014). For the improvement of arm and hand function, effective interventions include constraint-induced movement therapy (CIMT) or modified versions of CIMT (mCIMT) (Kwakkel et al., 2015). This treatment approach involves the repetition of task-specific training using the affected limb while restraining the unaffected (Langhorne et al., 2011). Task-specific training, otherwise known as functional task practice, emphasizes the patient’s learning or relearning of motor skills and is “based on the premise that practice of an action results in improved performance of that action” (Winstein et al., 2016, p. 129). Other physical therapy interventions for upper limb function include bilateral arm training, which describes a process that involves the use of both arms simultaneously in an independent manner, and electrostimulation, which describes an approach that involves the delivery of electrical stimulation to the peripheral neuromuscular system through electrodes (Langhorne et al., 2011). These forms of rehabilitation, as well as high-intensity training, repetitive task training, and robot-assisted training, have been tested and used to improve the motor function of the hand (Langhorne et al., 2011).

Occupational therapy allows for the assessment of the impact of stroke on a patient’s coordination, motor function, sensation, visual perception, and cognition (Rowland et al., 2008). Occupational therapy models place emphasis on the interactions between the patient, the activities of daily living (ADLs) they are performing, and the environment in which these activities occur (Govender & Kalra, 2007). Some occupational therapy methods aimed at improving the function of the upper limbs include stretching, static and dynamic splinting, and

muscle strengthening, which aids in the development of grasp, reach, and object manipulation skills (Rowland et al., 2008). Observational assessments are conducted to determine a patient's ability to complete tasks and activities previously established in their daily lives to determine attainable and specific goals related to these activities (Rowland et al., 2008). These activities might include self-care tasks like grooming, showering, and getting dressed, as well as other activities like eating, taking medication, and cleaning. A patient undergoing occupational therapy for upper limb function may practice using everyday objects, including keyboards, mobile phones, jars with different lids, various books and magazines, as well as zippers and buttons (Rowland et al., 2008). Occupational therapy can greatly improve a patient's performance in activities, and there is evidence to support that therapy that targets personal ADLs can increase performance scores following an assessment and reduce the risk of deterioration and dependency (Legg et al., 2007).

Both physical and occupational therapy are crucial to the recovery of motor function, helping patients regain the abilities needed to complete ADLs and gain functional independence. With advancements in technology, new digital tools and devices are transforming traditional methods of rehabilitation, making therapies like physical and occupational therapy more engaging and adaptable. The integration of these technologies allows for tailored, interactive experiences through the rehabilitation process.

### **2.1.2. Technology for Stroke Rehabilitation**

In addition to physical and occupational therapy, more novel therapies have been used in conjunction with traditional task-specific exercises for stroke rehabilitation. An increasing number of robotic-based rehabilitation devices combine motorized mechanical components with visual feedback and interactive programs to assist with hand function and maintain patients' motivation (Hatem et al., 2016). These robotic devices, including arm supports and other robot-assisted therapies, employ exoskeletons that aid in arm, wrist, and hand movements and can generate or mimic a variety of forces or motions for repetitive practice (Chen et al., 2019).

Alongside the development of robot-assisted therapies, virtual reality (VR) and augmented reality (AR) environments have also been developed for stroke rehabilitation. There is ongoing research that systematically studies the clinical effects of VR games or virtual exercises for the rehabilitation of upper limb motor functions (Chen et al., 2019). These technologies are able to accurately capture complex variables throughout motor rehabilitation, including time, pressure, and speed (Postolache et al., 2021). VR immersion techniques

introduce more playful and engaging aspects of rehabilitation through interactions with gamified elements or serious gaming (Hatem et al., 2016). These games prompt patients to complete activities like pouring water or using a hammer with their affected arms, providing a controlled and safe environment that aims to translate into real-life applications (Chen et al., 2019).

Sensors are often used in rehabilitation to measure patient movement and provide feedback (Chen et al., 2019). Romeo et al. (2017) proposed the use of instrumented objects to investigate and explore human grasping strategies. Instrumented objects are objects equipped with sensors capable of collecting data on force, pressure, velocity, and others. These objects have been developed using sensors such as force/torque sensors to measure and collect dynamic values of the hand, including grasp pressure and finger posture (Simone et al., 2007). Additionally, instrumented objects have been developed to aid in the performance of ADLs, such as books or utensils integrated with sensors for force measurement. The primary objectives of these instrumented objects included quantifying the forces applied during grasp exercises, estimating the angles of orientation, and detecting instances of slippage. Although these devices may not be specifically designed for stroke patients, sensor-integrated objects can assess functional tasks performed by hand. For example, instrumented books or utensils can precisely examine palmar or lateral grasp while completing activities like picking up large objects or eating (Memberg & Crago, 1997). Other instrumented objects can allow clinicians to obtain accurate measurements of joint angles in a patient's hands as well as forces exerted during pinching tasks (Marek et al., 2023).

The integration of these technologies throughout the rehabilitation process not only supports physical recovery but delivers customized and responsive interventions. Digital platforms introduce interactive and gamified experiences, while instrumented objects allow for progress tracking and goal setting. This convergence of robotic assistance, virtual reality, and sensor-based instrumentation redefines traditional methods of rehabilitation with comprehensive, data-driven approaches. By integrating real-time feedback systems and remote monitoring capabilities, rehabilitation becomes more personalized and accessible, effectively bridging the gap between clinical care and home-based therapy.

## **2.2. Limitations of Existing Rehabilitation Methods and Research**

There is evidence that supports the concept that stroke rehabilitation is best provided in specialized rehabilitation settings with interdisciplinary teams of clinicians and staff (Jutai & Teasell, 2003). However, these methods of rehabilitation are often more costly and require more

time and travel for patients who live outside urban areas, which can be challenging for patients who experience difficulty with mobility. Specifically for patients who reside in rural communities, rehabilitation units may be smaller and provide more generalized rehabilitation with fewer clinicians (Jutai & Teasell, 2003). Stroke patients in small towns may rely on community transportation to attend rehabilitation appointments, which often entail long waits and travel times, causing stress to patients (Mårtensson, 2023). This can be particularly challenging for patients living with disabilities who face additional financial difficulties, as stroke rehabilitation can lead to significant out-of-pocket expenses (Ganesh et al., 2017).

Technological rehabilitation solutions such as VR or robotic devices also entail challenges with use. These devices often require patients to be more technologically proficient as they often add a layer of complexity and sometimes require setup facilities that patients may have difficulties with (Chen et al., 2019; Jones et al., 2010). Technological devices and interfaces can produce usability challenges and difficulties in adopting these rehabilitative interventions over long periods. These challenges are further complicated by technology developers who often overlook the importance of simple user interface designs or sufficient instructions for patients and clinicians to effectively apply the technology (Jones et al., 2010). There are concerns about privacy and system security associated with these devices as well (Chen et al., 2019). Additionally, interactive platforms, serious games, and other digital or VR environments can be costly and may not be easily tailored for specific rehabilitation purposes, offering more general interventions and exercises (Chen et al., 2019).

Although traditional stroke rehabilitation interventions, such as physical therapy, are beneficial to patients and remove the difficulties associated with technological rehabilitation devices, these interventions can be demanding, repetitive, tedious, and resource-intensive (Saposnik et al., 2010). Research on the experiences of stroke patients revealed that some individuals who received outpatient rehabilitation described the exercises as monotonous and felt disconnected from real-life contexts (Mårtensson, 2023). These exercises included picking up large objects and putting them aside or moving small items from one container to another. Lack of patient interest and reduced motivation in the rehabilitation process can cause severe detriments to the quality of rehabilitation and prolong an already costly rehabilitation period (Postolache et al., 2021). Stroke patients explained that it was more beneficial to incorporate exercises that connected to their interests or felt more meaningful or fun (Mårtensson, 2023).

Motivation and engagement remain considerable challenges in clinical settings of stroke rehabilitation as well as when prescribing exercise for the home environment. Because home-based therapies require patients to regulate their exercises independently, it is crucial to provide engaging rehabilitation exercises that integrate both internal and external motivations, are entertaining, or adapt to a patient's progress (Chen et al., 2019). Motivation in the context of stroke rehabilitation is poorly understood and is shown to have blurred boundaries (Verrienti et al., 2023). However, there is a strict link between motivation and levels of participation, as deficits in motivation significantly alter the scale of patient involvement throughout rehabilitative interventions where active engagement is crucial for recovery (Verrienti et al., 2023). There is a need to develop more engaging rehabilitation tools that are widely accessible, accepted by patients and caregivers, and promote long-term adoption and use (Sanchetee, 2022).

### **2.2.1. Home-Based Stroke Rehabilitation**

Following a stroke, patients may be discharged from hospitals due to a lack of equipment or resources or the patient's desire to stay with friends and family (Sun et al., 2023). It is, therefore, critical to ensure that home-based stroke rehabilitation or domiciliary interventions and devices are designed to allow for remote engagement, allowing patients to continue their recovery outside of clinical settings.

Several supporting systematic reviews endorse task-specific and context-specific training for motor learning and suggest that interventions can and should be given in the patient's personal environment (Langhorne et al., 2011). Findings from a meta-analysis revealed that receiving occupational therapy services within the home improved and extended ADLs in the first year post-stroke (Langhorne et al., 2011). A study evaluating the mobility status of stroke patients one-year post-stroke found that patients who received post-discharge rehabilitation treatment found significant improvements in their mobility, and the opportunity of returning home after discharge may encourage greater involvement and participation in rehabilitation (Paolucci et al., 2001). According to Winstein et al. (2016), upper extremity rehabilitation programs can be administered in various settings, including hospitals, clinics, and in a patient's home. A systematic review followed by a random, controlled trial (RCT) indicated that outpatient methods of stroke rehabilitation and home service models exhibit comparable results in regard to activity and mobility of the upper extremities, including a patient's ability to engage in ADLs (Winstein et al., 2016). A systematic review of therapy-based rehabilitation

services administered to patients living at home found that patients were able to perform ADLs more independently and had a higher likelihood of maintaining that ability (Legg et al., 2007).

In addition to the ability to perform ADLs more independently, home-based stroke rehabilitation (HBSR) is also associated with greater patient satisfaction and reduced strain on caregivers, as well as a decrease in hospital readmission rates (Allen et al., 2014). Treating patients in a familiar environment offers the advantage of stimulating both mental and physical activity, providing more meaning to tasks (Van Der Veen et al., 2019). The integration of home-based and community-based rehabilitation services with an early supported discharge can reduce the overall cost of stroke rehabilitation by 15% without compromising patient outcomes in comparison to standard care (Allen et al., 2014).

Telerehabilitation has been widely used for stroke recovery and describes the use of telecommunication technologies between therapists and patients to conduct therapy sessions (Chen et al., 2019). Although this is an emerging field, home-based technological systems allow for the remote reception of feedback from therapists. When considering the implementation of HBSR, it is necessary to address gaps that may arise among patients and caregivers, as well as healthcare practitioners, following a patient's discharge (Van Der Veen et al., 2019). A study conducted by Van der Veen et al. (2019) revealed that healthcare practitioners highlighted the importance of their active involvement in treating patients following a stroke. Other key elements that factor into implementing HBSR include the importance of a structured and well-organized communication platform or facility. A survey of existing remote rehabilitation technologies describes various devices that integrate elements of remote monitoring as well as opportunities for clinicians to provide feedback through voice communication, video conferencing, and application-assisted communication (Sun et al., 2023).

Designing effective remote or HBSR technologies presents opportunities to overcome barriers such as limited access to rehabilitation centers or hospitals, challenges with transportation, and a lack of access to specialized care. These devices enable patients to continue completing rehabilitative interventions from the comfort of their homes. However, a systematic review of home-based technologies for stroke rehabilitation highlighted that while healthcare providers (HCPs) were able to better engage patients in clinical settings, the absence of the therapist in the home environment led to destructured sessions and reduced engagement (Chen et al., 2019). Studies have shown that patient adherence to rehabilitation programs without the support of professionals at home is often poor, as exercises may be seen

as boring, tedious, or difficult to complete (Balaam et al., 2011). Therefore, it is crucial for technology developers to carefully consider the design of these devices and interventions in ways that enhance usability, sustain motivation, and promote adherence to rehabilitation.

### **2.2.2. Motivation and Engagement in Rehabilitation**

Motivation plays a critical role in the recovery process for stroke patients. Rehabilitative interventions that motivate patients and sustain patient engagement are thought to improve both cognitive and motor performance (Verrienti et al., 2023). As motivation is a key factor in stroke rehabilitation, many studies have drawn on various theories of motivation to explore its influence on behaviour. The understanding of these theories plays a significant role in adapting designed systems and technologies to better support those recovering from stroke (Balaam et al., 2011).

Self-determination theory (SDT) is a framework that explains that in order to maintain behaviours and be self-determined, patients must remain autonomously motivated (Saebu et al., 2013). This framework is increasingly being used in studies concerning health-related behaviour changes (Saebu et al., 2013). People and patients tend to feel more motivated to act or sustain engagement after observing effects driven by their own actions (Verrienti et al., 2023). The theory further explains that patients are more likely to feel motivated and regulate health-related behaviours if their needs for autonomy, competence, and relatedness or connection are fulfilled (Saebu et al., 2013; Verrienti et al., 2023). Autonomy refers to one's need to feel in control of one's actions, while competence refers to feeling confident in one's ability to complete tasks. Relatedness refers to the need to feel a sense of connection to others or a sense of belonging within a community. The theory further highlights the role of intrinsic and extrinsic motivation as central features of SDT, providing the groundwork to understand motivation in stroke rehabilitation (Kusec et al., 2019). Intrinsic motivation refers to a desire to engage in activities derived from one's own interest or enjoyment, while extrinsic motivation describes the desire to accomplish tasks based on external factors, specific outcomes, or rewards (Kusec et al., 2019). It is proposed that motivation in patients during the subacute phase of stroke is influenced mainly by extrinsic factors like positive feedback from healthcare staff or family members (Verrienti et al., 2023). Achieving a sense of autonomy, competence, and relatedness then moves a patient's motivation from an extrinsic to an intrinsic level, resulting in more regulated exercise behaviours and, consequently, long-term improvements (Verrienti et al., 2023). Both intrinsic and extrinsic motivation can alter engagement and task performance in healthcare settings. Identifying factors influencing a patient's intrinsic and

extrinsic motivations in rehabilitation can lead to improvements in the quality and quantity of task performance (Kusec et al., 2019).

