W21C

Final Report

HealthTech Home: Evaluating the Use of Technology to Support Aging in Place

October 10, 2023

UNIVERSITY OF CALGARY

Authors

Anna Bradford, MBT[1]

Kathryn Arnold, MSc[1]

Juliette Bricker, BDes[1]

Project Contributors

Shane Virani, MSc, PMP[1]

Adam Turner, BA[1]

Amanda Chen, BSc[1]

Jenna Naylor, MHLP, CPT[2]

Ann Toohey, PhD[3]

Jayna Holroyd-Leduc, MD, FRCPC[3,4,5]

Affiliations

1. W21C, O'Brien Institute for Public Health, Cumming School of Medicine, University of Calgary
2. The Brenda Strafford Foundation Ltd.
3. Brenda Strafford Centre on Aging, O'Brien Institute for Public Health, Cumming School of Medicine, University of Calgary
4. Department of Medicine, Cumming School of Medicine, University of Calgary
5. Department of Medicine, AHS Calgary Zone

Correspondence

Shane Virani
Program Manager| W21C Research and Innovation Centre
O'Brien Institute for Public Health | Cumming School of Medicine | University of Calgary
Phone: 403-210-7424 | Email: shane.virani1@ucalgary.ca | w21c.org

Table of Contents

1 Executive Summary

The Brenda Strafford Foundation approached the W21C Research and Innovation Centre to conduct an independent evaluation of the HealthTech Home, a designated condo aimed at exploring how the integration of smart and connected infrastructure and technology can support aging in place. The project hypothesized that by adopting and integrating new technology in the HealthTech Home, the participant will be better equipped to live safely, independently, and with dignity than if the technology was not present.

The evaluation followed a case study methodology, wherein a single participant was monitored over a year-long period. The purpose of the evaluation was to gain deeper insights into the participant's experience of living in the HealthTech Home and the impact the associated technology had on their quality of life and support needs.

Four semi-structured interviews with embedded design thinking activities (i.e., card sorting) were conducted with the participant throughout the year and occurred approximately one month after each new technology installation. Surveys including the Older People Quality of Life questionnaire and the Affinity for Technology Interaction scale were also administered.

The data was analyzed for any major themes, as well as through the lens of a heuristic evaluation to identify any celebrations and violations related to a set of established design principles. Data was also visualized through a user experience map.

The results support the evaluation hypothesis in the following ways:
- Living Safely
  - Installation of tools that helped minimize risks and hazards to maintain a safe and accessible environment (e.g., Fixed accessibility and mobility safety features, fixed alert systems with remote capability, mobile safety nets, remote access to the home)
  - The ability to build and maintain a support network within a vibrant community minimized loneliness (e.g., Located within a desirable neighbourhood, ability to build new and maintain existing relationships)

- Living Independently
  - Installation of tools that improved mobility and assisted with activities of daily living (e.g., Mobility rehabilitation, home maintenance aids)
  - The neighbourhood around the HealthTech Home supported walkability and accessibility (e.g., Amenities within walking distance)

- Living with Dignity
  - The installation of tools of the participant's choosing, as well as the ability to customize and personalize the functions and features within those tools (e.g., Ability to choose tools and technologies, ability to change settings and features to fit current needs and to adapt over time)
  - Fostering dignity through a holistic experience

The results also highlighted areas of improvement that diminished the ability to live safely, independently and with dignity:

- Living Safely
  - Not being able to rely on proper installation for features to work (e.g., Unreliable safety features, unintended health impacts caused by improper installation)
  - Over-reliance on external support network (e.g., Non-local emergency alert contacts)
  - Limited opportunities for resident-initiated social activities (e.g., Local support and social networks)

- Living Independently
  - Missing tools that support universal design (e.g., Non-standardized placement and missing accessibility features)

- Living with Dignity
  - An overwhelming introduction to too many systems and new technologies (e.g., Multiple operating systems, multiple lighting systems)
  - Lack of personalization (e.g., Aesthetics)

By following the recommendations and considerations in this report, this evaluation supports the possibility of similar HealthTech Homes supporting aging in place.

2 Introduction

2.1 Background

Aging in place means to live where you choose as you age. However, changes to cognitive, sensory, and physical abilities over time can lead to functional impairments requiring the need for additional services and support that can disrupt aging in place. Aging in the right place (AIRP) involves supporting older adults to live as long as possible in their homes and communities while recognizing that where an older person lives impacts their ability to age optimally and must match their unique lifestyles and vulnerabilities (1). The principle of AIRP is to enable older adults with diverse needs to maintain their independence and autonomy in later life and continue to stay socially connected in the place where they live and feel competent, comfortable, and in control (2,3).

While aging in place has been a policy priority in rapidly aging Canada, a lack of complementary public and private support poses challenges for many older adults and their family members. There exists an abundance of smart, connected, and health technologies that may aid adults to age in place if properly integrated into the home.

2.2 Project Overview

The Brenda Strafford Foundation (BSF) purchased a condo in an independent living facility in Calgary that sits adjacent to a seniors' wellness community. BSF approached the W21C to conduct an independent evaluation of the HealthTech Home with a focus on the experiences of the participant and the impact the technology has on their quality of life and support needs.

This HealthTech Home has provided a space to explore how incorporating smart and connected infrastructure and technology can enhance quality of life and ideally make it possible for someone to age in the right place. This technology included smart and connected devices around lighting, smart displays, and voice assistants (see Appendix 8.2 for a full list of devices). It also included health-focused technologies designed to support areas such as health monitoring and health management. Additional partners include Health Cities, who have provided project management consultation, and Best Buy Health as a technology partner to equip the HealthTech Home.

2.3 Evaluation Objectives

This evaluation aimed to understand the impact and experience that smart and connected technologies (e.g., voice-activated digital assistants) and health-specific technologies (e.g., wellness monitoring) could have on a single participant's ability to age in place.

Specifically, the purpose of the evaluation was to:
1. Understand the experience of living in the HealthTech Home including identifying the benefits and the challenges of the various technologies as they relate to the participant's goals and ways of living.
2. Provide recommendations and guidance on how the experience and technology can support future participants to 'age in the right place.'

Evaluation Hypothesis: By adopting and integrating new technology in the HealthTech Home, the participant will be better equipped to live safely, independently, and with dignity, than if the technology was not present.

3 Methods

3.1 Procedure

Separate from their participation in the HealthTech Home project by the Brenda Strafford Foundation, the participant was asked to participate in the HealthTech Home evaluation.

The participant underwent four interview sessions and completed two surveys over the 12-month period from July 2022 to July 2023. During the one-year evaluation period, various smart, connected, and health technologies were implemented incrementally by the BSF. Informed consent was collected at each time point and interview and survey data was collected from the participant about their support needs, health status, and experiences within the HealthTech Home.

The evaluation occurred in four phases:

Phase 1: Move in assessment and post-implementation of smart technologies

An initial questionnaire assessment and interview were conducted to collect baseline data on the participant's current needs, technology comfort (4), quality of life (5), and their concerns and perceptions relating to the HealthTech Home project and the technology within. This interview is referred to as T1.

Phase 2: Post-implementation of health and safety technologies

Two months post-move-in, the participant was interviewed again to reflect and elaborate on their experience. This interview is referred to as T2.

Phase 3: Post-implementation of health-focused technologies

This phase took place after the implementation of the health-focused technologies and occurred after nine months of residence. This interview is referred to as T3.

Phase 4: Assessment after one year of living in the HealthTech Home

This phase took place shortly after the participant had moved out of the HealthTech Home after their 12-month stay and included a final survey and exit interview. This interview is referred to as T4.

3.2 Timeline

Figure 1 outlines the timeline of events that occurred throughout the HealthTech Home evaluation. The colour scheme denotes when products were added from the participant's perspective. For example, the technologies shown in green were added to the HealthTech Home prior to July 15, 2022, but this is when the participant was first able to interact with them. Additionally, the technologies shown in grey were previously owned by the participant, and thus used before the participant moved into the HealthTech Home.
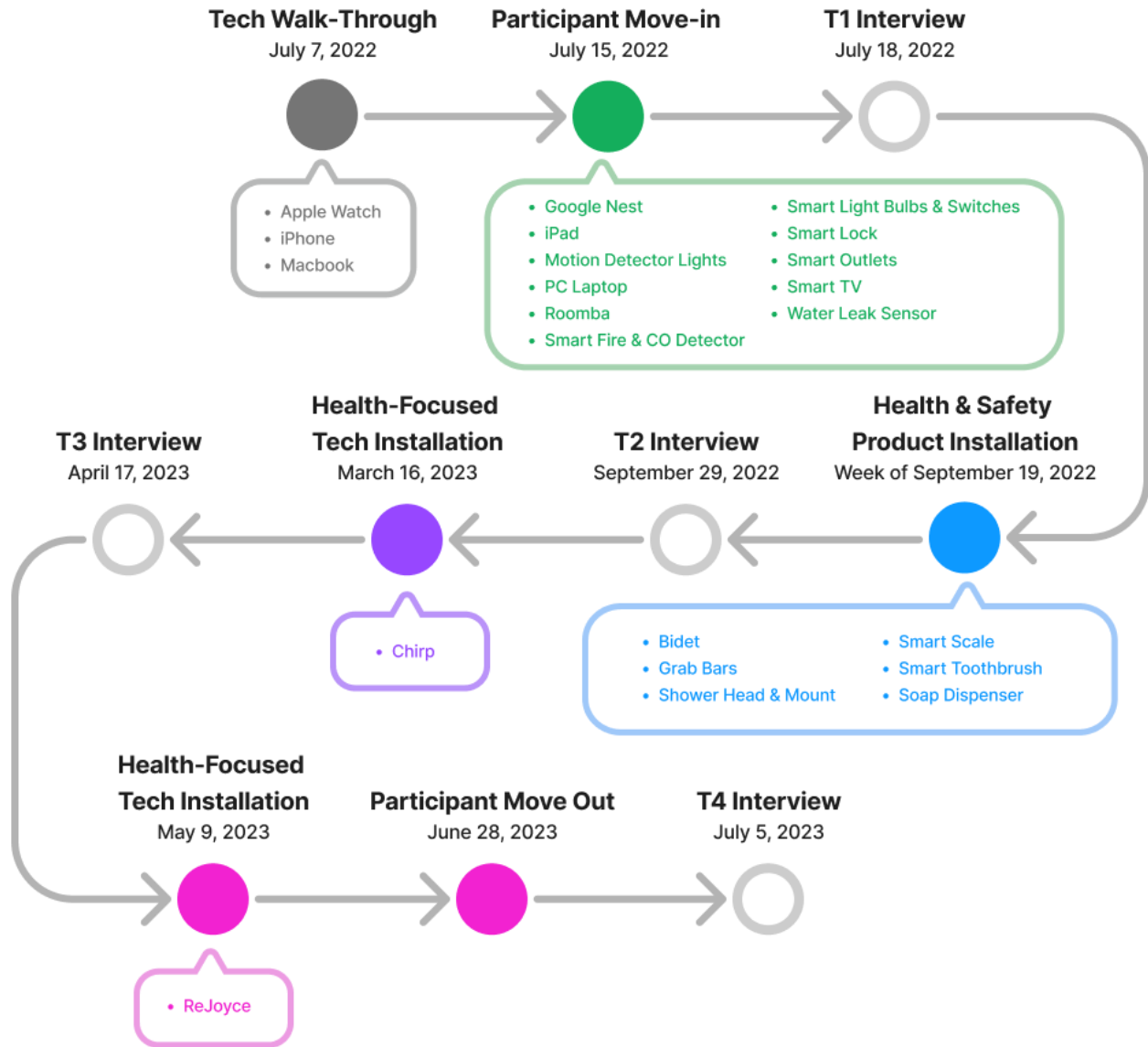
FIGURE 1. TIMELINE OF HEALTHTECH HOME EVALUATION EVENTS. TECHNOLOGIES SHOWN IN GREY REPRESENT THOSE PREVIOUSLY OWNED BY THE PARTICIPANT, TECHNOLOGIES IN GREEN ARE THOSE ADDED PRIOR TO T1, TECHNOLOGIES IN BLUE ARE THOSE ADDED PRIOR TO T2, TECHNOLOGIES IN PURPLE ARE THOSE ADDED PRIOR TO T3, AND TECHNOLOGIES IN PINK ARE THOSE ADDED PRIOR TO T4.