### **2.3. Research Questions**

The objective of this thesis is to explore opportunities to address the limitations in the current methods of stroke rehabilitation, including technical usability and accessibility challenges and a lack of engaging or motivating exercises in traditional therapies. This thesis investigates the use of instrumented objects to support effective, home-based rehabilitation and identifies factors that can enhance patient engagement and long-term use of rehabilitative devices. The thesis aims to answer the following questions:

1. What are the needs and experiences of rehabilitation patients concerning their use of technology for rehabilitation?
2. How can an instrumented object support rehabilitation for stroke patients?

### **3. Methodology**

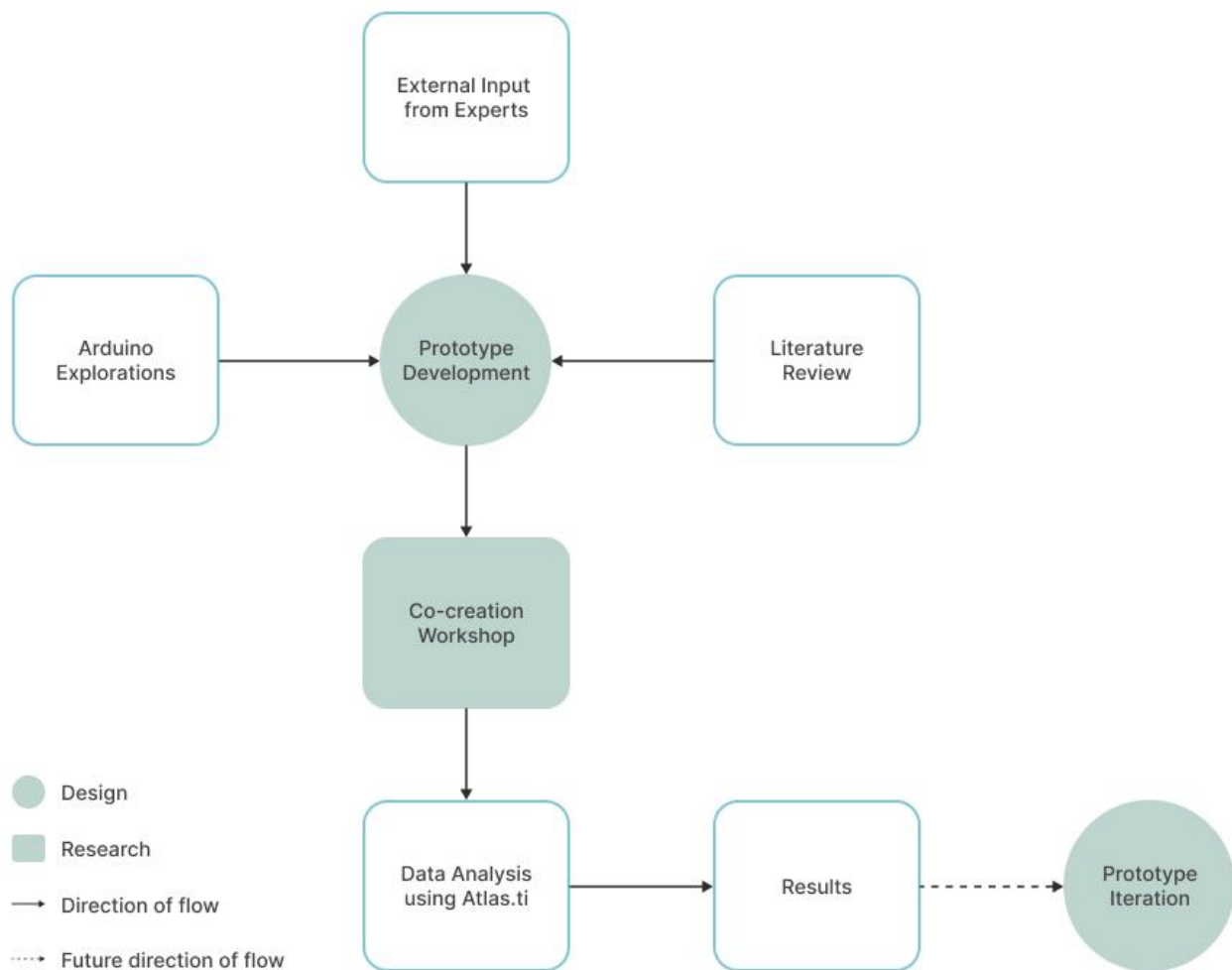
This thesis adopts a Research through Design (RtD) practice, using participatory design methods to gather data and insights to create more efficient and engaging technologies for stroke patients. Participatory design methods attempt to actively involve the people being served through the design process to ensure that their needs are met (Sanders & Stappers, 2012). A key element of participatory research lies in the attitudes of researchers and the “location of power” during the research process (Cornwall & Jewkes, 1995, pp. 1667–1668). While participatory design methods emphasize community empowerment, they retain hierarchies from traditional methods of research, with researchers maintaining traditional research roles, expertise, and power (Cornwall & Jewkes, 1995). However, within the landscape of participatory design is the co-creation approach, which emphasizes a more collaborative and shared innovation process (Pirinen, 2016). Co-creation prioritizes the involvement of stakeholders throughout all project stages and recognizes participants as being valuable in their individual domains of expertise, while researchers become facilitators and learners (Pirinen, 2016; Vargas et al., 2022). As defined by Sanders and Stappers (2008), it is a term that refers to any act of collective creativity. Co-creation promotes the “creation of value” through a collaboration between stakeholders in the process of understanding complex problems and evaluating relevant solutions (Vargas et al., 2022, p. 2).

There is a growing body of literature exploring the definition and domains of co-creation and its applications (Galvagno & Dalli, 2014). In the context of this RtD practice, the co-creation approach involved engagement from various stakeholders including rehabilitation patients, technology developers, healthcare providers, and caregivers at a co-creation workshop.

#### **3.1. Research through Design**

RtD is a scholarly approach that employs the insights gained through design practices and processes to generate new knowledge or provide a better understanding of complex issues (Godin & Zahedi, 2014). Through this approach, researchers are introduced to novel perspectives on problems, producing insights and artifacts that serve as tools to further investigate these issues. The strength of this approach lies in gaining an actionable understanding of complex challenges and continuously reflecting on these problems during the creation of artifacts or prototype iterations that propose solutions (Stappers & Giaccardi, 2024). Christopher Frayling, who coined the term “research through design,” associated creation with research and explained that designers or researchers who engaged in RtD created new objects

and experimented with different materials and processes to garner insights (Godin & Zahedi, 2014). This involves the customization of technology to produce previously unconsidered outcomes, documentation of the methodology employed in a practical experiment, and the communication of these results (Frayling, 1993). Design activities and materials—specifically artifacts or prototypes—play a central role in knowledge generation and are crucial to the RtD process. They serve as vehicles to demonstrate a proof of concept, critique developing theories, and present opportunities for interactions and engagement (Giaccardi, 2019).



**Figure 1**

*Flow diagram depicting the Research through Design practice adopted for this thesis.*

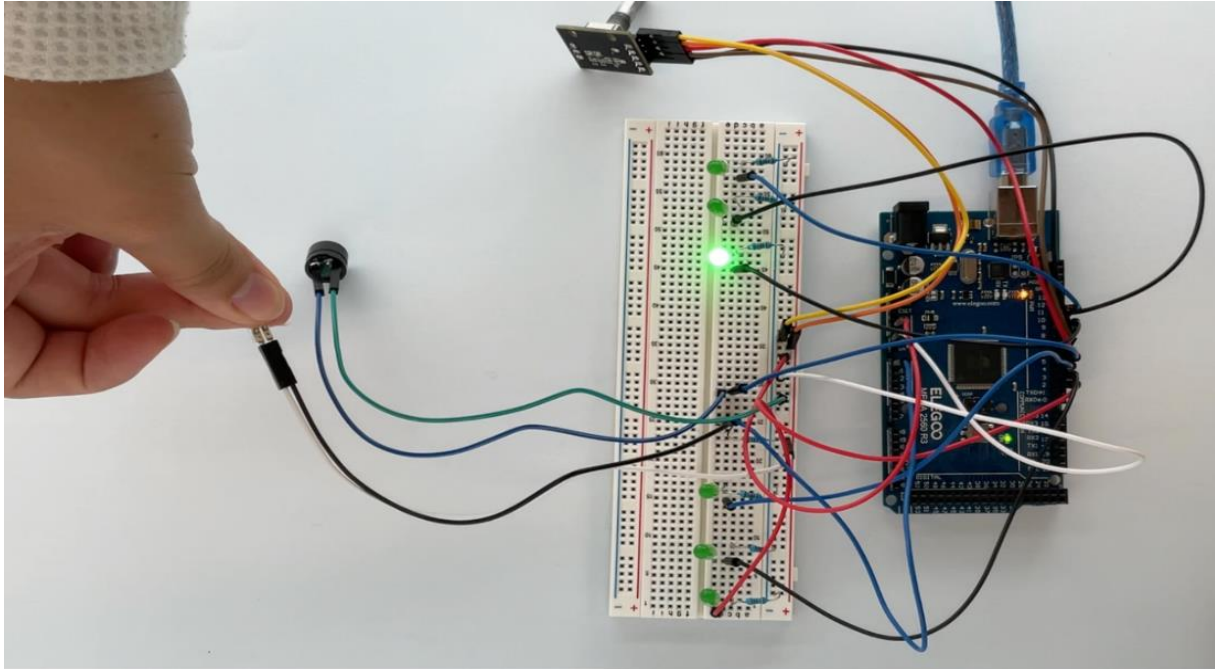
Figure 1 depicts the processes employed in this thesis, which follow an RtD framework. Secondary research, including a literature review and insights from experts at the York University Centre for Aging Research and Education student symposium, explored existing tools

and exercises to improve fine motor skills post-stroke and informed the design of the initial instrumented prototype. This prototype was then introduced in a co-creation workshop to gather qualitative data on participant engagement with technology and feedback on the usability of rehabilitation devices. Analysis of this data provided insights into the experiences of patients, caregivers, healthcare providers, and technology developers, highlighting areas where future iterations of the prototype could enhance patient engagement in stroke rehabilitation.

### **3.1.1. MorlensRehab Prototype Creation**

The prototype is named MorlensRehab and was developed with inspiration from exercises commonly introduced to stroke patients in occupational therapy, identified through the literature review. The instrumented device incorporates key exercises designed to improve fine motor skills, including grasping, twisting, and pinching. These movements are drawn from task-specific rehabilitation activities like opening a range of jars or containers, fastening clothing items like buttons or zippers, and sorting through small objects like coins (Rowland et al., 2008). These specific activities aim to practice fine motor skills and help to regain dexterity at home, as patients are often encouraged to continue these activities outside of therapy programs (Rowland et al., 2008). While repetitive actions are essential to the recovery of fine motor skills, stroke rehabilitation exercises are perceived as monotonous, which can hinder patient engagement. By housing these exercises in a kaleidoscope, it aims to make the rehabilitation process more engaging and fun. Patients can add small objects from their environment into the device to create new, vibrant, and colourful images. The design of MorlensRehab encourages users to complete rehabilitation exercises through the natural actions of playing with a kaleidoscope.

The prototype development involved experimenting with Arduino to integrate sensors for measuring grasp pressure and rotational movement (Figure 2). Pressure sensors were embedded within the body of the prototype, while rotary encoders were incorporated into the twistable top to measure grasping and twisting, respectively. LED lights and a buzzer were added to provide visual and haptic feedback in response to those actions. Based on findings from the literature review, sensors in rehabilitation technology are not only employed to measure patient movement and exercise but to provide visual and haptic feedback as well (Chen et al., 2019). This real-time feedback can inform users of the accuracy of their actions and indicate whether there are issues with form or technical issues that need to be resolved (Chen et al., 2019).



**Figure 2**

*An exploration of creating visual feedback with LED lights in response to pressure applied on a sensor using Arduino circuits.*

Initial design materials included sketches, a user flow diagram (Appendix A), and storyboards (Appendix B), which illustrated user interactions with the technology and the feedback provided. Audio instructions were recorded to guide patients through each exercise integrated into MorlensRehab. As the exercises were performed, LED lights indicated that the sensors could detect pressure applied to the prototype. Once an exercise was completed, the user could press the blue button to signify that they were ready to move on to the next exercise.

Figure 3 depicts the 3D-printed prototype with sensor-embedded finger grooves, a twistable top with a textured surface, and a removable cap to place small items within the prototype. The prototype of MorlensRehab takes into consideration the design of affordances to more accurately guide users on how to use the device. Affordances are properties that help define the interactions that are available or offered by the prototype (Gaver, 1991; Leung et al., 2023). They can improve the usability of artifacts and help users complete physical actions more effectively (Hartson, 2003). The finger grooves function as a physical affordance, informing users how to correctly hold the device so that the embedded sensors can accurately track grasp pressure. The 3D-printed prototype uses bright colours and varied textures to differentiate between interactive and movable parts of the device. The removable lid is yellow,

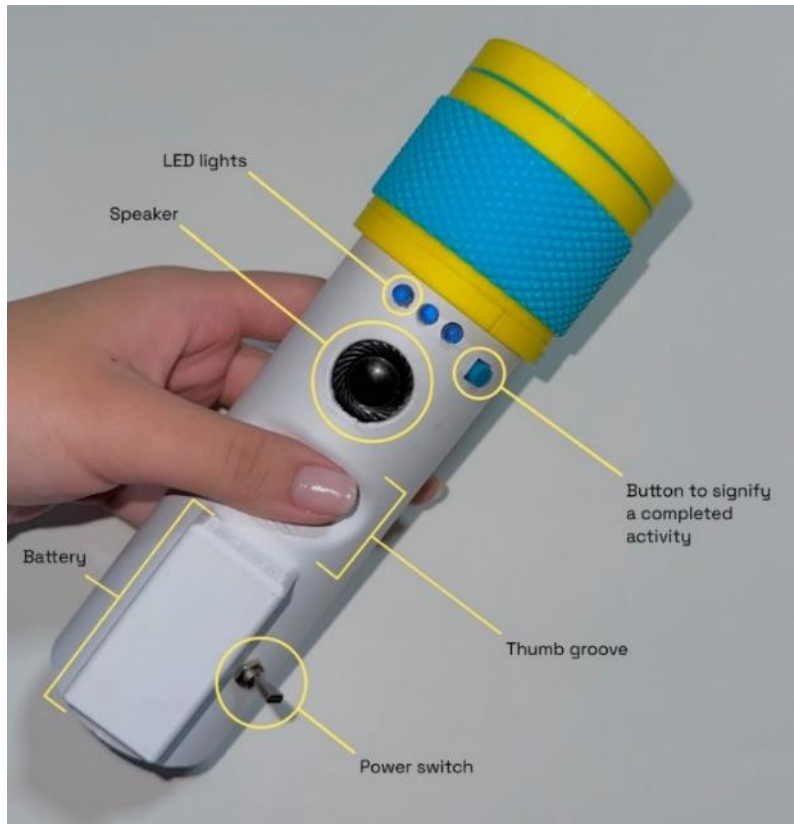
which visually signifies a detachable segment, while the twistable top is primarily blue. The blue textured surface on the twistable segment is an affordance as it provides a visual and tactile indication that the top segment can be held and twisted. The texture provides a firmer grip, enabling patients to grasp the top better while removing the lid.



**Figure 3**

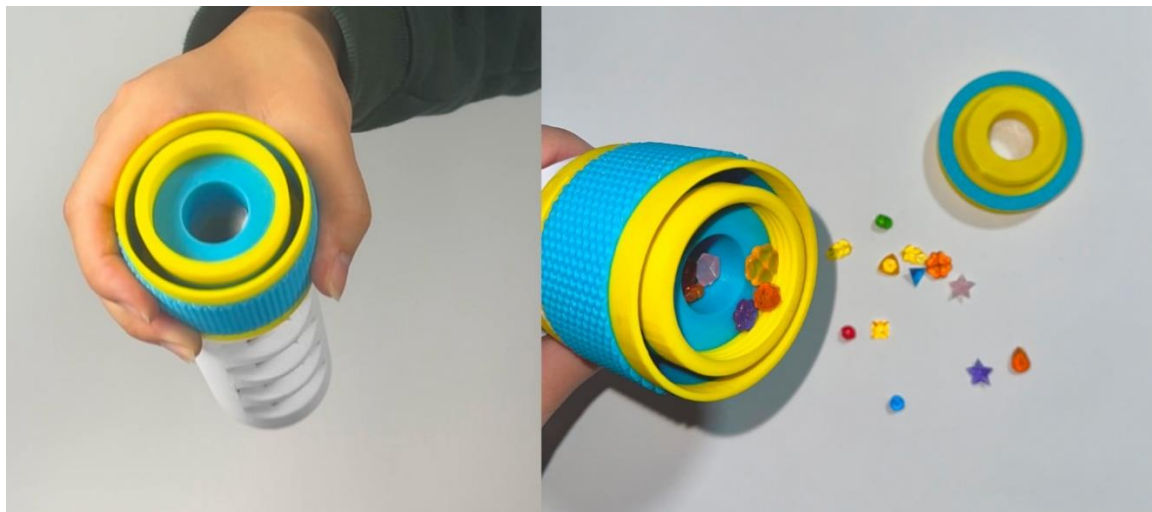
*A prototype of MorlensRehab with pressure sensors embedded into finger grooves.*

Figure 4 depicts the LED lights and speaker, which provide visual and auditory feedback, as well as the battery, power switch, and a groove indicating thumb placement. It also shows a blue button that patients press after completing an exercise. Figure 5 depicts the top of the prototype, where a removable lid allows patients to place small items, such as beads or buttons, to change the visualizations created through the device, and Figure 6 depicts the base of the prototype, where an eyepiece allows users to see the reflected images.



**Figure 4**

*The back of the prototype houses the power switch, LED lights, and a speaker.*



**Figure 5**

*The top of the MorlensRehab prototype can be removed and small objects can be placed inside to create vivid images.*



**Figure 6**

*At the base of the prototype, there is an eyepiece that allows users to look through and see the reflected images.*

The physical design properties of the MorlensRehab prototype were developed based on findings from the literature review as well as the initial explorations with sensors. The integration of occupational therapy exercises within the device informed the physical design of the prototype and required it to fit comfortably within a patient's hand to enable the tracking of grasp pressure. The finger grooves are a design property and physical affordance that provide visual cues on how to properly grasp and interact with the prototype. It also had to include a segment that could be twisted, along with a detachable lid, to allow for customization of the small objects in the top. The visual design properties of the prototype aimed to make the device feel more inviting. The use of bright colours aimed to convey a sense of playfulness and allowed patients to differentiate between movable segments, providing visual guidance on how to interact with MorlensRehab.

The prototype was then used in the Scavenger Hunt session of a co-creation workshop titled the Collaborative Technology for Healthy Living (CTHL) workshop, where participants reflected on their personal experiences with rehabilitation and technology and provided feedback and insights into the design of the prototype.

### 3.1.2. Co-Creation Workshop

The CTHL co-creation workshop was conducted with 19 participants from urban city centers and rural towns, fostering a wide range of perspectives and insights. Participants from all four stakeholder categories were invited to attend the full-day CTHL workshop to share their lived experiences with rehabilitation, rehabilitative technologies, and how technology can support home-based rehabilitation. The workshop took place at the York University campus and was divided into two sessions: *Show and Tell* and *Scavenger Hunt*. These sessions were part of a more extensive set of tools called TUNGSTEN Tools, which enables technology developers, researchers, service providers, and organizations to understand how people interact with technologies and what they value, creating better technologies for older adults (*TUNGSTEN Training*, 2024).

**Table 1**  
*Show and Tell Group Compositions*

Group 1	Group 2	Group 3	Group 4
Rehabilitation patient	Rehabilitation patient	Rehabilitation patient	Rehabilitation patient/ Caregiver
Rehabilitation patient	Technology developer	Rehabilitation patient	Rehabilitation patient
Technology developer	Technology developer	Technology developer	Technology developer
Healthcare provider	Healthcare provider	Technology developer	Technology developer
	Healthcare provider	Healthcare provider	Healthcare provider

Prior to the start of the workshop, participants signed and returned informed consent forms (Appendix C) and filled out a demographic questionnaire that identified their name, age, the stakeholder role that most applied to them, their area of residence, and previous experiences with remote health technologies (Appendix D). Participants were then divided into four groups, each consisting of at least one rehabilitation patient, one healthcare provider, and one technology developer. Table 1 shows the group compositions of the Show and Tell groups.

During the Show and Tell session, each group was given a set of worksheets and two hours to share technologies they liked and disliked or abandoned (Appendix E). Participants were asked to describe how they obtained the technology, how they learned to use it, and what they liked or disliked about it to their group members. A scribe was appointed in each group to take note of what was discussed on the worksheets. Figures 7 and 8 depict the Show and Tell session where qualitative data regarding individual experiences with these technologies was uncovered, highlighting participant preferences or frustration and factors that may have influenced their continued use or abandonment of the device. At the end of the Show and Tell session, each group shared their discussions with the larger workshop (Figure 9). It is important to note that participants were not instructed on what types of technologies to bring. Instead, participants used their interpretation of technology when bringing devices they loved and disliked or abandoned.



**Figure 7**  
*Group 2 sharing their experiences with resistance bands during the Show and Tell session.*



**Figure 8**  
*Participant 4 sharing a picture of his loved technology, an instrumented knee brace, with group 1 during the Show and Tell session.*



**Figure 9**

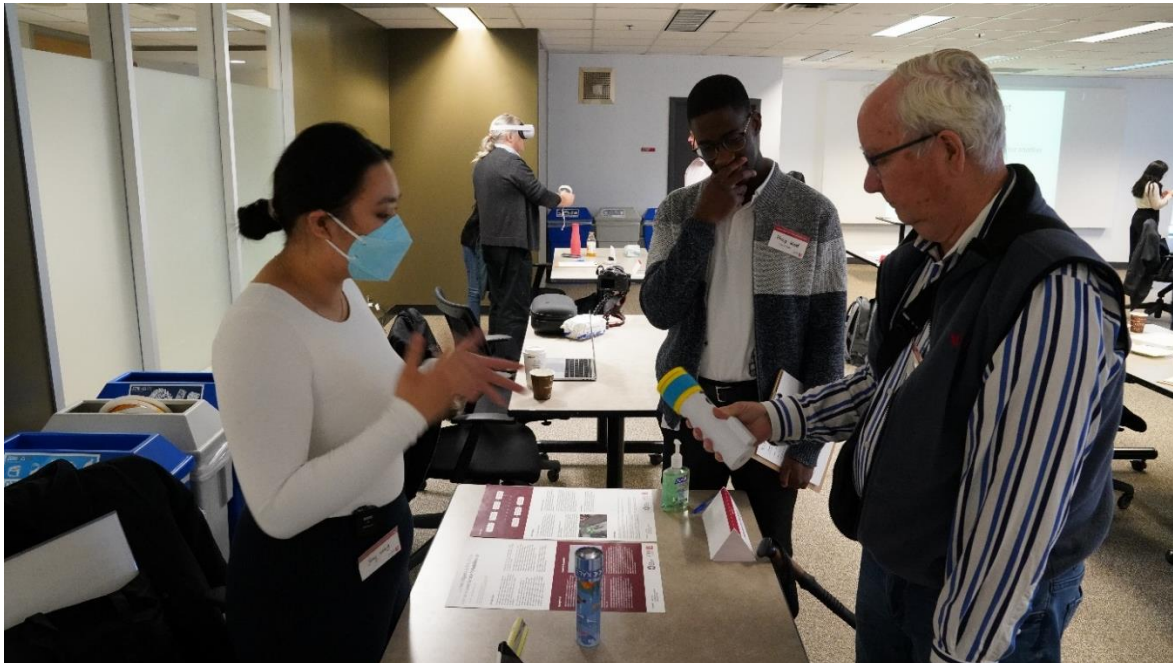
*Participant 13, a rehabilitation patient, shares group 3's discussions with the rest of the workshop participants during the Show and Tell session.*

In the second session, Scavenger Hunt, participants in pairs interacted with seven technologies across seven technology stations (Figure 10). The MorlensRehab prototype was one of these technologies (Figure 11). Each pair moved through the stations, where the researcher or rehabilitation technology developer introduced the devices and guided participants in interacting with them. Participants were provided with feedback sheets to document their experience with each device and commented on whether the device was easy and enjoyable to use and whether they would use the device (Appendix F). They also shared insights on any challenges they encountered and suggested modifications that might enhance the user experience with the device. Feedback provided by the participants highlighted areas of improvement that could be addressed in future iterations of the instrumented object.



**Figure 10**

*Technology developers set up their technologies at different booths for participants to interact with during the Scavenger Hunt session.*



**Figure 11**

*Participant 13, a rehabilitation patient, interacting with the prototype of MorlensRehab during the Scavenger Hunt.*

### **3.2. Ethics**

Ethics approval was obtained by York University's Office of Research Ethics. All participants who were contacted to participate in the workshop were provided with information regarding the purpose and methods of the study. Participants each received and signed a consent form that outlined any ethical considerations. They also returned consent forms allowing for video and audio recordings.

### **3.3. Participants and Recruitment**

Workshop participants were recruited through flyers, emails, and word of mouth. Various community day programs and health organizations were contacted, including MedEx Health Services, The Neighbourhood Organization, and The Vaughan Pain and Wellness Centre. The recruitment criteria required that participants belong to one of the following groups: rehabilitation patients, caregivers, healthcare practitioners, care providers, and rehabilitation technology developers. Nineteen participants from various stakeholder groups participated in the co-creation workshop. Of these participants, six were rehabilitation patients, one was a caregiver, five were health and care providers, and seven were technology developers. To ensure diversity in our sample, we collected demographic data, including participant sex, age, residential location (small town or urban area), stakeholder role, and prior experience with tele-wellness services.

### **3.4. Data Analysis**

Audio recordings and worksheets from the Show and Tell session, along with feedback sheets and audio recordings from the MorlensRehab booth during the Scavenger Hunt session, were analyzed using thematic analysis in Atlas.ti. Guided by Braun and Clarke's (2008) framework for thematic analysis, codes were applied to the recording transcripts to identify patterns and themes within the data.

The thematic analysis began with familiarization of the data through reviewing the workshop audio and video recordings and transcribing each of the four Show and Tell groups as well as the recorded MorlensRehab Scavenger Hunt booth. After reviewing the transcribed data, each transcript was uploaded onto Atlas.ti, where codes were applied to participant quotations in the transcripts. Inductive coding captured insights from the data that were potentially relevant to the research questions and reflected participant likes and dislikes, needs, challenges, and

experiences with technology and rehabilitation. Additionally, each code was added to a code book that outlined the definition of the code as well as its inclusion criteria. After each transcript was coded, common codes were organized into groups that allowed patterns and, later, key themes to emerge. These themes were refined following reviews of the transcript to ensure that they accurately reflected the participant discussions and data. The themes were then defined and renamed to convey the significance of each theme clearly.

## 4. Results

### 4.1. Demographic Information

**Table 2**

*Demographic Information of Study Participants*

Participant	Sex	Age (years)	Resides in small town	Stakeholder role	Has experience with tele-wellness
P01	Female	31	No	Rehabilitation patient	Yes
P02	Female	68	Yes	Rehabilitation patient	No
P03	Female	-- <sup>A</sup>	--	Technology developer	--
P04	Male	24	No	Healthcare provider	Yes
P05	Female	81	Yes	Rehabilitation patient	Yes
P06	Male	80	Yes	Rehabilitation patient/ Caregiver	Yes
P07	Female	45	No	Healthcare provider	Yes
P08	Male	70	No	Technology developer	Yes
P09	Male	35	Yes	Technology developer	Yes
P10	Female	43	No	Rehabilitation patient	Yes
P11	Male	25	No	Healthcare provider	Yes
P12	Female	26	No	Technology developer	Yes
P13	Male	72	No	Rehabilitation patient	Yes
P14	Female	--	--	Rehabilitation patient	--
P15	Female	27	No	Technology developer	Yes

Participant	Sex	Age (years)	Resides in small town	Stakeholder role	Has experience with tele-wellness
P16	Female	--	No	Healthcare provider	Yes
P17	Male	48	No	Healthcare provider	Yes
P18	Male	--	--	Technology developer	--
P19	Male	56	No	Technology developer	Yes

<sup>A</sup> -- Participant did not provide an answer.

The workshop participants ranged in age from younger participants (24) to older adults (80+) from both urban areas as well as smaller towns and rural areas (Table 2). Out of the 16 participants who completed the demographic questionnaire, only one reported not having prior experience with tele-wellness or remote health technologies like wearable fitness devices, health tracking applications, teleconferencing platforms, or remote rehabilitation services.