3.3 Data Collection

Semi-structured interviews were conducted to gain a deeper understanding of the participant's experience in the HealthTech Home. All interviews were audio recorded using a digital audio recorder for in-person interviews and using Zoom for remote interviews. The first in-person interview (i.e., T1) was video recorded with a camera, and the remote interviews (i.e., T3 and T4) were video-recorded via Zoom. No video recording occurred for T2. The in-person recordings took place in the participant's residence (i.e., the HealthTech Home).

Two card sorting activities were completed during the T3 and T4 interviews to further prompt discussion. The participant rated each product as either a 'need,' 'nice to have,' or 'could do without' item. Additionally, the participant ranked the usefulness of each product on a scale of 1 to 7, with 1 being not useful and 7 being very useful.

Surveys were administered via Qualtrics and included a quality of life assessment using the Older People Quality of Life (OPQOL) questionnaire and the Affinity for Technology Interaction (ATI) scale to assess changes in comfort and use of technology (5–7). Surveys were administered after all four interviews, however, the participant only completed the surveys after the T1 and T4 interviews.

3.4 Data Analysis

The data was collected and analyzed concurrently to provide written recommendations to the Brenda Strafford Foundation in the form of update reports to make informed changes and additions to the technology offered in the HealthTech Home (8,9). Three update reports were provided:
1. Summary of Evaluation: Results from T1 and T2 Data Collection in October 2022,
2. Summary of Evaluation: Results from T3 Data Collection in May 2023,
3. Summary of Evaluation: Results from T4 Data Collection in July 2023.

Comparative methodology was used to redefine themes as data was analyzed across the phases, and a heuristic evaluation of the technology used was also applied as an additional lens (10–12). Deductive analysis was conducted against the interview transcripts using a heuristic evaluation framework. MURAL was used as a data sorting and synthesis platform to code and conceptualize the data.

Survey data was used descriptively to identify trends over time and to provide additional context to the qualitative data analysis.

4 Findings

4.1 Gerontechnology Domains

Gerontechnology aims to apply technology to assist in dealing with problems and difficulties arising from aging so as to give older people the chance to lead lives that are healthier, more independent, and more socially engaging on a continual basis (13). Studies in many developed parts of the world suggest that the use of gerontechnology by seniors has the potential to greatly alleviate aging-related problems (14). Gerontechnology usage can be classified into four domains of home and daily living, communication, and education and recreation:
- **Home and daily living**: technology that supports home and daily tasks, increases personal safety, and increases convenience, allowing for more health and recreation time.
- **Communication**: technology that supports communication with others.
- **Healthcare**: supports the management of health and health conditions.
- **Education and recreation:** used on a voluntary basis in free time.

Research in gerontechnology shows that overall technology use is improved when products and services are equitably distributed under each of the four domains. Table 1 provides an overview of the product distribution against the gerontechnology domains, with the colours indicating the time point at which the technologies were added as follows:
- Products previously owned by the tenant are in grey.
- Products added before T1 are in green.
- Products added before T2 are in blue.
- Products added before T3 are in purple.
- Products added before T4 are in pink.

TABLE 1. BREAKDOWN OF HEALTHTECH HOME TECHNOLOGY WITHIN THE GERONTECHNOLOGY DOMAINS.

Home and Daily Living	Communication
• iPhone • Apple Watch • Water Leak sensors • Smart Lock • Roomba • Motion Detector Lights • Smart Light Bulbs & Switches • iPad • Google Nest • Smart Fire & CO Detector	• iPhone • MacBook • Apple Watch • Google Nest • iPad • PC Laptop
Healthcare	**Education and Recreation**
• Apple Watch • Sleep support for sleeping patterns (gentle wake/ gentle sleep) via Google Nest • Smart Scale (purchased by the participant) • Grab Bars in Master Ensuite • Bidet • Smart Toothbrush (purchased by the participant) • Soap Dispenser • Shower Head & Mount • Chirp • ReJoyce	• iPhone • Apple Watch • iPad • Smart TV

4.2 User Experience Map

"Even before I was chosen to live here, I had said …."In my life, I have lived with roommates," [and by agreeing to move in] I feel that I have a roommate that is called the smart condo. So when I read on your papers that the privacy is going to be less privacy, because I'm part of the project, I said, "This is exactly what I had [thought] when I read the ad." For me, the way I see it, is I feel that I have a roommate and the roommate is the smart condo."

The user experience map (Figure 2-4) is an overview of all of the technologies installed in the HealthTech Home throughout the evaluation timeframe. The main map has two axes: the coloured block columns on the X-axis represent a timeline between each of the interviews. Each period's size is representative of the length of time it was (e.g., T3 was many more months than the other terms making it longer in width on the map). The Y-axis represents the number of user violations or user celebrations for each product. Each interview contained comments on the technologies about how they either hindered or helped the user, which were then noted and quantified on this map. Since technologies were added during different terms, each item is a shade of the colour from the term it was introduced, but it did not appear

on the user experience map until it was mentioned in an interview (e.g., an item in a shade of blue was introduced in T2 but first appears in T3 as it was first mentioned in the T3 interview).
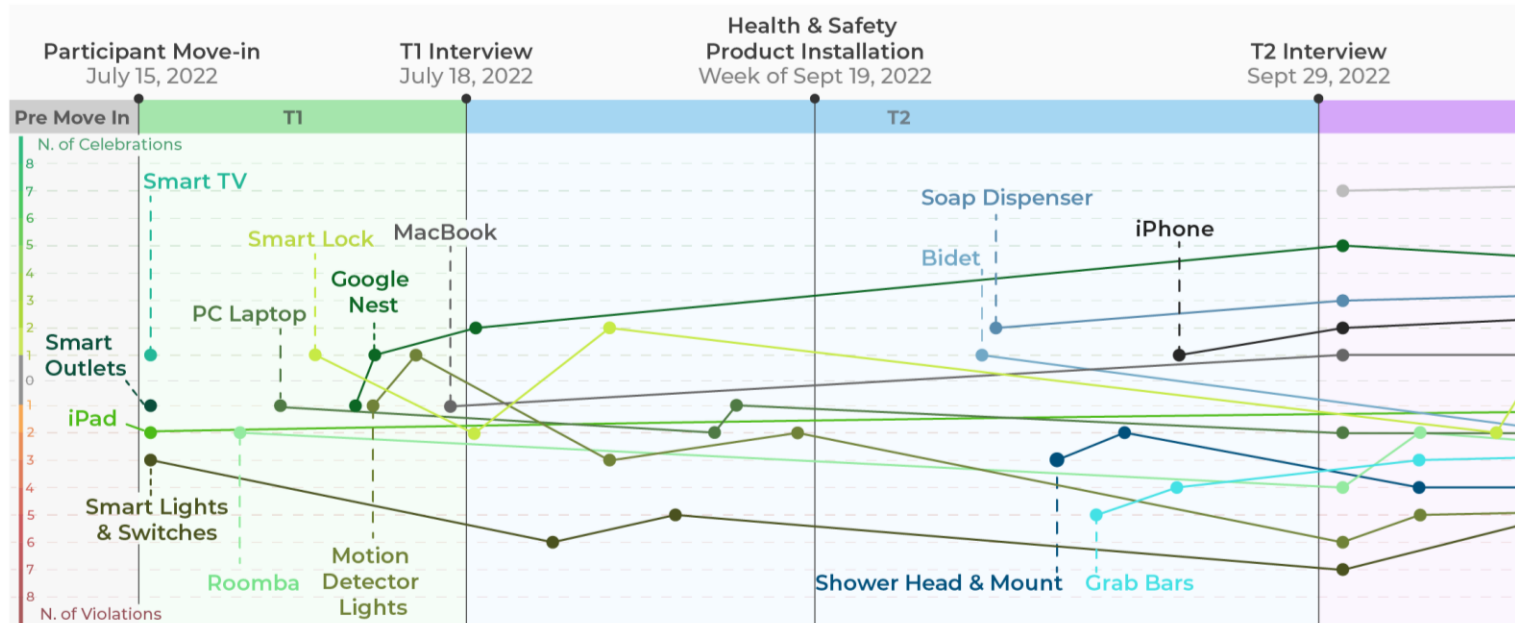
Below the map containing all the technologies are comments about the HealthTech Home as a whole. It sorts the comments into four categories ranging from things the participant loved, thought were nice, were not as enjoyable, and things that hindered them.