Six participants indicated having experience with wearable fitness devices like the Apple Watch or Fitbit to monitor their health. On the demographic questionnaire, participant 4, a healthcare provider, described having a positive experience using an Apple watch to track vitals like sleep patterns and blood pressure. Both participant 11, another healthcare provider, and participant 15, a technology developer, also described having positive experiences using wearable fitness devices, explaining that the technology is intuitive and there was little difficulty setting up and using the device.

While most of the questionnaire feedback described positive experiences with remote health technologies, some participants mentioned occasional challenges. Participant 11 explained that after using his Fitbit for some time, he felt uncomfortable with the constant monitoring of his steps and vitals. Participant 9, a technology developer, recounted that the devices were “glitchy’ but did the job.” Participant 17 and participant 7, both healthcare providers, mentioned that the technology they used was costly for individuals to purchase. Additionally, several participants who experienced using teleconferencing platforms for consultations explained that they preferred in-person appointments.

## 4.2. Show and Tell Results

**Table 3**

*Liked and Disliked Technologies*

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Liked Technologies	Disliked or Abandoned Technologies
Adaptive bicycles	Alexa or Siri
Duolingo	Social media
iRobot	Calorie Tracker
Resistance bands	Zoom
Running shoes	Bosu ball
Gerry Connect	Physiotherapy website
CPAP	Virtual care
Vehicle	Smartphones
Hearing aid	Fitbit
Chirp	Apple watch or smartwatch
Opioid management app	iPod
Portal for health records	iPad or tablet
Automatic car starter	
Pillow	
Knee brace	
PS4	
Wordle and NYT games	
Left-handed scissors	
Smart phones	
Fitbit	
Apple watch or smart watch	
iPod	
iPad or tablet	

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The Show and Tell session provided insights into a variety of technologies that participants loved, as well as technologies that were disliked or abandoned (Table 3). Loved technologies included resistance bands, adaptive bicycles, knee braces, and more interactive digital platforms like the New York Times Wordle, Gerry Connect, or Duolingo. Participants

highlighted features that encouraged their use, including elements that contributed to the rehabilitation process, were multi-functional, convenient, and easy to use.

*“[Resistance bands are] so simple. It's basically just a rubber band. But they have so many applications for strength building, rehab, all kinds of things.”* (Participant 15, technology developer)

Zoom was mentioned as a disliked technology by four participants, who cited difficulties with directionality, a lack of social connection, or increased misunderstandings when used in educational settings.

*“... I started getting into communication and communication, communicative systems. And the motivation was to develop better telecommunication systems than Zoom ... it lacks what I call directionality. If someone points into the camera or if someone looks into the camera, everyone on the other end feels pointed at or feels being looked at.”* (Participant 18, technology developer)

*“And really it was the lack of social connection, the increased chance of errors in understanding, just the impoverished communication that's there, and also really having to depend on [Zoom], especially over the last few years.”* (Participant 19, technology developer)

Several technologies, including smartphones, tablets, iPods, and Fitbits, received mixed reviews, as some participants described these devices as essential and enjoyable, while others found them frustrating to use. Participant 15 presented Fitbit as a loved technology and explained that they enjoyed using Fitbit to track their heart rate during physical activity. In contrast, participant 10 expressed frustrations with the wearability and challenges with the device, which led to the abandonment of their Fitbit.

*“I'm primarily a dancer, and I really liked [Fitbit] for just even tracking my heart rate and just seeing how that changes over time with my training.”* (Participant 15, technology developer)

*“... because I have to charge [the Fitbit] all the time. I always forget to charge it. And then it's the wristbands; they're always some itchy ones or something. Something is always wrong. So yeah, I gave up on Fitbits.”* (Participant 10, rehabilitation patient)

**Table 4**  
*Themes from the Show and Tell Session*

Theme	Codes	Quotations
Motivation and Engagement	Motivation and Engagement	“She’s on these cycling apps, right? If she can be the fastest woman to do this route, it really motivates her.”
	Gamification	“... [Duolingo] which is a language app, and it's completely gamified, and it's kind of good in that it gives you lots of things, and you can do it for 10 minutes and build your language skill.”
Reliance on the Internet	Connectivity and Bluetooth	“... it seems most of the people here are using things and they have apps, and they have connectivity, but not everybody is going to be in that situation, will have reliable Wi-Fi.”
	Downloadable or Offline Use	“Yeah, well that's why I discovered there's an archive, so before I get on a plane or something, I can download a bunch of stuff.”
Plug-and-Play	Automation	“... [calorie trackers] require too much work ... we talked about automated information, like the steps in my iPhone, I do like, but having to sit down and put import recipe ... I don't.”
	Convenience	“So, in my experience, the more simple, the better. People are more likely to consistently use it. If you had a big system ... people get tired of it. Or you need more time to do it. Versus if you can just pick up something and go. It’s easier.”
	Accompanying App or Website	“So, if you want to use the app, you have to at some point download the app, but then it sits standalone.”
	Simple to Use	“And some additional comments about [resistance bands] ... Very simple to use and quite robust.”

Theme	Codes	Quotations
Privacy	Privacy, Consent, and Security	"... why this need to collect my conversations if I put [voice control] on? But for the users, why? What is the intention or motivation to have that function?"
	Closed Circuit	"... [Gerry Connect is] a closed loop system ... only authorized people can sign in."
Social Connectedness	—	"... there's also some dangers in that if you have a robot that's, say, changing the bed or moving you around, you need to worry about the social interaction that's lost. Normally you'd have the care worker coming in, and that's an easy opportunity for social interaction."
Onboarding Users to New Technology	Setup with Expert	"It was actually VHA delivered it to me ... They set [Gerry Connect] up for me. They also set up all my closed loop folks. So, they did all the heavy lifting."
	Lack of Instructions	"And one dislike was the current smartphones, there's no manuals ... to browse the internet." "Yeah, the manuals are poor, and they often don't even ship one."
	Difficulty Learning	"... if you've been told 'do this,' and you do it, and it's not giving you what you need, that's often a reason people will walk away. They go 'that's not for me,' 'I can't do that,' 'I must be too stupid,' or 'it's not going to work,' or 'I'm doing it wrong.'"
	Instructions Provided	"And [the physiotherapy website] was multimodal ... there were video instructions, there were written instructions, there were all these different instructions that it gave."
Monitoring Health and Wellness	—	"I use the watch for measuring steps every day in combination with the Apple phone. I use the phone also for heart monitoring and the watch ... if I go into an AFib mode, the watch will detect it and it'll send a signal so I have evidence of when I was in an AFib mode."

The thematic analysis of the Show and Tell session transcripts revealed seven key themes that influence the effectiveness and use of the specific technologies presented by the participants: motivation and engagement, reliance on the internet, plug-and-play, privacy, onboarding users to new technology, social connectedness, and monitoring health and wellness. These themes reflect elements of technologies that influence the usability and sustained engagement of a device, like ease of use, convenience, compatibility with other platforms or apps, features to enhance social connections, and the inclusion of instructional material. Each theme encompassed various codes assigned during analysis, which highlighted well-liked features of technologies, ways participants interacted with or responded to technology, and their preferences for specific functions. Table 4 provides a more comprehensive description of the themes and the coding inclusion criteria.

#### **4.2.1. Motivation and Engagement**

Factors relating to motivation and engagement drive the adoption and sustained use of technology. Participants described different features of technology that motivated or demotivated them to engage in activities involving specified technologies, including gamified elements and feedback.

*“But [Duolingo] does have this sort of gamified aspect ... You try and encourage people to participate.”* (Participant 19, technology developer)

*“You try and make it more fun, to reinforce it, to give you feedback, you know, which is good, but you know, it'd be nice to turn the dials a little bit on.”* (Participant 19, technology developer)

*“So I have to wear [the CPAP] at night. It's not easy, so it's taken me a lot of time to get used to it. But you know one of the motivators is it has a little, part of the application is that it has a scoring system.”* (Participant 13, rehabilitation patient)

Participant 13 explained that the application that accompanied the CPAP machine was able to track their sleep patterns and oxygen intake overnight. It provided the user with a nightly sleep score based on the data collected. The scorecard not only monitored sleep but reinforced adherence to the sleep apnea treatment and motivated the user to continue using the device.

Conversely, participants expressed how certain tracking features and activity goals could be demotivating. One participant shared their experience with step counters and described feelings of anxiousness due to the pressure to reach their step goal. They explained that the reminders to be active spoiled their natural enjoyment of being active and were ultimately

demotivating. The participant found that she enjoyed and engaged in physical activity more when they stopped using the step counter.

*“I know it's like counterintuitive, but I find the step counter actually demotivating for me ... I actually deleted the step counter thing, and I'm working out way more or doing something because I'm not thinking ... it feels like I'm more anxious about trying to get these steps instead of just being active.”* (Participant 12, technology developer)

Other technologies prompted users to set goals and were found to be motivating. Participant 6 shared that a family member found cycling technology motivating through the combination of physical activity with competitive elements and scenic views displayed by the device. They enjoyed the combination of entertainment and exercise with a set goal of completing bike routes as quickly as possible. Participant 19 shared this sentiment, explaining that their daughter also enjoyed the combination of physical activity and competition. She used a Fitbit to monitor her speed while cycling and was motivated to be the fastest cyclist on the specified route.

#### **4.2.2. Reliance on the Internet**

The majority of technologies presented by participants relied on network connectivity, including calorie trackers, e-health portals, and the New York Times Wordle. Participant 3 expressed the utility of downloadable content when discussing Wordle, noting that the archives allowed them to download puzzles prior to boarding a plane. While downloadable content is convenient and beneficial for technology users, it hinges on network connectivity, which poses a barrier for residents of rural areas or smaller towns where internet access can be limited. One participant from a rural town commented on their limited access to the internet, which hindered their ability to fully engage with technologies like Wordle.

*“And you don't have internet.”* (Participant 1, rehabilitation patient)

*“Exactly ... [Instructions are] on the website. Well, now I have to wait to be able to either go to North Bay or somewhere where I can [access the internet]. It's a huge barrier. Huge barrier. I hate it.”* (Participant 2, rehabilitation patient)

#### **4.2.3. Plug-and-Play**

Participants highlighted the convenience of technologies, particularly those integrated with accompanying apps or websites for purposes such as monitoring. For example, participants who enjoyed using Fitbit found it easy to use and connect with their smartphones.

*"I'd say I used to use a Fitbit watch, and I just found it was really easy and convenient."*  
(Participant 15, technology developer)

*"So, if you want to use the app, you have to at some point download the app, but then it sits standalone."* (Participant 3, rehabilitation patient)

*"... so, on the app, I just drag it down, and then it says syncing [Fitbit] Versa 4, and it syncs automatically with the watch."* (Participant 1, rehabilitation patient)

A feature that significantly impacted the utility of the technology was automation. Some participants discussed how a lack of automation resulted in more time-consuming technological solutions, which discouraged them from using the technology altogether. The incorporation of automated systems reduced the amount of effort and time needed from the participants and minimized the potential for human error. Participant 9, a technology developer, encountered this challenge when using a calorie tracker that required tedious manual input.

*"So, the automated stuff, you can get behind because you don't have to do anything ... But when you're tasked with six hours of inputting data to go in [the calorie tracker] from the one hour of work you've just done, it doesn't make sense."* (Participant 9, technology developer)

#### **4.2.4. Privacy**

Older participants shared anecdotes of fraudulent incidents and experiences with scammers, which have made them more cautious of the privacy and security features of technology. While some technologies boast features that protect personal information, others lack protective measures, putting users at risk for cyber-attacks. Participant 13 expressed concerns about being deceived through insecure technologies and discussed the closed-circuit Gerry Connect technology they had been using.

*"... in the condo that I live in, we've had several cases of people being scammed ... seniors, widowed women in particular, who are being scammed by professional scammers."* (Participant 13, rehabilitation patient)

*"... I see that as a challenge for both, for the developers of technology but for the users to regain confidence and trust in the system that has been shaken."* (Participant 13, rehabilitation patient)

*"... the critical issue is that if you allow [Gerry Connect] into someone's home, you have to be 100% sure that it's secure. Someone could hack it. And all of a sudden, you've got a fake face showing up as a grandson."* (Participant 13, rehabilitation patient)

Participants 6, 11, 14, 15, and 19 discussed privacy features and issues with consent in relation to voice recognition software like Siri or Alexa. The participants emphasized concerns with the collection of private data and the monitoring of in-home conversations.

*“Yeah, I am concerned. I know I mentioned this again, but just the data - who's having access to that? If someone hacks that, and then they see, “oh, this person's in their home at X amount of times during the hours and stuff, if that gets into the wrong hands, that's really serious.”* (Participant 11, healthcare provider)

*“... how comfortable are you even having Amazon knowing ... Alexa knows a lot about you, right ... In your home, what you're doing, what you're talking about.”* (Participant 19, technology developer)

#### **4.2.5. Monitoring Health and Wellness**

Many of the participants' loved technologies allowed them to track or monitor different aspects of their health, including Fitbits and smartwatches, pain management apps, knee braces, and CPAP machines. These devices equipped participants to track their recovery progress and effectively manage their health goals remotely through the monitoring of physical activity, heart rate, and sleep patterns. Participant 13 described their use of a smartwatch to monitor alerts for potential health issues.

*“I use the watch for measuring steps every day in combination with the Apple phone. I use the phone also for heart monitoring and the watch. [...] if I go into an AFib mode, the watch will detect it, and it'll send a signal so I have evidence of when I was in an AFib mode, and I can think about what have I done that might have triggered it, if I've done anything unusual. And fall, I fell the other day, and I'm using, I use the watch as a tool to help me call someone for help. So that's been a perfect goal.”* (Participant 13, rehabilitation patient)

Other technologies, like Chirp, use sensors to monitor the location and movement of users around their homes. Specifically for patients who live alone or are home alone during the day, Chirp enables family members to track movement around the home and, in the case of an accident or fall, are able to notify for help. One healthcare practitioner shared their experience using e-health portals to access their own health records, lab results, and appointment logs. They explained that the e-health records had been a “game changer” and that all health documents were collated and easily accessed in one location (Participant 7, healthcare provider).

#### 4.2.6. Onboarding Users to New Technology

While onboarding and plug-and-play may appear to be similar, the theme of onboarding users to new technology encompasses distinct elements associated specifically with the initial setup and use of the technology, differentiating it from plug-and-play, which focuses on the seamless integration of a hardware component to a computer system. Onboarding refers to the process of familiarizing or integrating new users into a technology or system. This theme includes codes relating to setup and training and providing instructions or necessary information. Two older participants explained their difficulties with setting up new technologies or software and enlisted the help of professionals during setup. Participant 2 noted that while they have become accustomed to seeking assistance from experts, the resulting setup may not be the most optimal.

*“Yeah. So, when I do buy or when I upgrade, I’m a little bit more savvy now in saying, ‘here it is, you set it up,’ because I can’t.”* (Participant 2, rehabilitation patient)

*“... I have to rely on - Some of the things are how they’re setting it up, which is up to them.”* (Participant 2, rehabilitation patient)

Participants 1 and 5 both discussed using technologies that provide in-depth instructions. However, while Participant 5’s resistance bands were categorized as a loved technology, participant 1’s physiotherapy website was categorized as an abandoned technology. Despite the physiotherapy website offering written and visual instructions like the instruction booklet that accompanied the resistance bands, participant 1 found that the website was complex to navigate. The website access code eventually expired, rendering some instructions inaccessible.

*“... [there were] video, written and photo instructions. So, it was good in that sense that it was, at least it gave you videos showing you how to do the exercises.”* (Participant 1, rehabilitation patient)

*“Physio website. Complex to use. Code expires, and then you can’t access it anymore. So, I actually knew that was going to happen, so I downloaded them all as PDFs, but then you don’t get the videos because it’s a PDF.”* (Participant 1, rehabilitation patient)

A lack of clear instructions or poor training material can hinder the technological experience of users and make learning difficult. Integrating multimodal instructions can alleviate these challenges and barriers to accessing instructional material.

#### 4.2.7. Social Connectedness

Technologies such as Gerry Connect, Fitbit, and smartwatches include features that enable users to stay connected with family members. Contrastingly, other technologies like hearing aids, Wordle, and adaptive bicycles, which do not have intrinsic social features, facilitate equally strong relationships with friends and families of participants, as well as with other members of the community using the same technologies. Participants 1 and 3 highlight that playing Wordle has allowed them to keep in touch with distant relatives who also play on a daily basis.

*“... I play Wordle every day, actually, and it's how I keep in daily contact with my mom and my partner's aunt.”* (Participant 1, rehabilitation patient)

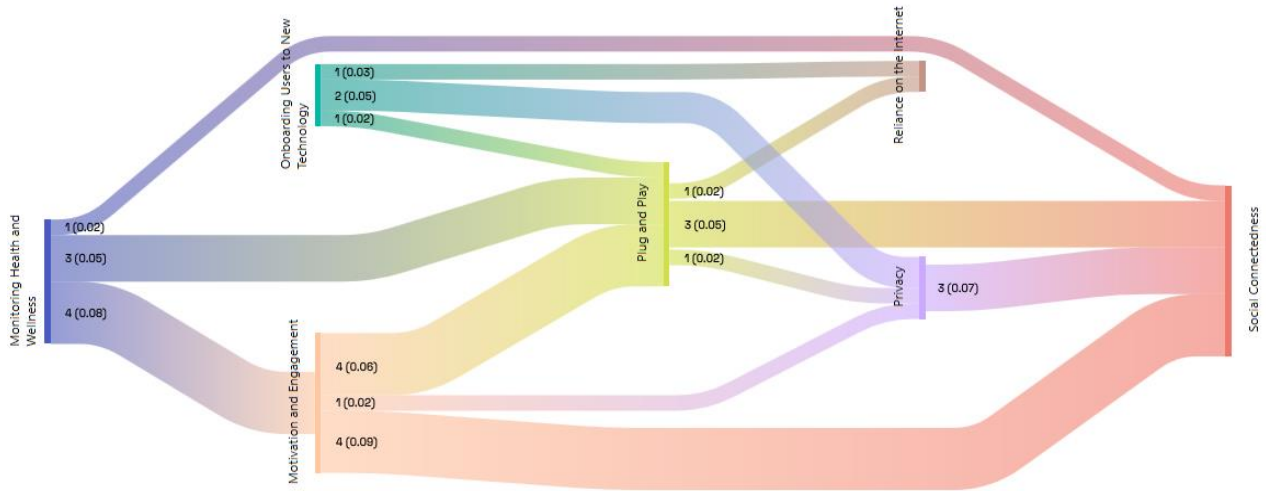
*“I love Wordle so much ... I actually feel like I'm closer to my family now because of Wordle.”* (Participant 3, technology developer)

Participants also discussed the adverse effects that some technologies have had on social interactions and interpersonal relationships. Digital platforms like social media and Zoom were cited for their distractions and their impact on communication. The prolonged use of Zoom throughout the pandemic contributed to feelings of social disconnect and challenges with communication.

*“... very few of us liked Zoom. We used it, we all used it a lot ... And really it was the lack of social connection, the increased chance of errors in understanding, just the impoverished communication that's there, and also really having to depend on it, especially over the last few years.”* (Participant 19, technology developer)

*“I think you mentioned Zoom. For me, I absolutely do not use it anymore if I don't have to, especially after having to teach labs through Zoom during COVID ... And there's just such a disconnect from being able to show someone math in-person versus through a screen, you're trying to explain, I mean they have the whiteboard option where you could draw things, but it just took so much more time.”* (Participant 15, technology developer)

### 4.3. Co-occurrences Between Show and Tell Themes



**Figure 12**

*Sankey diagram displaying frequency of co-occurrence and co-occurrence coefficient between all themes from Show and Tell data.*

The analysis of the co-occurring themes from the workshop data can be visually represented through Sankey diagrams. Using Atlas.ti software, themes from the Show and Tell session were analyzed for co-occurrence to determine the relationships between the themes. Codes from two themes were considered related and were included in the co-occurrence frequency when they appeared together in the transcripts from the Show and Tell data.

Figure 12 presents a Sankey diagram that illustrates the co-occurrences between all seven themes from the Show and Tell data. The values in the Sankey diagrams indicate the frequency of co-occurrence (shown outside the brackets) and the co-occurrence coefficient between themes (shown within the brackets). The co-occurrence coefficient demonstrates the strength of the relationship between the two themes, with a range from zero, which demonstrates a weak relationship, to one, which demonstrates a strong relationship. The theme of motivation and engagement co-occurred with the theme of social connectedness four times, with a coefficient of 0.09. Similarly, motivation and engagement co-occurred with monitoring health and wellness four times, with a coefficient of 0.08. The theme of plug-and-play co-occurred with the theme of monitoring health and wellness three times, with a coefficient of

0.05, and the theme of social connectedness co-occurred with the theme of privacy three times, with a coefficient of 0.07.

While the Sankey diagram displays low co-occurrence coefficients between the themes, it may mask meaningful relationships that deserve further exploration. A low co-occurrence coefficient may be caused by the small sample size of this thesis project or an unequal frequency between the two themes.

#### **4.4. Scavenger Hunt Results**

The thematic analysis of the worksheets and transcripts from the MorlensRehab booth in the Scavenger Hunt session resulted in the themes of clinical use and physical features (Table 5). After interacting with MorlensRehab, participants commented on the use of the instrumented object in clinical settings as an assessment or diagnostic tool. Participants also provided suggestions to enhance the physical features of the prototype to create a more comfortable and engaging experience when using the device.

**Table 5**  
*Themes from the Scavenger Hunt Session*

Theme	Codes	Quotations
Clinical Use	For HCP Use	“So, it could be a possibility that clinicians could have [MorlensRehab] and they could lend this to a patient for that time period.”
	Recognizing Different Users	“... [does the prototype) recognize the individual’s ID? The participant coming to [use MorlensRehab] might be A or B.”
	Transmitting and Visualizing Data	“I think it’ll be helpful for the person to have that too, that data, just so they can track their own progress. It’s more motivating that way.”
	Assessment or Diagnostic Tool	“Yeah, I felt like this could be a great study if you could be doing [with] someone [who] had a stroke, like as a point of entry at the hospital somewhere.”
	Needs an Introduction	“Where it says, ‘this is easy, something I would use,’ I mean, you’d have to be somewhere where [MorlensRehab] could be introduced to you,”
Physical Features	Hand Placement	“... I was going to say, [the finger pads are] quite far apart. If your hand isn’t that big, it wouldn’t fit.”
	Haptic Feedback	“... or even [incorporating] a clicking sound.”
	Sensor-Integrated Surface	“... make the whole [prototype] sensitive ... like the screen of a phone over the surface.”

#### 4.4.1. Clinical Use

This theme encompasses codes such as “visualizing data” and “recognizing different users,” which relate to the potential use of MorlensRehab in a clinical setting or with HCPs. These include the need for an introduction to the instrumented device, the ability to recognize various users and user data, the transmission and visualization of data, and its potential to be an assessment or diagnostic tool. Participant 16, a healthcare provider, saw the potential of the

device for monitoring the progress of stroke patients over time. They emphasized the value of using the device as an assessment tool in clinical settings and the importance of recognizing different users to avoid mixing patient data.

*“In terms of data collection, as you said, it could come directly to a physician ... So would it be a possibility that clinicians could have [MorlensRehab] and they could lend this to a patient for that time period, like for ten days, for example, for three months, and that could give them a set of data of what they're looking for.”* (Participant 16, healthcare provider)

*“But if [MorlensRehab] is a diagnostic tool or an assessment tool at, let's say a clinic, then it would have to be able to track which person is using this right now, what's their ID. And then it would kind of have to differentiate all the data to make sure that it's not mixing patient data.”* (Participant 16, healthcare provider)

Another participant emphasized the need for proper introductions to the device. They explained that without clear instructions, patients would not be aware of the device and its features and would, therefore, be unlikely to purchase or use it at home.

#### **4.4.2. Physical Features**

Some participants provided suggestions on physical features that would enhance the usability and comfort of the prototype. This included considerations for hand placements, incorporating haptic feedback, and suggestions for the integration of sensors on the device. Participants 5 and 8 expressed challenges with the hand placements and finger pads on the prototype, highlighting difficulties or discomfort in lining up their fingers with the finger pads.

*“Yeah, I was going to say, [the finger pads are] quite far apart. If your hand isn't that big It wouldn't fit. My hand fits okay but I can feel it's quite far apart.”* (Participant 5, rehabilitation patient)

*“See, that's my natural way [of holding the prototype] and they're much closer together than [the finger pads].”* (Participant 8, technology developer)

Participant 8 also noted that the integration of sensors that wrapped around the surface could mitigate difficulties with hand placement and enhance the usability of the device.

*“That would make it much more user-friendly. You don't have to actually, carefully put their fingers in known positions.”* (Participant 8, technology developer)

*“And it would even be able to measure [the size of a hand], which might be useful to calibrate when you're measuring the pressure. Because this arm with the small hand, presumably, is going to squeeze less strongly.”* (Participant 8, technology developer)

## **5. Discussion**

The goal of this study was to gain a deeper understanding of the needs and experiences of rehabilitation patients with technology to inform the development of engaging stroke rehabilitation technologies like MorlensRehab. Through a co-creation approach, the study considered the perspectives of stakeholders, including patients, caregivers, healthcare professionals, and technology developers. Insights from the Show and Tell session led to the emergence of seven themes—motivation and engagement, reliance on the internet, plug-and-play, privacy, onboarding users to new technology, social connectedness, and monitoring health and wellness. These key themes, combined with direct feedback and themes from the Scavenger Hunt, emphasized features that could make the prototype more engaging, user-friendly, and suited for use at home.

### **5.1. Perception of What a Technology Is**

Workshop participants discussed a wide array of liked and disliked technologies ranging from physical objects to digital platforms (Table 3). Although there were no restrictions on what constituted “technology,” the items brought in or discussed by participants demonstrated a broad understanding of the concept.

Some participants focused on digital tools such as Fitbit and smartwatches, health management apps, and voice assistants, while other participants highlighted non-digital tools like Bosu Balls, resistance bands, left-handed scissors, and running shoes. Additionally, not all technologies were directly related to rehabilitation. However, participants could see the supportive role the technologies could play in the recovery process. For example, participants discussed using smartphones to assist with communication in case of emergencies or issues with safety. The diversity of the highlighted technologies emphasizes the broader understanding that a “technology” is any tool that simplifies or helps to manage daily tasks, whether they are physical, analog objects or digital products. Technology is seen as a tool that supports their daily activities.

### **5.2. Game-Like Features and Positive Reinforcement**

Participants shared experiences with various technologies, each with different factors contributing to their engagement with the technology and motivation or demotivation to continue using them consistently. Gamification refers to the integration of game-like features like point systems, leaderboards, or badges in non-game contexts to increase motivation and

engagement (*Gamification and Game-Based Learning*, 2024; Martinho et al., 2020). Game-like features on digital platforms like Duolingo and Wordle incorporate scoring systems and badges, which encourage daily engagement for workshop participants. Gamification techniques have been beneficial in improving the physical, cognitive, and social well-being of older adults, and technologies like serious games are being explored as a method of delivering more encouraging and personalized treatments (Martinho et al., 2020). Game design elements are often integrated into healthcare technologies to enhance user experience while using the service. Although the CPAP machine does not include game-like elements, its accompanying interface provides users with a nightly sleep score and scorecard, which a participant described as feeling game-like and motivating. This feature, along with the positive affirmations provided by the interface, has positively influenced the participant's sustained use of the machine. Affirmations were another feature that contributed to increased engagement with technology. Participants explained that positive affirmations were displayed when effectively completing a task or activity. However, they were also displayed when tasks were not done correctly or did not meet a specified goal, which motivated participants to keep trying. They expressed the need for constant affirmation, as it helps participants stay motivated and aids in the continued use of technologies that improve their health.

Digital games are becoming an increasingly popular pastime for older adults as they provide a combination of challenge, competition, and reward (Khalili-Mahani et al., 2020). However, despite the growing interest in the gamification of digital health, many older adults have difficulty adopting these new technologies due to a lack of experience (Khalili-Mahani et al., 2020). In the study by Khalili-Mahani et al. (2020) on the stress responses of older adults to gaming experiences in relation to their cognitive abilities, the results indicated that while the games did not elicit stress responses and provided an overall enjoyable experience, most participants found the games to be visually intense and challenging to play. This is echoed in a systematic review by Martinho et al. (2020), which explains that older adults face difficulties understanding, accepting, and adopting new technologies and game mechanics, resulting in significant challenges in recognizing the benefits of these systems. This emphasizes the need for developers to consider the barriers experienced by older users to ensure that interventions with game-like elements are accessible and effectively integrated.