Additionally, an individual breakdown of each individual technology is located in Appendix 8.3.

FIGURE 2. HEALTHTECH HOME USER EXPERIENCE MAP PART 1/3.

FIGURE 3. HEALTHTECH HOME USER EXPERIENCE MAP PART 2/3.

User Experience Map HealthTech Home

Tech Item Legend

Apple Watch	Smart Lock	Smart Lights & Switches	Smart TV	Grab Bars	Shower Head & Mount	Smart Toothbrush	ReJoyce
iPhone	iPad	Motion Detector Lights	Roomba	Bidet	Water Leak Sensor	Smart Scale
MacBook	PC Laptop	Smart Outlets	Google Nest	Soap Dispenser	Smart Fire & CO Detector	Chirp

FIGURE 4. HEALTHTECH HOME USER EXPERIENCE MAP PART 3/3.

4.3 Themes

Values of the participant were drawn from the interviews as a frame for the thematic analysis.

4.3.1 Self-Sufficiency and Independence

Self-sufficiency and independence highlight the ability to provide for one's own basic needs, without the need to rely on external supports.

> "I want to be able to be on my own the longest I can and if I have access to things that's going to help me to enjoy life better."

For example, the participant noted how they valued having walkable amenities in their neighbourhood, as opposed to having to drive.

> "So that is something that I enjoy living here […] is being able to do all my things by foot."

4.3.2 Balancing Safety and Security with Personal Privacy

Ensuring a sense of safety without encroaching on personal privacy was a recurring concern for the participant when discussing product preferences.

> "Sometimes I'll come in, I have my stuff and, let's say, I have forgotten to lock the door, but I know it locks itself. So that secures me a lot."

While they wanted to feel secure and cared for (especially as it related to living alone), maintaining that feeling of safety should not come at the cost of feeling intruded upon.

> "I do enjoy having the [Google Nest] camera if I'm not [at home]. When I'm there, [I] don't really like it."

> "Knowing that the people are now seeing my movements in the place [with Chirp], I'm 50- 50 on it... [but I'm] happy if something would happen and I fell on the ground."

4.3.3 Elevate Comfort and Simplify Everyday Living

Previously referred to as 'Quality Convenience,' this theme encapsulates the idea of not only making life more comfortable but also simplifying daily living activities. For example, the participant noted several services, such as a catering or house cleaning, that they would be happy to pay for if the service provided was quality.

> "I like food, but I like when it's really good food… I would [like to] have three meals a day from a caterer. This is something that I would love."

> "I have hired a cleaner… I like when it's clean, but I'm struggling with my shoulder."

4.3.4 Personalization and Choice

The participant noted the difficulties in finding products that aligned in both form (how it looks) and function (how it works). Their experiences underscored the importance of tailoring design and product choices to the unique needs and preferences of individual users, both prior to and after moving in.

"I think the [grab] bars should be nicer. I think they're plain, the same bars they installed [for] so many years probably. Why don't they make them white like the shower, just blend so they don't show."

"I really, really like the idea of having the bidet to help me be clean, but [the orientation of it is] kind of a little inconvenience."

4.3.5 Connection and Social Needs

The theme of connections and social needs was prevalent in discussions about both present and future needs. The participant emphasized the importance of establishing and nurturing relationships, as well as finding ways to alleviate feelings of loneliness.

"I have friends from all different age groups. And life stages too."

"Not being alone, even though I live alone [is important to me]."

"I would [like a] phone that I could chat with someone whenever I want [about day-to-day struggles] … [I would like to talk to] someone that doesn't know [me], that is just there to listen."

The participant valued not only their existing connections but also sought avenues to forge new ones, further showing the important impact of meaningful connections.

"[Some residents] decided to put a table and some chairs [by the elevator] and started to do some puzzles. I was absolutely in love with this… it was a social point every day during December. I thought it was absolutely amazing."

"I had suggested… a potluck in my place. The door is going to be open. You feel like coming, you come. We ended up being, I think we were 8 in my place, you know, and I know for sure that that event [would] not have happened if we didn't have that little [puzzle] nook that we had during this time."

4.4 Heuristic Evaluation

4.4.1 Heuristic 1: Provide a Sense of Place (Visibility of System Status)
Interventions should keep users informed through appropriate, timely feedback. This heuristic is focused on helping people orient themselves through landmarks, wayfinding, and progress indicators, clearly showing users the effect of their actions with corresponding feedback.

The participant indicated that while they were aware that the Roomba was programmed, they did not know when it was scheduled to run. Because of this, they began to think that the Roomba was malfunctioning until it finally ran at a surprising time.

"No [I have not used an iRobot before]. I have some friends that have something similar, but I had never experienced or had that before in my life. And it was funny because, during the weekend, I was expecting to see it move whenever, and it didn't work. I said, "Oh, maybe it's not programmed." And then at 9:00 AM [Monday, a BSF representative] knocks on my door and it was so funny because [they] arrived and this [thing] starts… I said, "It didn't work all weekend. I was waiting for it to work.""

The participant didn't know why certain lights were voice-activated and others were not. Not all the lightbulbs were smart bulbs (e.g., kitchen island), and not all smart bulbs were controlled with voice recognition. Additionally, the user had difficulty with the lights: they turned on and off at random times and multiple apps were required to operate the bulbs. There were no visual aids indicating which lights were connected to the Internet of Things (IoT), making it difficult for the participant to troubleshoot.

An immediate notification to indicate task completion, such as audio signals when the laundry machines or microwave were finished, was appreciated as a reminder cue.

> "I really, really like that [the washer] sings when it's done … because if I'm doing something and the washer's done, I like to know and I take my stuff. Same thing for the dryer… I like that it tells me."

The parkade lacked audio-visual feedback to signal if other vehicles were currently entering or exiting. A notification or method of instant feedback about the location of other vehicles entering or exiting the parkade could help the user orient themselves better.

> "I'm in the van and the door opened, but nobody is coming in. I'm just going to go out, but I'm waiting [for] the person [to] come in. But I decided to go forward, but the person went in, so I just moved, and I didn't realize that [there was a] cement beam and I scratched all my van."

However, the instant feedback related to the pressure provided by the smart toothbrush was confusing to the participant and over-complicated the process.

> "I know I feel it's kind of complicated. It's like telling me I'm not putting pressure enough or putting too much pressure, and I'm saying, I'm just brushing my teeth. And you're telling me all this. This is like too much for me."

Technology that helps monitor the home, such as the water sensors, helped the participant feel more at ease while they were away from home. While there were never any incidents, the participant appreciated that they would receive instant notifications if something were to occur.

> "Sometimes, if I'm not at home and I have an alert, I like it. It's all [the] little things that kind of ease my mind."

The participant appreciated the interactions with the Google Nest when they leave and return home.

> "When I leave I always say, 'Hey Google, I'm leaving,' and it would say, 'Goodbye, have a nice day so,' and it's funny, but because I live by myself, I am sure, having someone saying, even if it's Google, but I enjoy having someone say have a nice day, and when I would arrive, 'Hey, Google, I'm Home,' and that the welcome back… It puts a smile on my face, even if I had a hard day just knowing that somebody is greeting me."

In addition to providing greetings, the participant also appreciated the comfortable and welcoming environment that the Google Nest voice recognition was able to provide.

> "I really like the voice recognition with Google [and] when I asked it to put music [on] or ask to put the lights on or off."

The smart scale feature that shows progress over time was appreciated by the participant, as overall trends can be observed.

The participant enjoyed the Apple Watch feature which tracks activity levels as it motivated them to be more active.

> "When I look at my rings… I think it's a motivator… At night, if I look at my watch and I'm close [to filling the ring], I can say, oh, come on, go take a 10 min walk, and you're gonna have your ring filled... So this is a technology to make you move, to encourage you to make you move."

4.4.2 Heuristic 2: Match a Mental Model (Between the System and the Real World)

This heuristic capitalizes on people's existing knowledge of how a system works based on their past experiences with real-world objects. Information should leverage the users' perception of the world rather than making them adapt or conform without a need for training. Including familiar elements and activities in the interface will help users move through the experience with ease. This heuristic applies to words, objects, how a digital experience makes users feel, and their expectations for a process. Familiarity is what makes these experiences enjoyable.

The participant appreciated the predictable behaviour of the motion detector lights as they moved through the condo. They were immediately able to understand the sensor's usage even though it was a new technology for them.

> "I had noticed that when the lights are off in the living room, dining room, or bedroom, the light would go on because of the motion sensor, so I noticed that. I was like, 'Whoa, this is so cool.'"

Ultimately, the participant felt that the motion detector lights were not necessary at this time, though the lights would potentially become more useful as they aged.

> "The motion detector [lights], I'm not a hundred percent sure if I would install it [in my current home]. I think I would not install it right away, but maybe in 10 years I would."

The participant had difficulty operating the voice-activated lighting system as some bulbs were not connected to the IoT voice-activated lighting system.
The integration of electrical outlets further complicated the IoT voice-activated lighting system, as it hindered the user's ability to troubleshoot any malfunctions in an intuitive manner, such as the straightforward method of plugging in a lamp or using a light switch.

> "I wanted to put my lamp and just plug it in here." But I said, "My lamp didn't work." Even though I would switch it on and off, it didn't work, so I just unplugged it for the weekend. And I said, "I'll ask how it works."

The participant noted that they were able to identify the water leak sensors without being prompted. However, the participant was initially still uncomfortable leaving the condo without testing their appliances first and ensuring they did not leak. This may indicate that the user was either unaware of

the functionality of the device, or simply did not trust the sensors enough for them to leave the facility, despite having an app on their computer that would notify them of any leaks.

Security was an important consideration for the participant. While the HealthTech Home included a smart lock system, it initially felt unfamiliar to the participant as it functioned differently than their previous security systems.

> "Actually, during the weekend, in the condo that I was, in Edmonton, I knew I cannot forget my keys because I [would be] locked out. And here, I was like, "Oh, you go out and the door doesn't lock." I said to myself, "I kind of like that the door locks when I go out." So [the Geek Squad tech] programmed it that after two minutes, the door locks. So even if somebody comes in, the door will lock also after two minutes. I think it's a nice security to have that after two minutes, it locks."

The participant had prior experience with MacBooks and as such, used their personal device instead of the provided PC laptop. However, after their personal MacBook broke, the provided PC laptop was used, allowing the user to continue their daily tasks, such as answering emails.

> "I have an Apple laptop, but it's not working anymore. So I'm using the… laptop from here. So I have been using this [PC] laptop because mine doesn't work."

However, as the participant gained more experience using the provided PC laptop, they noted that the MacBook was more user-friendly than the PC laptop.

> "If you would ask me which one is more user-friendly, absolutely the MacBook, because when I [do] whatever I do on the PC, I have to think more."

Since the participant had not owned a TV or had cable for a long time, they appreciated being able to control the smart TV with their iPhone, which was a device that they were more familiar with.

> "I use my phone [to cast to the smart TV]… So I would put this TV show on my phone… I would click on this [icon], and after that it would go on the TV."

As grab bars were not present in the bathrooms when the participant first moved in, they had grown accustomed to navigating the space without them. When grab bars were later installed in the ensuite bathroom, their placement impacted the way the user entered the shower. The participant had to swing the shower door in the opposite direction than before, causing them to readapt their mental model of how to access the shower.

As previously noted, the participant appreciated sound notifications. Thus, they expected the fridge to beep if left open, as their previously owned fridges had this functionality.

As the participant became more familiar with the technology within the home, they appreciated the simplicity of incorporating it into their daily living activities. For example, they appreciated being able to turn the lights on and off using voice commands.

Overall, living in the HealthTech Home has helped the participant gain experience and knowledge of smart technologies and they now seek out smart technologies (e.g., scale, toothbrush) to help support daily living.

> "Now if I have to buy something, my first thing [I think of] is do they have something that is smart?"

4.4.3 Heuristic 3: User Control & Freedom

This heuristic focuses on allowing for choice over technology and limiting forced inter-dependencies between systems. When it's easy for people to back out of a process or undo an action, it fosters a sense of freedom and confidence. This allows users to remain in control of the system, avoid redundancies, and reduce frustrations.

Initially, the participant noted their appreciation for the lighting options, citing the ability to unplug them or change the name associated with the lights to better align with their use of the space if desired. However, the participant was restricted in choice as manually adjusting the lights does not override the pre-programmed, automatic light features. Despite attempted fixes, such as adjusting the motion detector light's sensitivity, the lights were continually activated by the participant's cat. The participant had to completely turn off the bedroom motion detector lights to prevent the cat from turning the lights on at night.

> "[The moment] I said to myself, "Okay, we need to fix this," is when I went to bed. And if [the cat] was moving in the house while this light goes on, and then the living room side, it would still go on. And the bedroom light would go on."

Despite the motion detector lights being reprogrammed to address the above issues, the participant continued to have problems. In particular, the lights would automatically turn off during use in the main living area after exceeding the programmed timeframe, leaving the participant in the dark.

> "It's the worst thing, the sensor. [The] sensor is programmed from, let's say, 8 in the morning until 10 at night. Okay. But let's say it's 11 p.m. and I'm still up. I would put a light on, but because it's supposed to be off at 10, even though I'm putting it on, it's gonna stay on just a little bit, and after that's just down. So when I was outside my routine, let's say a few hours of being up now, or if even if I [people over] the lights would go off, and I'm saying for no reason. But now I know that there's a reason. But I felt that having this sensor it didn't work for me."

The participant did not know why certain lights were voice-activated and others were not. There was no visual map that showed which ones were connected or should be connected. Additionally, not all the lights were on the IoT, and the participant found the inconsistent naming of lights and light bulbs to be confusing.

The participant was further confused by having two different platforms that do voice commands and their respective intended purposes.

Integration of features such as Airplay were an added functionality that gave the participant the control and freedom to continue to watch programs as normal, from their laptop or iPhone.

> "I have to say that I've been roughly 15 years without the TV. It's not because I don't watch TV. But I watch TV on my laptop, on my phone, so [the Geek Squad tech] showed me a bit of the remote and he showed me how... How did you call it? Airplay? So, the Airplay, that I never knew about this. He showed me the Airplay mode to be able to put it on the TV while I have it on my phone or something. That's good."

The ability to unplug unfamiliar devices was also appreciated by the participant, even when consequences were not apparent.

> "And also, I had unplugged this [light strip] ... Why did I unplug this? I wasn't sure. Yeah. But [the Geek Squad tech] explained to me that that was meant to be under the bed, so I have some lights that I'm going to place, like he said to me. [In the end] it was nice to have those."

The participant was given a PC laptop, despite already owning a MacBook. The PC laptop did not contain any apps that integrated with the IoT, so it was initially a redundant piece of equipment for the participant. The multiple systems, tablets, and devices provided further confusion and hesitancy for the participant.

The participant noted that the number of apps loaded onto their iPad was confusing, as they did not know if they were interrelated or functioned similarly. They also noted a hesitancy to use the full capabilities of technology present in the HealthTech Home, such as the out-of-home monitoring functions, due to the device not being owned by the participant and therefore they would not remove it from the condo.

> "It's mine for the year. I won't bring it out of the condo, in my phone, when I'm going to bring it out. That's why I was saying, "Yes, I would use this inside, but I wouldn't [take it outside]." If it was mine personally, yes, I would bring it with me. But because it's not, I want it to stay here."

The participant noted that they already owned and carried an iPhone with them daily and expressed a desire for the ability to choose what device and where the applications are loaded.

> "I have an Apple laptop, and they have the... I don't know if it's a PC or... No, it is a PC the way it looks, for sure. So it's a PC laptop but I asked him if there were some apps on it or something. He said, "No, this is for you... You can use it like you would use a laptop."

While the participant appreciated being able to use their iPad or iPhone to separate apps when and how they wanted, they noted that not all the app settings could be controlled from their iPhone. As a result, they had to use the iPad to make setting adjustments.

> "I can do everything or almost everything [using my iPhone, but] let's say that I needed to change some settings I would need the iPad... I cannot change [the settings] with my iPhone, I need to have the iPad to change it."

The participant was able to turn off the Google Nest camera security feature based on their current needs and desires. They could choose not to use the available technology while understanding that as their needs change, this may be a feature that they are interested in reinstating.

> "When [the Google Nest] would detect movement, I would be filmed and I would get a picture on my phone. I really, really hated it, and I asked to remove that.

Multiple devices available to the participant (e.g., Google Nest, iPhone, iPad) had the functionality to set an alarm, allowing the user freedom to select which device they use. Alternatively, the user could decide to forgo setting an alarm altogether.

Additionally, the participant liked having the different voice recognition systems such as Google and Siri available to them, as they could use the more convenient option at any given time.

As the participant's cat had learned to turn on the Roomba using the buttons on the docking station, the participant was able to utilize the childproof feature of the Roomba to prevent their cat from turning the device on at inopportune times.

The bathtub had a shower head, but no shower curtain rod or shower curtain, which limited the participant's ability to use that bathroom to its full capabilities as they were restricted to taking showers only in the master ensuite bathroom.

The kitchen had multiple storage options with sufficient storage space at levels accessible to the participant, so they could choose not to use the higher cabinets out of their reach.

Although the participant understood that Chirp is not camera-based, they were slightly uncomfortable with its monitoring aspect and it being able to track their movements throughout the day.

> "Knowing that the people are now seeing my movements in the place [with Chirp], I'm 50-50 on it... [but I'm] happy if something would happen and I fell on the ground."

The participant was able to choose whether or not to use the provided technology. While the participant initially enjoyed the smart toothbrush, over time they found it less useful and stopped using it.

4.4.4 Heuristic 4: Consistency & Standards

This heuristic focuses on using consistent wording and actions, as well as following common conventions. Any differences from the norm should be emphasized and the user made aware. Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

The participant found the matching of logos on devices and app symbols to be particularly useful. Even when they did not immediately know exactly what an app's function was, they could easily determine which item within the condo it was for based on the app's icon.

> "Let's say, another device that I didn't know that exists is the Phyn. I don't know if you would pronounce it like this, P-H-Y-N, I think. So this app is [for] those little devices. Do you know what it is? I'll show you. It's only because I had the training... So Phyn, you see it's the same logo. I didn't know that [smart leak detector] exists. I was like, "Wow. Pretty good."

> "This, I know about this. I know this is the light bulbs [Hue app]. I think some of the apps are together because I know this is the light bulb. And if I go there, I have the lights also, so maybe they're kind of interconnected together."

The participant also realized that anything using electricity could be integrated with the IoT. However, the participant noted confusion when the Google Home device dimmed different lights than requested,

as well as why some lights and light bulbs were voice-activated, and others were not. Not all the lights were on the IoT, and the participant found the inconsistent naming of lights versus light bulbs to be confusing. This confusion was further increased by the multiple apps controlling the lighting system.

> "I didn't notice [that not all lights changed colour], and it was one out of the three [lights]. I'll say, "Hey, Google put all the lights off." [Google responds]. So 14 lights, the technician explained that let's say, there's three, and three, and three in the bedroom. But there's a few that are not on it."

Additionally, while some of the smart light bulbs in the home have the capacity to change to different colours, not all have this feature.