### **5.3. Onboarding and Initial User Setup**

Onboarding refers to the process of introducing and familiarizing users with new technology or technological systems. This might include setting up the device and providing any necessary instructions and support to ensure that users understand how to use technology effectively. In the context of this study, the theme of onboarding users to new technology encompasses instances where participants spoke about the initial setup of their technologies, the instructions or lack of instructions provided, and their overall experience learning to use the technology. Many participants, specifically older adults, emphasized the importance of clear and accessible instructions or manuals due to prior negative experiences with technology. The frustration prompted by a lack of instructions or difficulty navigating software can lead to the abandoning of technology altogether. Older participants also explained that they sought out support from professionals to set up digital devices and initiate the onboarding process. However, one drawback of relying on experts is the difficulty participants experience customizing device settings afterwards. In contrast, participants described experiences where the onboarding process was straightforward, with clear and easily understandable instructions. These participants were provided with multimodal instructions, including illustrated instruction booklets and access to video instructions online. A comprehensive onboarding process which encompasses setup, training, and integrating and familiarizing the user with new technologies is a critical factor in creating a positive interaction and sustained engagement with the new technology.

### **5.4. Challenges with Internet Connectivity**

A few workshop participants residing in rural towns voiced challenges with internet access. The theme of reliance on the internet encompasses factors relating to connectivity and Bluetooth and accounts for instances when participants mentioned downloadable content or features that allowed for offline use. While offline capabilities were not embedded into all of the technologies that were discussed, participants noted that specific features of their loved technologies permitted offline use, enhancing their engagement and interaction with the software. One participant mentioned that in their area, they relied on limited data plans to use digital platforms and had to travel to the closest town to connect to the internet. Rural areas in numerous countries experience a digital divide due to limited monthly broadband allocations, fewer service providers, and the high cost of internet connectivity (Hodge et al., 2017). These barriers can cause a loss of opportunities to access training and necessary technological

support in rural areas (Hodge et al., 2017). The participants described feeling frustrated when certain features of a device were reliant on Wi-Fi, as access to networks posed a significant barrier. Specifically regarding digital instructions, participants mentioned challenges accessing websites or having to travel for internet access to view instructions. Features such as downloadable content and instructions were seen as extremely advantageous, especially for those in rural areas, and kept participants engaged with the technology regardless of the status of their connectivity.

## **5.5. Themes that Co-Occurred with Motivation and Engagement**

Motivation is a widely explored limitation within stroke rehabilitation, especially within domiciliary rehabilitation, as it has a significant impact on patient engagement and outcomes in motor rehabilitation (Kusec et al., 2019). The themes that co-occurred with motivation and engagement from the Show and Tell results were privacy, social connectedness, monitoring health and wellness, and plug-and-play. These themes provide insights into factors that contributed to participants' sustained use of technology.

Figure 12 depicts a Sankey diagram of the co-occurring themes as well as the frequency of co-occurrence and the co-occurrence coefficients, which measure the strength of the relationship between the themes. Although the co-occurrence coefficients are low and may indicate a weak co-occurrence in larger datasets, exploring these connections within this smaller sample can contribute to a better understanding of how participants interacted with technology and how these factors may have shaped their experience with the devices.

### **5.5.1. Privacy and Data Security Concerns**

Privacy emerged as a theme during the Show and Tell session and was a common concern among some of the workshop participants, particularly older adults. Participants expressed a range of concerns surrounding privacy and security when using rehabilitation technologies. Their specific concerns were regarding unauthorized access to their data, safeguarding for data storage, and potential data breaches. Participants also recounted experiences where they were misled by scams involving personal information and financial fraud through digital platforms. These experiences can be jarring and cause distrust of technologies. Participants described feeling suspicious, worrying about potential threats, and “losing confidence in the interchanges of the internet” (Participant 13, rehabilitation patient).

They expressed concerns about embracing technology as it increased their potential risk of fraud.

They highlighted the importance of features that protected their data and emphasized the need for more effective security measures. One rehabilitation patient who shared their experience with a virtual communication software called Gerry Connect highlighted the advantageous integration of a closed-loop circuit, which allowed only authorized users to contact the participant and access the system. This closed-loop circuit was created during the onboarding process and enhanced the participant's experience as they felt more comfortable with picking up the device, knowing that only authorized users could call.

Participants were concerned about the constant collection of surveilled data within their homes by voice recognition software like Siri or Alexa. They emphasized concerns with the potential collection of personal information and worried that the voice recognition software was privy to private conversations and user spending habits or was able to note times in the day a participant's home may be empty. Unauthorized access to private information could cause serious repercussions and rightfully demotivate users from accepting new technologies. A study conducted by the Oregon Center for Aging and Technology measured the willingness of older adults to share health data and found that while the older adults willingly shared monitoring data with family members and physicians, there was high concern that the data may have been given to others without their consent (Boise et al., 2013).

Those affected by past experiences of fraud may find it challenging to openly accept new technologies. Concerns with the security of their personal information can have a significant impact on an older patient's engagement with technology. By effectively addressing issues of privacy and security, technology can foster a stronger sense of trust with users and encourage users to engage with these tools more confidently. As suggested by Boise et al. (2013), programs or services using monitoring systems or internet technologies should consider establishing safeguards to minimize risks associated with internet data transmission. It is crucial to implement effective privacy and security measures in rehabilitative technologies to help users "regain confidence and trust in the system that has been shaken" (Participant 13, rehabilitation patient).

### **5.5.2. Ease of Use and Automation in Technology**

Plug-and-play is the theme that was most frequently discussed during the Show and Tell session. In computing, plug and play refers to the connection of a device or hardware to a computer system that requires little configuration or intervention from the user. This theme included codes such as automation, ease of use, technology with accompanying services and platforms, and overall convenience. Participants highlighted their experiences with the seamless transfer of data from one device to another and expressed preferences for automated systems. They described the time-consuming nature of manual input, which has the potential to introduce an element of human error. Participants are more motivated to use technology that incorporates automation as it reduces the effort required to use the technology and relieves the cognitive load when syncing data on multiple devices. There is a demand for technologies that are easily integrated with other existing devices on a network, which is driven by the offer of comfort and convenience, specifically among aging consumers (Arthanat et al., 2020). A review of advanced technologies for stroke rehabilitation and recovery found that a common barrier experienced by stroke survivors using wireless devices was the complexity of operations (Jones et al., 2010). Jones et al. (2010) suggest that to many stroke patients who use smartphones and apps face barriers with dexterity, vision requirements, and complex interfaces. This challenge can be mitigated by permitting easy adoption, such as seamless integration between Bluetooth devices, hands-free headsets, interfaces, or downloadable applications (Jones et al., 2010). These new technologies can support rehabilitation processes by providing straightforward, plug-and-play access to different functions, ultimately making the technological experience more enjoyable and accessible for patients.

### **5.5.3. Sustaining Engagement Through Social Connections and Health Monitoring**

The theme motivation and engagement co-occurred with the themes of social connectedness and monitoring health and wellness. These three themes were interconnected as many participants found progress tracking technologies with social features engaging. Technologies like Fitbit and cycling devices integrate features for both health monitoring and social connections.

The theme of social connectedness describes instances relating to building relationships, communication, and interactions with other people through features on the device or by immersing themselves in communities that use the technology. Many participants described loving technology that provided them with opportunities to interact with their friends

and family or community members. These technologies allowed family members to connect and monitor the activity of their loved ones, providing reassurance for those who do not live with their families. Conversely, some participants expressed a distaste for online communication platforms like social media. During the Covid-19 pandemic, the majority of participants were reliant on digital platforms to communicate with others. Some participants emphasized that the prolonged use of social media was distracting and hindered interpersonal relationships after the pandemic subsided. Older participants echoed these sentiments, noting that new digital substitutes for face-to-face interactions are often difficult to navigate, and instructions may not be provided, making them frustrating to use.

The results highlight a complex relationship between engagement with technology and social dynamics. Findings from the workshop suggest that technology does not need to integrate social features in order for people to feel connected to one another. For example, participants mentioned that completing the New York Times Wordle strengthened their interpersonal relationships, as the shared activity led to discussions and social interactions with others naturally. These nuanced perspectives emphasize the importance of considering direct and indirect social features when designing technology.

Health and progress monitoring technologies were very commonly used and were highly valued by the participants. Technologies that allowed health and fitness data to be tracked helped participants meet goals and were able to provide family members and clinicians with progress reports of their loved ones and patients, respectively. This shared data can foster a sense of connection between family and friends. The participants emphasized that having the ability to track their progress encouraged them to stay consistent with their rehabilitation routines. In the context of stroke rehabilitation, technologies that enable health tracking not only empower patients undergoing rehabilitation but also support healthcare practitioners as well. Existing technologies are being studied that combine tangible devices for rehabilitation with integrated systems for patient check-ins (Eng & Pastva, 2022). These technological systems enable patients to complete rehabilitation exercises, collate data on muscle stimulation, track motor recovery, store electronic medical records, and allow for remote supervision (Eng & Pastva, 2022). Participants who experience challenges accessing rehabilitation clinics or are reliant on home-based rehabilitation interventions benefit from health monitoring features. These features enable remote monitoring and immediate adjustment of treatment plans. For instance, technologies like the Opioid Management App oversaw participant 16's use of prescribed opioids for treatment. They explained that the app consistently provided reminders

and real-time updates on the progress of their treatment. It also allowed the participant's clinician to view their progress, enabling them to monitor their patient remotely, which promoted the continued use of the technology.

#### **5.5.4. Co-occurring Themes and Self-Determination Theory**

Self-Determination Theory has become an increasingly relied-upon framework in studies relating to health behaviours. In the context of stroke rehabilitation, it provides insights into how motivation can sustain prolonged engagement. The results of the co-creation workshop highlight themes as well as co-occurrences between the themes that align with the principles of SDT.

The co-occurrences between motivation and engagement, monitoring health and wellness, plug-and-play, and social connectedness illustrate the three core needs highlighted by SDT. According to the theory, a person becomes self-determined when their needs of autonomy, competence, and relatedness are met. Satisfying these needs has been predicted to enhance the motivation and maintenance of healthy behaviours over time (Ng et al., 2012). Feeling a sense of autonomy and competence can be supported by technologies or rehabilitative devices that adopt a plug-and-play setup and allow patients to monitor their exercises, health, and progress. The theme of social connectedness also co-occurs with motivation and engagement and delivers on the need to feel connected or related.

*"... I have a tendency to take [the CPAP] off at night. I don't really like it. But [the application] motivates me to say, I've got to make eight hours. And I said to my wife, my wife asked me many mornings, 'how did, what was your score last night?' So today I felt like I'm going to school ... and I got a 99 ... you do have a scorecard ... so it keeps track of all of your days." (Participant 13, rehabilitation patient)*

Participant 13 explained that there was an initial adjustment period when they began using their CPAP machine but noted the technology's ability to track their sleep and set personal sleep goals. Tracking features can support a patient's sense of autonomy, and the satisfaction from achieving a high score and successfully keeping the device on overnight demonstrates a sense of competence, both of which can reinforce patient motivation. Additionally, the feeling of relatedness is enriched through support and interest from their spouse, further reinforcing their use of the device. The combination of the scorecard and positive feedback provides extrinsic motivation, as the rewards of their actions encouraged the participant to continue using the device.

The co-occurring themes align closely with the principles of SDT and highlight the importance of satisfying the needs for autonomy, competence, and relatedness. Technologies that support these needs can encourage patients to take an active role in monitoring their progress, encourage rehabilitative goal setting, and foster social connections with those around them. The integration of these principles can contribute to increased feelings of motivation and sustained engagement with the devices and the recovery process.

## **5.6. Feedback on the MorlensRehab Prototype**

The insights and themes from the Scavenger Hunt session provided valuable feedback for potential refinements of the prototype. The two themes that emerged were physical features and clinical use, both of which highlight opportunities to improve the comfort and usability of MorlensRehab. These considerations align with other studies on instrumented rehabilitation technologies.

Physical modifications to the prototype would enhance its usability and comfort. Feedback from the Scavenger Hunt session highlighted areas for improvement, particularly relating to finger placement and the overall size of the prototype. Several participants expressed discomfort with the placement of the sensors, which could result in difficulties operating the device and inaccurate data collection through the sensors. Participant 19, a technology developer, suggested altering the position of the sensors across a wider, flatter surface to create more flexible placements for the hand. Using an array of sensors that are uniformly distributed across the surface of the prototype can reveal “key correspondences between different regions of a human hand while it is manipulating objects,” improving the accuracy of grasping information and creating a more comfortable experience for patients using MorlensRehab (Sundaram et al., 2019, p. 698).

Although the initial prototype was designed to support the rehabilitation of a stroke patient’s fine motor function, the device could be adapted for use in clinical settings to evaluate a patient’s fine motor progress over time. Instrumented technologies such as wearables were recognized as promising options for assessing different aspects of motor function in stroke patients (Maceira-Elvira et al., 2019). Some sensor-based devices have been successfully used for diagnostic purposes and allow healthcare practitioners to evaluate the execution of ADLs in stroke patients (Maceira-Elvira et al., 2019). These devices are also advantageous in offering precise measurements of changes to motor function and efficient wireless transmission of complex data (Maceira-Elvira et al., 2019). In order for MorlensRehab to be used effectively in

clinical settings as an evaluation or assessment device, modifications would be required to collect, store, transmit, and visualize data over time. Participant 16, a healthcare provider, stated that the device would also need capabilities to differentiate between patient profiles and data as well as considerations for privacy or security measures. Implementing the insights from the Scavenger Hunt session can enhance the functionality of MorlensRehab and improve its overall usability and engagement.

## 6. Project Limitations

The design of MorlensRehab involved the integration of Arduino circuits and sensors in addition to the physical development of the prototype. While the current prototype effectively demonstrated the functionality of the device and allowed participants to interact with MorlensRehab, a higher-fidelity version may have provided a broader range of feedback from workshop participants. More advanced fabrication resources and the addition of industrial design expertise would have helped in creating such a prototype.