> "There's only one [light bulb] that does the colour… I think that if you're going to put the option of putting a colour, I think the light bulb should be all the same colour."

Despite settings being adjusted for the motion detector lights, the lights continued to go on and off at undesired times. The participant expressed that the motion detector lights were more of a hassle than their switch-based or voice-activated counterparts.

It was clear the participant was much more familiar with Apple products than PC and Google. Having multiple different platforms that respond to voice commands was confusing for the participant, even though different operating systems were likely used for different purposes (e.g., Siri and Google).

The participant noted that the smart lock did not consistently work to automatically lock the door, which undermined their confidence in the lock's reliability.

Additionally, the shower grab bars were not installed with a standardized placement, which could have an impact on safety. Having guidance from a professional or a standardized placement for the grab bars and incorporating the participant's input would have made the participant feel more confident in the placement and with entering and exiting the shower safely.

> "I think that someone from the project should be there. Because when they came and installed the grab bars, I didn't know exactly where to put them, and that put a lot of stress [on me]. I assumed that they would know [where to place the grab bars], and they assumed that I would know."

4.4.5 Heuristic 5: Prevent Errors by Anticipating Needs & Abilities
This heuristic focuses on preventing errors from occurring in the first place by acknowledging and embracing people's differing abilities and activating environments and situations to support them. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action. This heuristic also encourages technology providers to provide graceful recovery for mistakes and help users get back on track.

As previously mentioned, the auto-lock feature of the smart lock after two minutes was appreciated by the participant. It provided them peace of mind to know that their residence was secure in case they forgot the manually lock the door. The participant also appreciated the practicality offered by the smart lock; if they forgot their keys, their phone could be used to unlock the door.

The motion detector lights were installed despite knowing that the participant had a cat. This caused many problems for the participant in the days leading up to their first Geek Squad visit.

> "The thing that I laugh [at] is... Let's say, that I went to bed at Friday night, and I'm in bed and the lights goes on because my cat was walking."

While the participant appreciated the bedroom motion detector lights when they got out of bed in the middle of the night, they also led to considerable sleep disturbances due to their sensitivity. The lights were often triggered by the cat or by the participant simply rolling over in bed.

> "As soon as I move in my bed, my bedroom light would go on... In the middle of the night, I'm just changing sides, but the sensor would detect me and the light will go on."

Additionally, the participant's cat learned how to turn on the Roomba, which led to it turning on at inopportune times and disturbing them.

> "[The cat] learned how to put [turn the Roomba] on. So there were times at 2 a.m., 4 a.m., she started the Roomba... and it wakes me up."

The participant noted that the bedroom lights were not installed on the app, whereas the rest of the lights were.

> "I think if I say, "Hey, Google, bedroom lights on." Yeah. Now, it goes on. Because this was not put on the app."

The participant also noted that they would appreciate if the smart light bulbs provided a notification through the app when they were close to being burnt out so that they could line up assistance ahead of time to help with safe bulb replacement.

The participant was provided with a PC laptop and an iPad, despite already owning an iPhone and MacBook that were also compatible with the HealthTech Home features and equipment.

Grab bars were not pre-installed in the senior living facility, and during the grab bar installation, they were only added to the ensuite bathroom shower. Therefore, grab bars were not present in the other bathroom within the HealthTech Home to assist the participant as they enter and exit the bathtub. When installed, however, the grab bars helped the participant feel more secure.

> "When they installed the [grab] bars in the shower, I did think it was useful. Even my few neighbours came [over] once in a while to my place and they were saying, "Oh, I wish I would have some [grab bars]." ... I think I'm lucky to have them."

The participant's input helped facilitate other updates in the ensuite bathroom. The user's mobility limitations were taken into consideration and a bidet and wall-mounted soap dispenser in the shower were added to help make maintaining their hygiene easier. While the user was able to determine a workaround, their conditioner was too thick to pass through the soap dispenser, which is designed for body wash, shampoo, and conditioner.

Additionally, a detachable shower head was installed. Initially, the participant could not reach the detachable shower head, ultimately defeating its purpose, so a mount was installed for the shower head so it could be positioned lower and within reach. However, this mount did not take future needs into consideration, as the angle could not be adjusted to account for different positioning, such as sitting.

> "The idea is great, but what they installed is not great because when you put [the shower head on the mount], it is not adjustable, so the water is not splashing where it's supposed to."

Due to physical limitations, the participant had a difficult time reaching the back of the laundry machines.

The parkade lacks audio-visual feedback to help the user respond accordingly when other vehicles are currently entering or exiting.

4.4.6 Heuristic 6: Minimize Complexity by Emphasizing Recognition Over Recall

This heuristic focuses on making information clear, simple, and easy to find for the user. Minimize the user's memory load by making elements, actions, and options visible. Avoid making users remember information. The user should not have to remember information from one part of the interface to another. Information required to use the design should be visible or easily retrievable when needed.

The symbols of the apps matched the technology they controlled, making it easier for the user to intuitively identify the app that controlled the device they wanted to use, rather than relying on their memory.

The participant had trouble remembering the names of the different lights when turning them on or off with the Google system, as well as remembering which lights were bulb-based or switch-based.

Due to multiple apps controlling different lights and devices, the user had to remember which ones achieved the desired outcome. Additionally, if the participant wanted to take a shower, they had to remember to turn on the ceiling lights due to the motion sensors for the bathroom motion detector lights being in the bedroom.

Offering to have Geek Squad come to the condo in person rather than a long tutorial video to memorize also supported this heuristic. The participant's ability to record the conversation also reduced the information they had to remember at the time by providing them with a tool to reference when needed.

However, having multiple tablets was more confusing than helpful, and as a result, the participant defaulted to their iPhone, which they were already familiar with, rather than attempting to use the tablets.

After the participant went a prolonged time without using an app, they had difficulty remembering how to operate it. The participant noted that including technology that supports relearning after time away would be helpful.

> "There was some stuff let's say I'm taught. And because I'm not using the software every day, I like to know how to do it, but I forgot because it's like 2, 3, 4 months that I didn't use it. So this is something that I think software [should have an icon you can click for reminders on how to use it] … If we don't remember, we can click on it, we should be able on the software to say,

"remind me how to start, remind me how to do step 2, remind me how to do step 3," and it would pop up on the screen."

The participant was easily able to use the smart lock app to check if the front door was locked when they were away. This provided them with a sense of security and allowed them to rely on sources other than memory to ensure important tasks were completed properly.

The participant noted that they would value additional indicators for the house's technology, such as the oven or washer providing audio-visual feedback if anything was left inside them after the initial timer went off.

"I'll do my laundry and I forgot about it in the washer. And the next day, and sometimes, 2 days later I said to myself, "Oh, no!"… It's hard to get out the smell after you know… I'm sure that if the washer would have a sensor that there's still clothes in it like connected to your phone or a kind of buzzer that there's still clothes in it [this would no longer happen]."

The smart scale provided the participant with a history of the recorded weight information, so they did not have to recall changes from the past and could observe trends over time.

"I enjoy the app with my scale… On average, once a week I'll weigh myself… I enjoy having that [information] on my phone and having the history of my weight."

The participant appreciated that if they were to fall in the home, Chirp would help them figure out what to do next, as opposed to having to recall what to do in the situation.

"If you fell and you're in distress… you don't think straight. So, knowing [there are] fewer steps you can [have to remember is reassuring]. You don't have to think."

The activity rings and notifications provided on the Apple Watch served as gentle reminders throughout the day to the participant to be physically active.

"When I look at my rings… I think it's a motivator... At night, if I look at my watch and I'm close [to filling the ring], I can say, oh, come on, go take a 10 min walk, and you're gonna have your ring filled... So this is a technology to make you move, to encourage you to make you move."

4.4.7 Heuristic 7: Flexibility and Efficiency of Use

This heuristic outlines the need for catering to both inexperienced and experienced users by providing the ability to tailor frequent actions. Shortcuts — hidden from novice users to avoid confusion — may speed up the interaction for the expert user. Flexible processes can be carried out in different ways so that users can pick their preferred method.

During the initial visit, the participant was new to the HealthTech Home so frequent uses and preferences were not yet apparent. After living in the HealthTech Home for several months, the participant gained a greater understanding of the technology available and found innovative ways to make their life easier. For example, they used the smart lock to let in their friends or cleaning people when they were not home.

> "On Monday last week, when [the cleaning person] was available, I was not home, and I know that [they] can buzz me at the entrance and I can let her in, and because the door lock of my suite is on my phone, August, you know, so it's easy like I just let her in, and [they] went to clean the suite."

Additionally, the smart lock feature used the proximity of the user's phone to unlock the door, allowing the participant quick and efficient access to the home.

> "I really feel when I'm arriving with groceries or whatever, even going through my purse, I feel that sometimes I'm tired when I arrive or other urgent needs as soon as I arrive, this [automatic smart unlock activated by my phone] saves me a lot of time."

After using the multiple tablets within the HealthTech Home to control different devices, the participant later installed the relevant apps to their iPhone for increased ease of use.

The participant appreciated the flexibility and freedom that Google Nest voice recognition controls allowed them to have.

As the Roomba kept getting stuck during its programmed cleaning times, the participant had to change the settings so it would only turn on while they were home so they could remove the obstacles, such as the stools in the kitchen, and help it get unstuck. This removed the efficiency that the product was intended to provide.

> "I ended up not using [the Roomba] that much because it gets stuck in many places… I think the idea is great, you know, but where it gets stuck, I'm saying to myself it shouldn't get stuck. It should have some kind of brain that is thinking [on] its own. Okay, I'm stuck, I need to get unstuck and have a device that they're able to get unstuck and know not [to] go back there. If I just remove it like just a little bit, it goes back in the same place and gets stuck again."

While the participant appreciated the idea of the adjustable shower head, they noted that the lack of adjustability in the mount undermined its intended function, preventing the water from flowing as desired.

> "The idea is great, but what they have installed is not great... The hook that holds the head is not adjustable, so the water is not splashing where it's supposed to be."