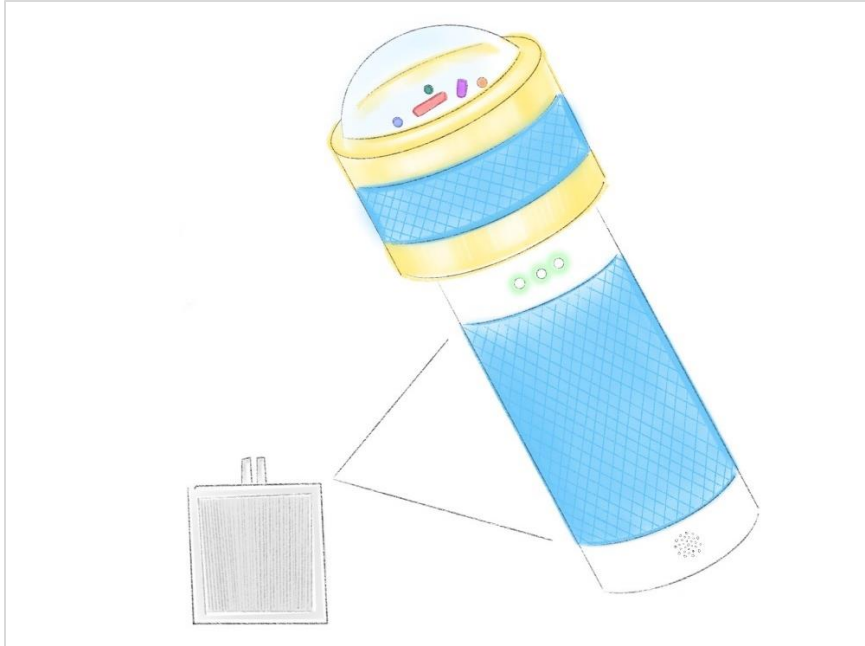
While the study employed an RtD approach, which emphasizes iterative development and the reflective nature of design, due to time constraints of the thesis program, there were limitations in the ability to implement study findings and create further iterations of the prototype. The MorlensRehab prototype was designed to incorporate only stroke rehabilitation interventions and patient experiences found in the literature. The prototype should include direct insights from rehabilitation patients or healthcare professionals during its development. However, the valuable insights and findings from the workshop establish clear guidelines for modifications and can support future iterations of MorlensRehab.

## 7. Design Implications

The themes that emerged from both the Show and Tell and Scavenger Hunt workshop sessions offer key insights that address the research questions guiding this thesis. The Show and Tell themes highlight participant interactions, preferences, and challenges with technology and inform the first question of what the needs and experiences of rehabilitation patients are concerning their use of technology for rehabilitation. The Scavenger Hunt session allowed participants to interact with MorlensRehab and offered feedback on how the instrumented object can better support stroke rehabilitation.

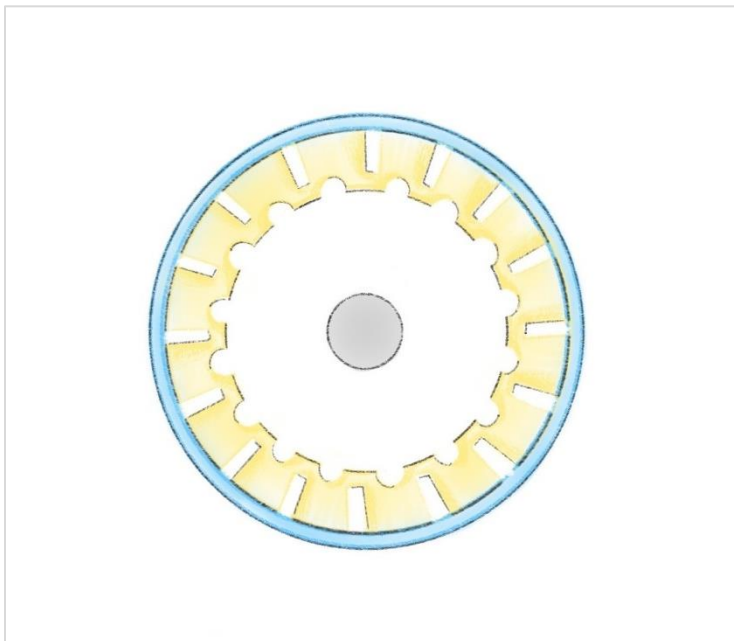
Key improvements for future iterations of the instrumented object were drawn from Scavenger Hunt themes and included modifications to the design of the physical features of MorlensRehab and opportunities to support its clinical use. One suggestion to enhance the design of the physical prototype was to modify the placement of pressure sensors, which can enhance the overall comfort and ease of holding or using the device. Several participants expressed difficulties with hand and finger placement, which could be alleviated through the re-positioning of the sensors. Additionally, participant 8, a technology developer, suggested using a more flexible array of sensors across a wider surface, which may mitigate this issue as well. While the initial design of the finger grooves on the prototype aimed to convey how to accurately grasp the device, the addition of more flexible sensors over the body of the device removes the need for finger grooves as the entire surface could allow for the tracking of grasp pressure (Figure 13).

Another suggestion to improve the physical design of the device was to better integrate haptic feedback. Participant 13, a rehabilitation patient, explained that the device might benefit from a clicking sound to signal completed rotations. Although haptic feedback was considered during the development of the initial prototype using a buzzer, technical limitations prevented participants from experiencing the haptic feedback during the workshop. Integrating this feedback and including auditory feedback in future versions could allow for a more responsive experience while using the instrumented device. Future iterations to the design of MorlensRehab could see the addition of grooves and notches between the segments of the prototype that twist against each other to ensure that haptic feedback is provided (Figure 14). The integration of these notches provides vibrational cues which indicate when full rotations of the top are completed.



**Figure 13**

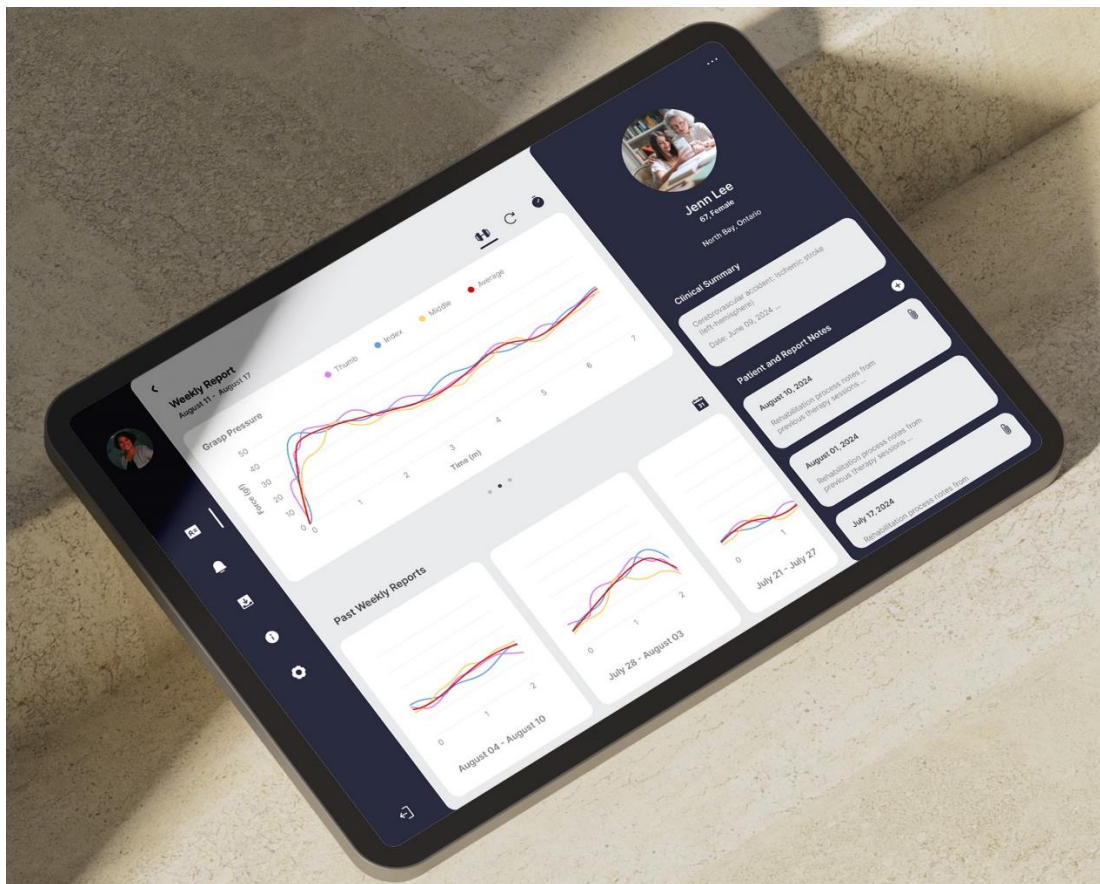
*Illustration of a future iteration of MorlensRehab where a wider, more flexible pressure sensor is placed over a larger surface of the device.*



**Figure 14**

*Future iterations of the device can include notches between the twisting segments to create haptic feedback as the patient twists the top.*

Themes from the Show and Tell session suggested opportunities to develop a more comprehensive experience with MorlensRehab to better support stroke rehabilitation. The themes of monitoring health and wellness, reliance on the internet, privacy, and social connectedness highlight opportunities to develop accompanying services and platforms to allow for these features and enhance the engagement of the instrumented object. Both participant 1, a rehabilitation patient, and participant 8, a technology developer, discussed opportunities to transmit and visualize data collected from the sensors. An accompanying app or website can provide users with an interface to visualize or track their motor activity and progress. Figure 15 is a mockup of an accompanying app. The interface shows a series of charts that depict the grasp pressure measured by MorlensRehab during patient use. With considerations for privacy, an accompanying app can allow users to securely share this information with clinicians or family members, enabling clinicians to monitor the progress of their patients remotely.



**Figure 15**  
*A mockup of an app that accompanies MorlensRehab and allows patients and clinicians to monitor progress when using the device.*

Ensuring that MorlensRehab seamlessly integrates with any accompanying applications or websites illustrates the theme of plug-and-play and can reduce the need to rely on experts for setup. Future iterations of MorlensRehab could include instructional manuals and videos on how to accurately use the technology and effectively set up any accompanying services. This can streamline the onboarding process, making the experience more accessible for patients and reducing the need for professionals to aid in the onboarding process. Additional resources that could be developed to create a more holistic experience for the patient include technology support channels to assist with software issues. It could also oversee a platform for patients to share images created using MorlensRehab with their family members or other patients using the device, enhancing the feeling of social connectedness.

The findings from this study inform design changes not only to the MorlensRehab prototype but also to the future design of stroke rehabilitation technology. Insights from the workshop highlight opportunities to develop rehabilitative technologies that are intuitive, user-friendly, and incorporate features that allow for progress monitoring and enhance social connectedness. These considerations significantly impact a patient's engagement with the technology throughout the rehabilitation journey. It also emphasizes the importance of including stakeholder perspectives in the process of development to ensure that technologies are designed to address the challenges they experience and are able to respond to the diverse needs of users. The findings from this study can contribute to the design of more engaging stroke rehabilitation technology that motivates sustained use.

## 8. Conclusion

This thesis explored the role instrumented devices can play in facilitating engaging home-based stroke rehabilitation. Through an RtD approach, it garnered a deeper understanding of the technological experiences of various stakeholder groups and uncovered insights that can create more accessible and engaging technical solutions. The study oversaw the development of the MorlensRehab prototype and a thematic analysis of data from a co-creation workshop involving rehabilitation patients, healthcare professionals, and technology developers, which identified factors that contribute to sustained motivation and engagement in rehabilitation.

Participant experiences with rehabilitation and technology revealed the seven key themes of motivation and engagement, reliance on the internet, plug-and-play, privacy, monitoring health and wellness, onboarding users to new technology, and social connectedness. A significant finding from the Show and Tell session was the aligning of the themes with the principles of Self-Determination Theory, specifically in meeting one's needs for autonomy, competence, and relatedness. The co-occurrences between several themes describe features of technology that can fulfil these needs, which play a role in patient motivation and the sustained use of rehabilitation technology throughout the recovery process. Additionally, the results of Show and Tell emphasized that technology serves as a tool or device that simplifies, manages, or helps in the completion of daily tasks, which significantly impacts the adoption of the technology.

During the Scavenger Hunt session, participant interactions with the MorlensRehab prototype underlined areas for improvement, suggesting modifications to create a more comfortable, engaging, and user-friendly iteration of the device. The workshop findings also emphasized the need for an ecosystem of supporting products or interfaces, including instruction manuals, an accompanying app to visualize progress, and access to technological support channels to create a more comprehensive experience with MorlensRehab.

The findings that emerged from this study contribute to the growing body of knowledge on the experiences of rehabilitation patients with technology, highlighting factors that promote and hinder engagement with digital tools. Identifying features that motivate active engagement and adoption of technology offers valuable insights that can guide the design of more effective and accessible rehabilitation devices.

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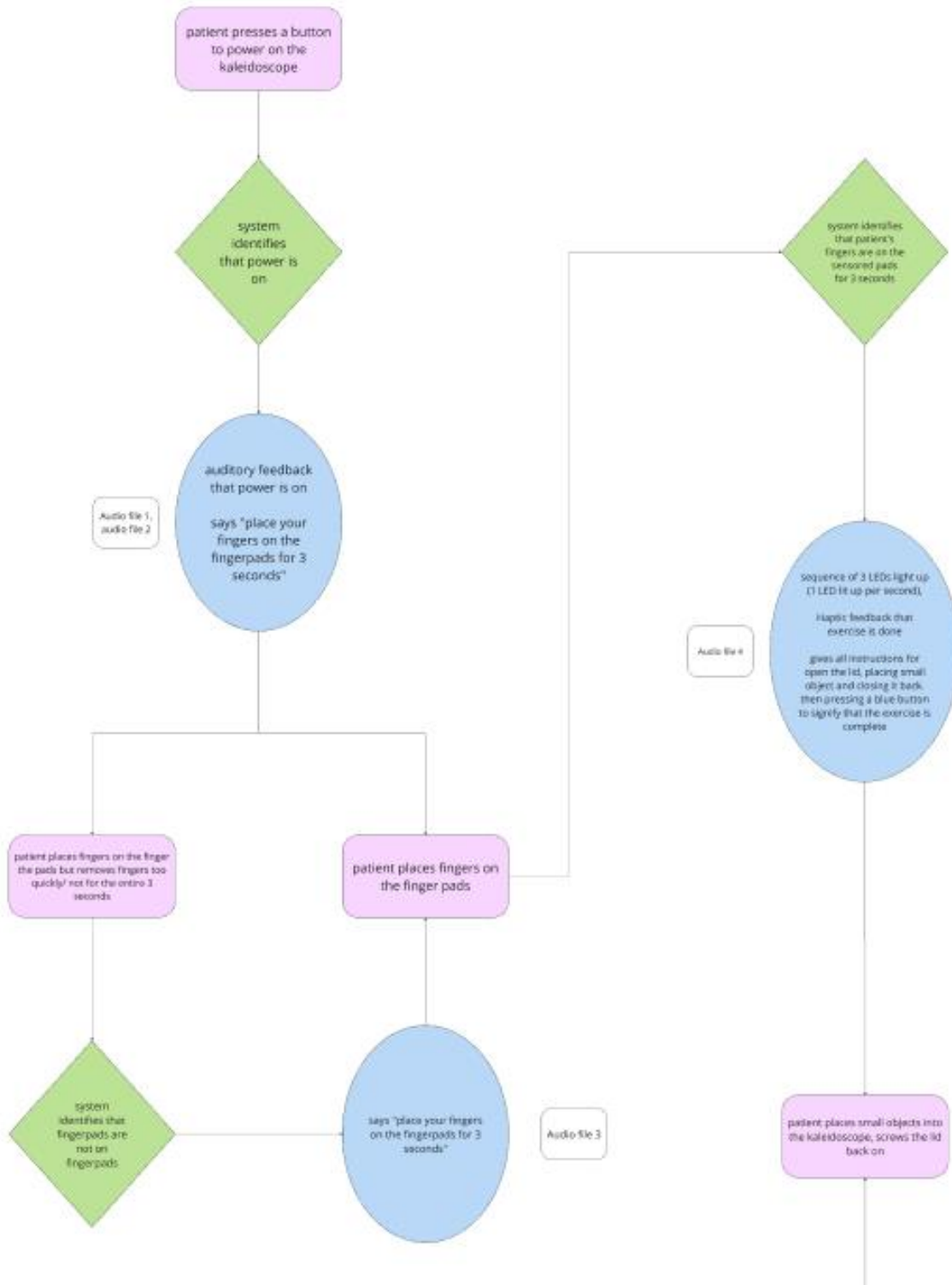
Winstein, C. J., Stein, J., Arena, R., Bates, B., Cherney, L. R., Cramer, S. C., Deruyter, F., Eng, J. J., Fisher, B., Harvey, R. L., Lang, C. E., MacKay-Lyons, M., Ottenbacher, K. J., Pugh, S., Reeves, M. J., Richards, L. G., Stiers, W., & Zorowitz, R. D. (2016). Guidelines for Adult Stroke Rehabilitation and Recovery. *Stroke*, *47*(6), e98–e169. <https://doi.org/10.1161/STR.0000000000000098>