The participant noted that they would have preferred to get all the different technologies at the beginning, so they could choose which they wanted to initially focus on and have more time with. While this would have steepened the learning curve, the user noted that this would have allowed them the flexibility to pick what technologies work best for them.

> "I would [have liked to have had] everything from the start… I think it's because you don't have to learn everything at once. But you know they're there. So if you want to learn more about one thing at first, let's say I would have the ReJoyce… maybe I would have focused more on the ReJoyce and less on the Google. But eventually I would have [also] learned the Google."

4.4.8 Heuristic 8: Universal Design and Aesthetics

This heuristic is defined by Universal Design considerations, which are important for deciding functions, features, and digital elements of a home. Universal Design is defined as the design of products and environments to be usable by all people, to the greatest extent possible, without adaptation or specialized design (15)*. There are 7 principles that were used to evaluate the extent to which Universal Design was incorporated.*

- *Principle 1: Equitable Use – The design is useful and marketable to people with diverse abilities.*
- *Principle 2: Flexibility in Use – The design accommodates a wide range of individual preferences and abilities.*
- *Principle 3: Simple and Intuitive Use – The use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.*
- *Principle 4: Perceptible Information – The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.*
- *Principle 5: Tolerance for Error – The design minimizes hazards and the adverse consequences of accidental or unintended actions.*
- *Principle 6: Low Physical Effort – The design can be used efficiently and comfortably with minimum fatigue.*
- *Principle 7: Size and Space for Approach and Use – Appropriate size and space are provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility.*

The participant appreciated the base apartment, for both its modern aesthetic and large size.

The black kitchen range contrasted well with the white countertops, allowing the participant to easily identify the stovetop. However, the oven was too low to the ground, requiring the participant to bend down to open and close it. Installing a wall oven would eliminate the participant's need to bend down or crouch.

A pull-out counter could be installed so the participant can prepare meals while seated on a chair. Due to the ample storage solutions in the kitchen, the participant's storage needs can be addressed using only the low-level cabinets within their reach.

Within the ensuite washroom, the showerhead mount is not adjustable, limiting its flexibility of use as needs and abilities change with the device. A larger shower that accommodates a drainage slope would be preferred, as well as an auto-shut-off feature if the water gets too hot. The wall-mounted soap dispenser in the shower helps reduce clutter, requires low physical effort to use, and makes the participant feel safer by eliminating the need to bend down and risk falling in the shower. The participant also noted how easy the product was to use and refill. The grab bars are not harmonious with the design of the bathroom, lack an aesthetic appeal, and may not be installed to safety standards. The motion sensor connected to the bathroom lights is in the bedroom, resulting in the bathroom light turning off as no movement is recognized.

> "I just went into the shower, that dim light was on and I was okay with that dim light to take my shower. But after a few minutes in the shower, the dim light… Because the sensor is in the bedroom and the sensor doesn't see nothing moving, so the light in the bathroom went off. So I'm in the shower and I'm in the dark now."

The participant noted that they had issues with the bidet and would find it more comfortable with an alternative orientation, expressing a preference for a front-to-back spray direction, rather than the current back-to-front orientation. Having a bidet with a warm water feature would also increase the

participant's comfort. Due to these issues, the participant ultimately stopped using the technology, citing possible health concerns.

> "I didn't use [the bidet] as much after, because I kind of was afraid to have a UTI."

The bathtub within the second bathroom was quite tall, making entering and exiting the tub difficult for those with mobility issues, especially without grab bars installed. The installation of a bathtub with a door as well as grab bars would ease entrance to the bathtub.

The height of items was a reoccurring issue. The washing machine was low to the ground, making it difficult to access. The step required to access the patio was too high and presented a tripping hazard. The peephole on the main door was too high for the participant to effectively use and see through.

> "All the doors of the [building have really high peepholes]. The person that has installed it is probably 6 feet high, and when you're 5 foot 3, I'm not able to look into it."

The participant enjoyed having the Google Nest programmed to play classical music when they returned home, thereby catering to their individual preferences. They also appreciated the other various features offered by the Google Nest, such as being able to check the temperature, play music, and display recipes with it.

As the Roomba kept getting stuck, the participant had to remove all their rugs so the device would not get stuck as often.

> "I ended up not using [the Roomba] that much because it gets stuck [in] many places. So I had little rugs that I finally ended up [removing]. Do I prefer to have the rugs and not using the Roomba or the opposite, and I said I would prefer to have the Roomba... So I ended up removing the rugs that I like."

4.4.9 Heuristic 9: Recognize, Diagnose, and Recover from Errors

This heuristic focuses on ensuring that the user can understand the problem and is offered a clear solution. Error messages should be expressed in plain language (no error codes), precisely indicate the problem, and constructively suggest a solution.

As previously indicated, the participant did not know why certain lights were voice-activated and others were not. The participant had no way of knowing which lights were connected and which were not, beyond initial trial and error.

The participant expected the fridge to beep if left open, as previous fridges they had used included this feature. The user also noted a notification identifying whether the oven or stove was left on would be helpful.

> "Something I would really like to exist, maybe it does exist, is about the oven. I would like to, if a burner or the stove is left unattended for a certain time, 5 minutes, 10 minutes, I would like to have an alarm on my phone that [says] "Are you sure you still want this to be on?" And because I have forgotten sometimes and this is something that I think we all do, even younger, sometimes we do... we forget something."

Additionally, the participant was confused about an unidentified beeping sound, which they thought may mean the smart lock was malfunctioning, however, this was unclear.

The smart lock does not notify the user of the type of batteries required for use or where they can be purchased (as they are not typical batteries), preventing their efficient replacement. During the timeframe in which the batteries need replacement, the user may have to go without the features provided by the smart lock. This may result in additional errors, such as forgotten keys, as they adapt to the new situation.

The participant was aware that the smart lock may not lock every time; however, they were able to check the app and determine whether or not the door was locked.

> "[The smart lock] works 90-95% of the time… Sometimes it gets stuck, and it doesn't lock. But if I'm in my bed and I'm not sure I can look it up and if it didn't lock, I will see on my phone."

After their initial trepidation, the participant valued the water leak sensors' capability to detect any leaks or overflows, enabling them to promptly address the issue or seek assistance, especially when they are away from home for extended periods.

The participant appreciated that their Apple Watch helped them orient themselves and determine the next steps when they fell, alerting for help if needed. They especially appreciated that they could use the device outside their home. Similarly, the participant appreciated that Chirp would alert for help if they fell in the home or if they said "help" twice, allowing for a greater range of support. The participant suggested that Chirp also be installed in the bathroom, as this is a location where they feel they have a higher likelihood of having an accident. As participants use the hallways for exercise in the winter, the participant also noted that the implementation of similar fall detection technology could be useful in the hallways.

> "I fell twice and both times the [Apple] watch right away was kind of vibrating… and it's asking you, "Did you fall? Do you want us to call 911?" So that was reassuring, I live by myself and [if] I fell… in the condo I thought it was so reassuring that I knew I just had to say "help, help" and the technology would start right away."

4.4.10 Heuristic 10: Help & Documentation

The best designs don't need any additional explanation; however, it may be necessary to provide documentation and support to help users complete their tasks. This heuristic focuses on providing the user with the necessary tools and information to help them achieve their goals. The information should be revealed at the right time to prevent a reliance on the user's memory.

The participant shared that it was helpful when the Geek Squad technician came to help them set up and adjust the HealthTech Home items, rather than having to figure it out all on their own. The participant also appreciated that it was the same technician who came for the follow-up visit.

The participant also found it helpful to voice-record the initial Geek Squad visit so they could refer to it later if they forgot any of the information.

> "So, the Best Buy technician came this morning, and I asked him if I could record his voice because I knew he would be here for an hour and a half, approximately, with all the

> explanations. I said that I may be overwhelmed [by the] information on technology, so I asked him, and he said, "Yeah, sure." So I have his voice and I can listen back, and if there's something I forget I can listen".

The pre-scheduled follow-up with the Geek Squad aided in progressively disclosing more complex and personalized information to the participant.

> "I know he's going to come back in two, three weeks. So, he said, "Use whatever. Write all your questions. And everything you would like me to put apps on your phone or all those things, we can do it at that point." So I was okay because if he would've said today, "Okay. What app would you like on your phone?" I would've said, "I don't know." But in two to three weeks, I will know."

Geek Squad was able to help reprogram the light issues that were occurring in the main areas of the home, and the participant had no further issues with the motion detector lights during the day.

The participant noted that for several technologies from T1, they were shown all the apps simultaneously, and expressed a desire to be able to practice them during this time. The participant further noted that the initial information provided when moving into the HealthTech Home was overwhelming. To facilitate their learning, the participant suggested that a document outlining the different apps and their functions would be helpful.

> "Have a clear sheet with simple steps written on them."

> "It was also challenging, learning all this new stuff... I'm usually pretty good, but remembering because you learn something, and sometimes you don't practice it right away, so I had some time to try to learn it again and learn it again. So this was a little bit challenging."

During the installation of the grab bars in the ensuite bathroom, the participant was provided with minimal support and documentation prior to installation. The participant felt that they had to make a rushed decision on placement and would have preferred to consult a professional (e.g., occupational therapist) on the placement of the grab bars.

> "I think that someone from the project should be there. Because when they came to install the grab bars, I didn't know exactly where to put them, and that put a lot of stress [on me]. I assumed that they would know [where to place the grab bars], and they assumed that I would know."

The participant appreciated that if they were to fall or have an accident in their home, Chirp would help connect them with their support network. The participant was never able to set up their care circle for Chirp due to their support network being busy during the installation period, which may be a limiting factor of the technology. However, as the participant was never able to get their friends and family on the Chirp care circle, BSF staff were able to help support and fill this role.

The Apple Watch also provided help for fall situations; the participant appreciated this coverage for external settings. Additionally, if the participant does not respond to the Apple Watch alert after the detected fall, the watch will contact emergency services and share the user's location.

4.5 Older People Quality of Life Questionnaire

The brief version of the Older People Quality of Life (OPQOL) questionnaire aims to assess one's well-being (6). As quality of life is subjective, the OPQOL incorporates socially relevant questions that incorporate themes such as positive outlook, social relationships, neighbourhood resources, financial circumstances, health, and independence.