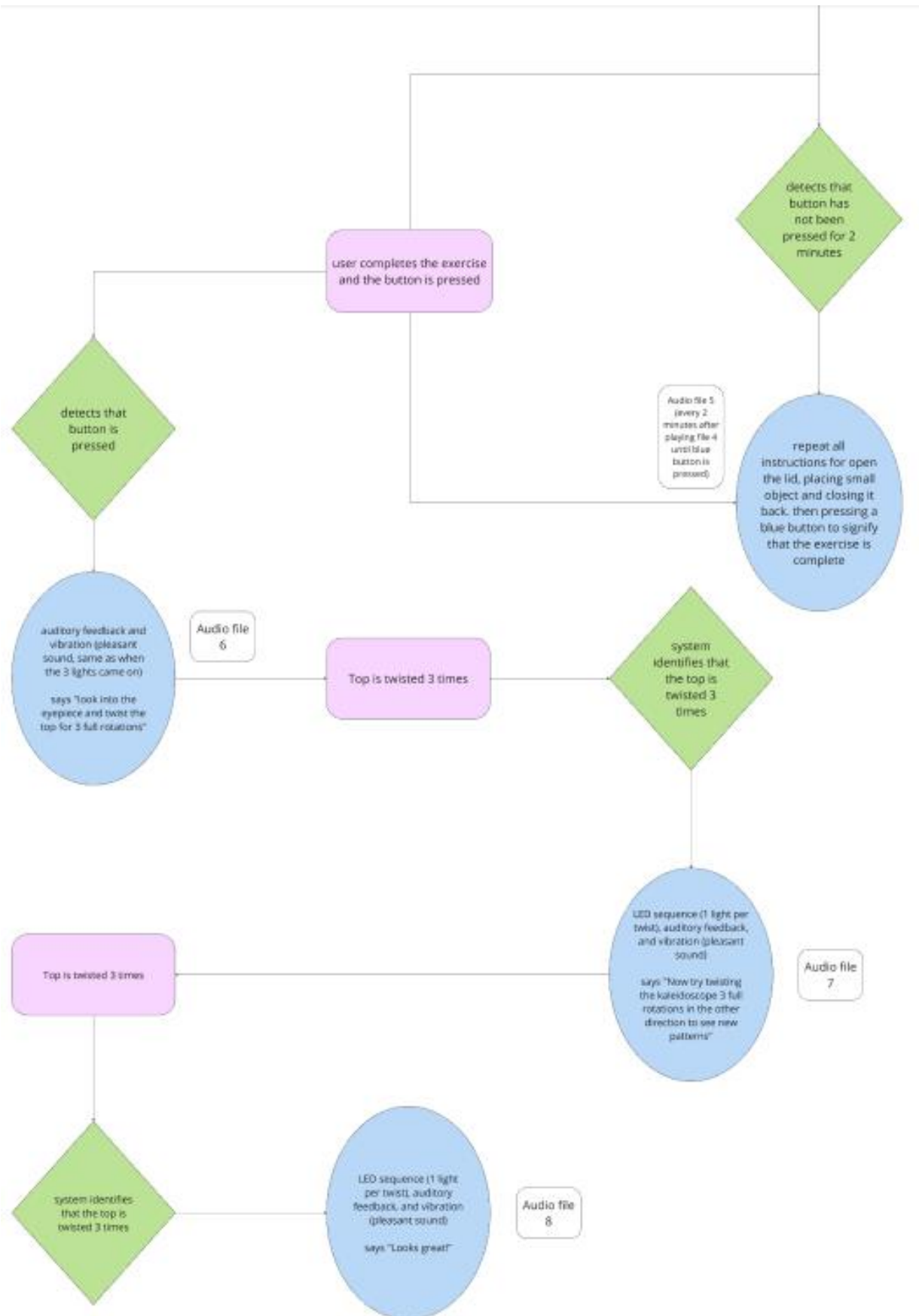
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# Appendix A

## Prototype User Flow





## Appendix B

### Prototype Storyboards



Press on the button



The kaleidoscope turns on and gives auditory instructions

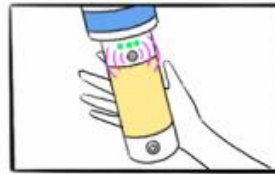
"Place your hand around the yellow portion and hold for 3 seconds"



Patient places their hand on the yellow portion for 3 seconds



3 lights turn on (one per second) and the kaleidoscope vibrates and rings to let the patient know they have completed the exercise



The kaleidoscope gives the next instruction

"Place one hand firmly on the blue and use your other hand to twist off the top"



The patient unscrews the top



The kaleidoscope instructs the patient

"Find small items to place into the kaleidoscope. When you're done, screw the cap back on"



The patient collects small flowers and leaves and places them into the kaleidoscope



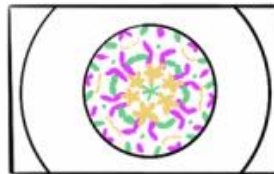
The patient twists the cap back onto the kaleidoscope



The kaleidoscope instructs the patient to "bring the eyepiece at the bottom of the kaleidoscope to your eye no twist the blue portion to see new patterns"



The patient brings the eyepiece to their eye and rotates the blue portion



The patient sees the pattern

## Appendix C

### Blank Informed Consent Form

#### Informed Consent

**Date:**

**Study Name:** Collaborative Technology for Healthy Living (CTHL)

**Researchers:** Robert S Allison (x20192, LAS 3051), Laurie M Wilcox, Shital Desai, Laurence Harris, Lauren Sergio, Celina da Silva, Taylor Cleworth, Niko Troje, Michael Jenkin and Matt Kyan

**Purpose of the Research:** We will investigate the most effective ways to provide remote healthcare (tele-wellness) to Canadians and the world in general. The goal of the project's is to create tele-wellness techniques for remote assessment and collaboration across multiple health maintenance scenarios.

**What You Will Be Asked to Do in the Research:** You will be asked to provide demographic information (e.g. age, gender, city/region of residence etc.) and information regarding your personal experiences with healthcare and/or tele-wellness. This information will be collected through a demographic questionnaire and moderated discussion sessions (involving approximately 30 participants), which may also include polling. The duration of the workshop will be approximately 3 hours. Your participation will either be in-person, or remote. The project is ongoing and will entail multiple workshops. Each workshop will be independent. Participants may participate in multiple workshops but are not expected to do so.

**Risks and Discomforts:**

We do not foresee any physical risks from your participation in the research. However, we will be asking questions about your personal experiences that you may feel uncomfortable answering. At any time, you may refuse to answer questions.

**Benefits of the Research and Benefits to You:** In addition to your contribution to this field of research, you will have the opportunity to gain insights and understanding of the current state and potential future directions of tele-wellness technologies and applications. You will also have the opportunity to learn more about recent research findings as well as contribute and benefit from the final products from the workshops. You may also learn about the experiences from other participants.

**Compensation:** As part of this research, participants that require transportation support due to physical limitations or difficulties with mobility will receive a \$50.00 gift certificate for each workshop. Participants who travel from rural communities will be reimbursed for accommodation and commute per workshop, as permitted by the York University policy. If you stop participating, you will still be eligible to receive the \$50.00 honorarium for agreeing to be in the project, even if you withdraw without completion of the research.

**Voluntary Participation and Withdrawal:** Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer, to stop participating, or to refuse to answer particular questions will not influence the nature of your relationship with York University either now, or in the future. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible. Should you wish to withdraw after the study, you will have the option to also withdraw your data up until the analysis is complete.

**Confidentiality:** Unless you choose otherwise, all information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research.

The principal investigator will keep a link that identifies you to your coded information, but this link will be kept secure and available only to the principal investigator and/or selected members of the research team. Any information that can identify you will remain confidential.

With your permission, statements made during the study may be directly quoted in future publications. However, we will ensure that your identity remains confidential and anonymous by attaching any direct quotes with anonymized labels or pseudo-names.

During the workshop, we will be taking notes, audio and video recording, as well asking you to fill out a demographic questionnaire. Electronic data will be stored on a secure, password-protected computer, only accessible by researchers involved in the project. Transcripts will be safely stored in a locked facility and only research staff/research

team members will have access to this information. All electronic data will be destroyed after 2 years, and transcripts after 10 years, following the end of the study. Confidentiality will be provided to the fullest extent possible by law.

This study may use the Zoom to collect data, which is an externally hosted cloud-based service. When information is transmitted over the internet privacy cannot be guaranteed. There is always a risk your responses may be intercepted by a third party (e.g., government agencies, hackers). Further, while York University researchers will not collect or use IP addresses or other information which could link your participation to your computer or electronic devices without informing you, there is a small risk with any platform such as this of data that is collected on external servers falling outside the control of the research team. If you are concerned about this, we would be happy to make alternative arrangements (where possible) for you to participate, perhaps via telephone. Please contact Dr. Allison for further information.

Recordings (audio/video) will be saved in a password protected file to research team members' local computer, not the cloud-based service.

Please note that it is the expectation that participants agree not to make any unauthorized recordings of the content of a meeting / data collection session.

**Questions About the Research?** If you have questions about the research in general or about your role in the study, please feel free to contact Dr. Robert Allison either by telephone at (416) 736-2100, extension 20192 or by e-mail ([allison@eecs.yorku.ca](mailto:allison@eecs.yorku.ca)). This research has received ethics review and approval by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Director, Office of Research Ethics, Kaneff Tower, York University (e-mail [ore@yorku.ca](mailto:ore@yorku.ca)).

#### Legal Rights and Signatures:

I \_\_\_\_\_ consent to participate in the *Collaborative Technology for Healthy Living Co-design workshop* conducted by *Robert Allison, Laurie Wilcox, Shital Desai* . I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form. My signature below indicates my consent.

**Signature** \_\_\_\_\_ **Date** \_\_\_\_\_  
Participant

**Signature** \_\_\_\_\_ **Date** \_\_\_\_\_  
Principal Investigator

#### Additional consent

##### 1. Audio recording

I consent to the audio-recording of my interview(s).

##### 2. Video recording or use of photographs

I \_\_\_\_\_ consent to the use of images of me (including photographs, video, and other moving images), my environment and property in the following ways (please check all that apply):

In academic articles	<input type="checkbox"/> N	<input type="checkbox"/> Y
In print, digital and slide form	<input type="checkbox"/> N	<input type="checkbox"/> Y
In academic presentations	<input type="checkbox"/> N	<input type="checkbox"/> Y
In media	<input type="checkbox"/> N	<input type="checkbox"/> Y
In thesis materials	<input type="checkbox"/> N	<input type="checkbox"/> Y

**Signature** \_\_\_\_\_ **Date** \_\_\_\_\_  
Participant Name:

**3. Use of quotations**

I \_\_\_\_\_ also consent to the possible publication of statements I have made during the workshop as a direct quote, with my identity anonymized.

**Signature** \_\_\_\_\_ **Date** \_\_\_\_\_  
Participant Name:

## Appendix D

### Demographics Questionnaire



### Collaborative Technology for Healthy Living Demographic Questionnaire

Name: \_\_\_\_\_

Age: \_\_\_\_\_ Gender: \_\_\_\_\_

1. What role applies to you? Check all that apply:

- Caregiver                       Technology Developer
- Healthcare Provider             Not Listed (please specify): \_\_\_\_\_
- Rehabilitation Patient

2. Where do you reside? (Township/City/Province): \_\_\_\_\_

3. Do you or someone you know have previous experience with tele-wellness and/or remote health technologies? (e.g. wearable fitness devices, health tracking applications, medical appointments on Zoom/Skype/teleconferencing, remote physiotherapy or rehabilitation sessions etc.)

- Yes     No

4. What technologies were used and what was the experience like?

# Appendix E

## Show and Tell Worksheet

Group # \_\_\_\_\_



### Collaborative Technology for Healthy Living Sharing Experiences

Name of the Person	Item Name	Like/Dislike?  <input type="radio"/> Like <input type="radio"/> Dislike	How did you get the technology? If it was obtained from someone, who gave it to you?	How did they learn to use it? Describe the process such as trial and error, instruction booklet, etc.	Provide additional comments about the product
		<input type="radio"/> Like <input type="radio"/> Dislike			

## Appendix F

### Scavenger Hunt Worksheet

#### Collaborative Technology for Healthy Living Technology Interactions

**Table 7. MorlensRehab**

	yes	no
This is easy to use	<input type="radio"/>	<input type="radio"/>
This is something I would use	<input type="radio"/>	<input type="radio"/>
This is something I enjoy	<input type="radio"/>	<input type="radio"/>

Other comments (e.g modifications, challenges you experienced, who it could be useful for, etc.):