No change was observed from the beginning of the study (T1) to the end of the study (T4) in quality of life. The OPQOL had the same, positive results at both time points. The participant responded to all items as 'strongly agree,' resulting in a mean average score of 5 at both time points. This indicates that the participant's experience in the HealthTech Home supported their high quality of life. As a note, the questionnaire is designed for people 65 years old and up, whereas the participant was below this age range.

4.6 Affinity for Technology Interaction Scale

The Affinity for Technology Interaction (ATI) scale aims to assess one's tendency to actively engage with technology (7). The ATI scale can provide insights into why users differ in their acceptance of certain technologies, their willingness to learn a new system, and their overall tendency to use, or not use, technology.

Changes were observed from T1 to T4 (Figure 5). As a note, a 5-point scale, rather than the original 6-point scale was used to maintain consistency and ease of use in the surveys administered to the participant. The mean average score decreased from the beginning of the study to the end (T1= 4.33; T4=3.67). This may indicate how the participant 'didn't know what they didn't know' heading into the study. While they originally considered themselves to be quite tech-savvy, having a year-long experience with exposure to many new and different technologies may have opened their eyes to how complex technology can be. Alternatively, this decrease may reflect how the participant's desire to learn about technology evolved over time. While initially very excited to learn about the new technologies, this desire may have reduced over time as they became more familiar with the technology in their everyday life and became more comfortable with not having to know everything about the technology they are using. They may have become more comfortable with simply using the technology, and having external supports in place, such as the Geek Squad support personnel, to fully understand the technology on their behalf. This reduction in affinity for technology does not necessarily indicate that the participant has developed a negative outlook on the technology, but rather that they have a better idea of what they do or do not like and how much effort they are willing to put in after their experience in the HealthTech Home.
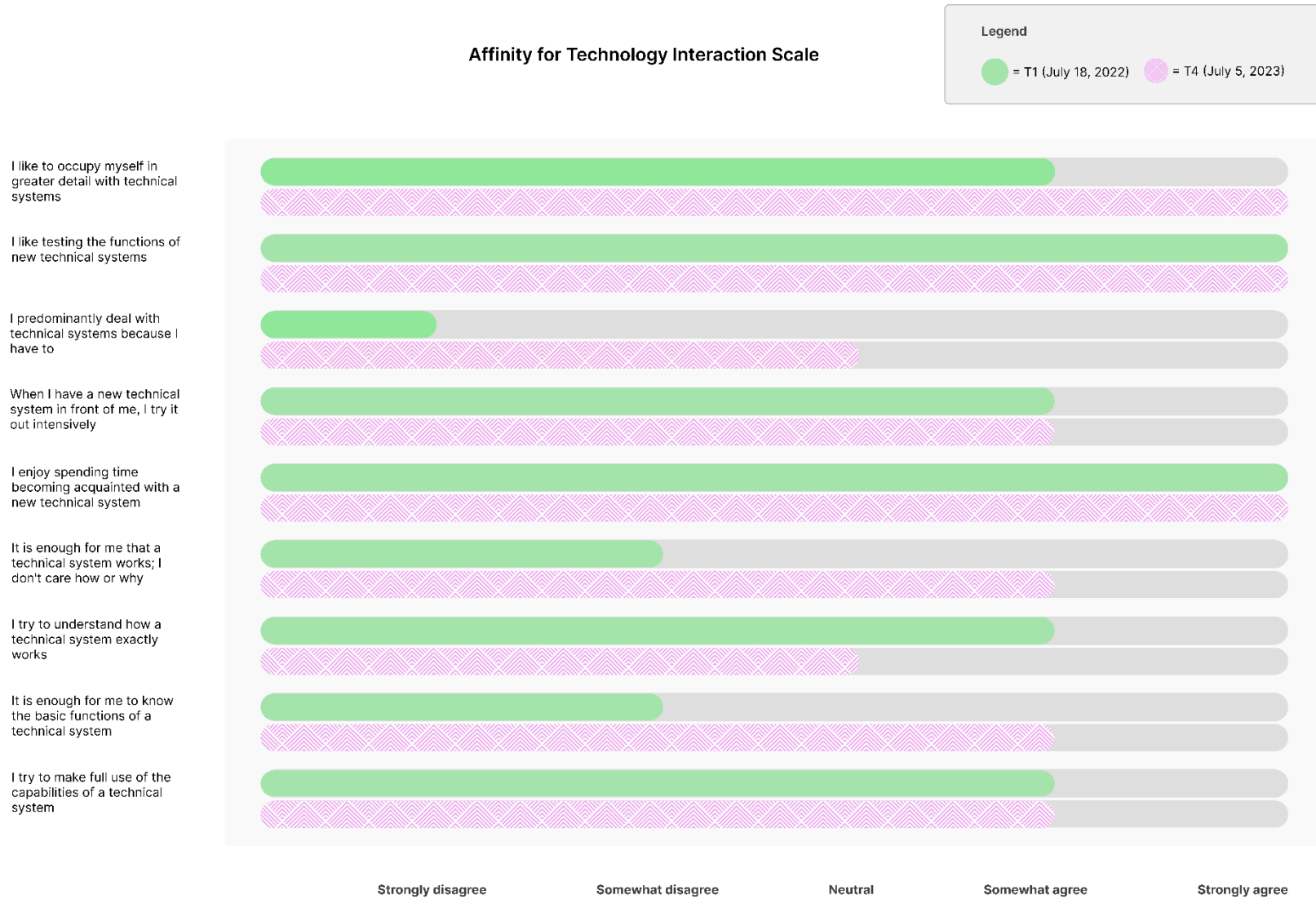
FIGURE 5. AFFINITY FOR TECHNOLOGY INTERACTION SCALE RESULTS FROM T1 AND T4.

5 Discussion

The evaluation of the HealthTech Home underscores the pivotal role that technology can play in enabling aging individuals to maintain their independence and quality of life within their own residence. The three domains of aging in place – living safely, living independently, and living with dignity – are discussed through how they were both supported and limited throughout this case study.

5.1 Living Safely

Living safely as an older adult requires taking measures to minimize risks and hazards to maintain a safe and accessible environment. This involves incorporating necessary precautions, such as fall prevention and proper medication storage. It involves regular communication with healthcare providers, being proactive about safety measures, and seeking help when needed. Additionally, having a support network of family, friends, and community resources can be invaluable in maintaining a safe and secure living environment.

5.1.1 Ways the HealthTech Home Supported the Participant to Live Safely

Several examples of how the HealthTech Home helped the participant to live safely are provided below.

1. **Installation of tools that helped minimize risks and hazards to maintain a safe and accessible environment**
   - *Fixed accessibility and mobility safety features*: Safety features, such as grab bars, were installed to help assist the participant in high-risk areas such as the bathroom.
   - *Fixed alert systems with remote capability*: Devices such as the water leak sensors, smart fire and CO detector, and the smart lock, were extra touches that made the participant feel more confident, comfortable, and secure when away from home.
   - *Mobile safety nets*: The inclusion of fall detection and emergency alert systems (i.e., Chirp, Apple Watch) made the participant feel secure if an incident were to occur.
   - *Remote access to the home:* The smart lock allows the user to open the front door, even when they are not home. This helps facilitate people such as their friends and family or external support such as a cleaning person enter the HealthTech Home without the user having to be present.

2. **The ability to build and maintain a support network within a vibrant community minimized loneliness**
   - *Located within a desirable neighbourhood*: The participant cited a strong sense of community as one of their main desires when choosing where to live. They felt safe to leave the HealthTech Home to get to where they wanted and needed to go.
   - *Ability to build new and maintain existing relationships*: Ways to feel less alone were common threads when discussing current needs, as well as anticipated future needs and concerns. They felt comforted by the knowledge that they were not isolated and were able to reach out to both neighbours and researchers in the study.

5.1.2 Ways the HealthTech Home Limited the Participant to Live Safely

While there were many ways that the HealthTech Home supported living safely, there were elements that threatened that safety that are important to consider for similar interventions.

3. **Not being able to rely on proper installation for features to work**
   - *Unreliable safety features:* The smart lock automatic lock feature did not work all the time, preventing the user from being able to rely on this feature to lock the front door.
   - *Unintended health impacts caused by improper installation:* The bidet was installed in a back-to-front spray orientation, which may have led to related health problems (i.e., urinary tract infections) for the user.

4. **Over-reliance on non-local support network**
   - *Non-local emergency alert contacts:* There is a trend that a resident's adult children, who may typically be considered their emergency contact, do not live in the same city as their aging parent. Therefore, they would not be able to respond to an emergency in a timely manner. It is recommended by the participant that there be local, building-specific people who could be notified of an emergency and who would have the physical ability to respond and arrive in person to assist. For example, the participant's family and friends' support network were too busy at the time of the Chirp installation to be added to the care circle.

5. **Limited opportunities for resident-initiated social activities**
   - *Local support and social networks:* While some of the building residents were keen on being a part of social gatherings, many of the resident-initiated social activities were shut down by the landlord or against community by-laws. For example, residents of the building started a social spot in the building hallways centered around completing puzzles. Unfortunately, the building had to disband the area for safety reasons, but the residents still desired a spot where they could casually meet other people from the building and host social events.

5.1.3 Additional Considerations for Enhancing the Ability to Live Safely

5.1.3.1 Technology Promoting User Safety

User safety in an aging in place setting is of the utmost importance (21,23,30). Technology can be used to support user safety, for example emergency alert systems such as fall detection (21,23,24). Technology should also be designed and implemented with safety in mind, such as using technology with wireless functionality to reduce tripping hazards (27). Additional modifications can be made to the home to improve safety, such as installing grab bars and ramps, creating a holistic environment that supports daily activities while mitigating hazards (31).

5.1.3.2 Technology as a Channel for User-to-User Communication

Technology's potential to facilitate communication between users and their support networks is a powerful tool to support successful aging in place. Enabling users to share select data with family and caregivers can lead to timely interventions, particularly in the case of emergencies like falls (16,17). Careful management of data sharing, ensuring it aligns with user routines and preferences, can preserve user privacy while optimizing support (18). Moreover, expanding communication channels between users and their care network, including physicians, can provide valuable insights for predictive health and timely interventions (19–21).

5.1.3.3 Influence from Being Monitored

The study highlighted the need to balance the benefits of monitoring user behaviour for health improvement with the user's comfort and privacy. Providing users with feedback and access to their own data could allow them to adjust their behaviour and actions to improve their health status (16,21,24). Additionally, providing users with the opportunity to share their data with their support

network can better inform healthcare-related decisions (16,21). Installing sensors above eye level when possible is a strategy to alleviate the perception of constant monitoring, thereby fostering a sense of autonomy and comfort for users (17).

5.1.3.4 Social Needs and Connections

Technology's role in fostering social connections was underscored, with the caveat that it should complement, rather than replace, face-to-face interactions (18,28). Technology-enabled entertainment and social companionship can combat social isolation, contributing to overall well-being (24).

5.1.3.5 Sense of Security During Technology Use

One prominent concern that also emerged is the issue of privacy and security. The aging population holds apprehensions about their personal information being exploited, especially with companies harvesting their data or others hacking their technology (19). Offering user training to clarify what information is being shared, how it's stored, and who can access it could go a long way in mitigating security concerns (17,18,22,23). By enabling users to control the information they share, technology can empower older adults to maintain their privacy while enjoying the benefits of smart and connected devices (16). Additionally, transparent communication of privacy terms and robust security mechanisms can build user confidence and prevent potential security breaches (16,24).

5.2 Living Independently

Living independently as an older adult means having the ability to successfully manage one's own daily life without the need for significant assistance from healthcare aids or family members. This can include aspects of one's life, such as healthcare and personal hygiene management, meal preparation, mobility and transportation, household management, and other daily living activities. It's important to note that living independently does not mean complete isolation from assistance or resources.

Ultimately, living independently as an older adult is about maintaining a level of self-sufficiency that aligns with an individual's physical and cognitive abilities, preferences, and comfort levels.

5.2.1 Ways the HealthTech Home Supported the Participant to Live Independently

Several examples of how the HealthTech Home helped the participant to live independently are provided below.

1. **Installation of tools that improved mobility and assisted with activities of daily living helped the participant to continue to live independently inside the HealthTech Home**
   - *Mobility rehabilitation*: The participant was provided with health-focused technology that aimed at rehabilitating and improving their ability to move. ReJoyce assisted the participant in addressing their shoulder mobility to promote ongoing health and wellness. Before the introduction of the ReJoyce, the participant had been using a reacher/grabber tool to help them retrieve items that were outside of their shoulder range of motion.
   - *Home maintenance aids:* The participant was provided with tools that helped clean the home and freed up their time for more leisure pursuits. For example, the Roomba helped the user maintain a clean home by sweeping dust and particles off the floor that would typically require somebody to sweep and vacuum by hand.

2. **The neighbourhood around the HealthTech Home that supported walkability and accessibility helped the participant to live independently outside of the home**

- *Amenities within walking distance*: The neighbourhood where the HealthTech Home is located supported the participant's preferred mode of transportation: walking.

5.2.2 Ways the HealthTech Home Limited the Participant to Live Independently

While there were many ways that the HealthTech Home supported living independently, there were elements that threatened this independence that are important to consider for similar interventions.

3. **Missing tools that support universal design**
   - *Non-standardized placement and missing accessibility features:* There were areas within the HealthTech Home that did not support the principles of universal design. For example, the grab bars in the ensuite bathroom were installed without proper consideration of universal design and standardized practices. The bathtub lacked a grab bar to assist safe entry and exit. The step required to get onto the porch presents as a tripping hazard. Several appliances that involve hot elements, such as the oven and microwave, were not placed at a good height for the user, which could lead to future accidents.

5.2.3 Additional Considerations for Enhancing the Ability to Live Independently

5.2.3.1 Accessible Housing and Technology Options

Accessibility is an important consideration in an aging population for both technology and housing, as it can profoundly impact the well-being and independence of individuals. Housing location is an important initial consideration, as it will impact the available accessible transportation options (21). Implementing mechanical supports, such as chair lifts, facilitates independence in daily activities (29). Additionally, safety measures such as ramps, grab bars, and stair lifts, are important accessibility features to incorporate in designs (29).

5.3 Living with Dignity

Living with dignity as an older adult is closely tied to living safely and living independently. It means maintaining a sense of self-respect and autonomy, even as one faces the challenges and changes that can come with aging. It involves recognizing and upholding the inherent value and rights of every individual, as well as ensuring they are treated with the respect, compassion, and support they deserve throughout the aging process. It involves empowering older adults to have a voice in their own care and to live a life that reflects their values, preferences, and desires.

5.3.1 Ways the HealthTech Home Supported the Participant to Live with Dignity

Several examples of how the HealthTech Home helped the participant to live with dignity are provided below.

1. **The installation of tools of the participant's choosing, as well as the ability to customize and personalize the functions and features within those tools**
   - *Ability to choose tools and technologies*: The participant was provided with the ability to choose against certain technologies or features, for example, the Google Nest security camera feature was adjusted to not turn on when the participant was home as it made them feel uncomfortable.
   - *Ability to change settings and features to fit current needs and to adapt over time:* There were situations where features were set up but needed to change as the participant began to use the tools, or as they became more familiar and experienced with them. As an example, when the participant's cat learned how to turn on and 'play' with the Roomba,

they were able to activate the childproof feature to prevent this unintentional activation from occurring and disturbing the participant.

2. **Fostering dignity through a holistic experience**
   - *Overall experience:* The participant's positive experience as a whole contributed to the feeling of dignity.

5.3.1 Ways the HealthTech Home Limited the Participant to Live with Dignity

While there were many ways that the HealthTech Home supported living with dignity, there were elements that threatened this dignity that are important to consider for similar interventions.

3. **An overwhelming introduction to too many systems and new technologies**
   - *Multiple operating systems*: While the participant was most familiar with iOS operating systems as they own an Apple Watch, MacBook, and iPhone, the HealthTech Home provided technology such as a PC laptop and a Google Nest. This steepened the learning curve and led to some initial confusion.
   - *Multiple lighting systems:* The HealthTech Home had many different types of lighting, such as motion detector-activated lights, smart bulbs, and smart switches. This was initially very confusing to the participant, especially as they didn't know which was which. Additionally, these systems continued to have glitches throughout their time in the home.

4. **Lack of personalization**
   - *Aesthetics:* The HealthTech Home has a relatively modern aesthetic, and the participant noted that they would have liked for the added assistive technologies to also fit this style, rather than coming across as a medical device or as something clearly designed for an older adult. For example, the participant noted that they would have liked it if the grab bars matched the style of the bathroom.

5.3.2 Additional Considerations for Enhancing the Ability to Live with Dignity

5.3.2.1 Supporting Technology Use Through Training

The significance of training in enhancing technology adoption and use cannot be overstated. Providing training on the use of technology can encourage users to develop a deeper understanding of how to use products and how to incorporate them into their daily lives (28,30). With a greater understanding comes a reduction in anxiety associated with the use of new technology (25). Specifically, training related to personal data control, privacy capabilities, and how to interact with their devices would be beneficial (16,28). Additionally, tailored training that matches users' existing technological proficiency levels and educational backgrounds is crucial (22,23,27,30,31). This training should encompass not only the functional aspects of technology use, but also focus on personal data control and privacy awareness. One-on-one training, along with documentation provided to address questions for future reference would also help support technology learning (29,32). Training users on the importance of specific technologies in their daily lives is critical to safe, independent living. By educating users about the relevance of specific technologies and by providing ongoing support and resources, the transition to technology-driven independent living can be facilitated.

5.3.2.2 Troubleshooting Technological Problems

The evaluation emphasized the importance of anticipating and addressing technological glitches that may arise. Factors such as technology updates, obsolescence, and the need for technical support must

be incorporated into the technology implementation strategy (28). To minimize disruptions and maintain seamless technology usage, a balance should be struck between the frequency of updates and the user's familiarity with the technology. The availability of in-person and remote technical support can greatly assist users in navigating technological challenges, subsequently reducing their reliance on family members and alleviating undue burden (16,21,28,31).

5.3.2.3 Readiness to Adopt

For technology to be impactful, it must be readily wanted and adopted by the users (21). Familiarity with technology, such as a smartphone, enhances user comfort with new technology and increases the likelihood of adoption (25). Providing information sessions and workshops within the community can help potential users become aware of the technology available to them and how it could be incorporated into their lives (23,31). Additional product support can help potential users determine exactly what technology would best meet their individual needs (30). Co-design workshops can facilitate conversations around how to best map existing technologies to user needs (20). Overall, these interventions should aim to address technology anxiety and motivation to more readily adopt technology (25).

5.3.2.4 Personalization of Technology According to Individual Needs

Diversity in user needs and capabilities is an important consideration for creating inclusive, accessible, and adaptable environments. Effective technology solutions should be tailored to accommodate the unique requirements, abilities, and limitations of each user (26,27,30,33). Furthermore, considering the living dynamics of multiple cohabiting individuals and adapting technology to accommodate their varying routines and preferences can enhance the overall experience and effectiveness of technology to support aging in place (19).

5.3.2.5 User-friendliness

Prioritizing user-friendliness in technology is pivotal for successful aging in place (33). Co-design, which involves the participation and contribution of older adults in the development process, can help facilitate designing technology that is better aligned with their needs (28). Implementing features such as simple instructions, larger fonts, voice-activated tools, and streamlined buttons are aspects of making technology more user-friendly for an older adult population (28).

5.3.2.6 Cost-effectiveness of Housing and Technology Services

Cost considerations emerged as a critical factor when the participant was determining what technology they would like to have in their home after their experience living in the HealthTech Home. The expense associated with integrating technology and support services can be a barrier for aging individuals (16,18,22,23,26,27,31). Providing cost-effective, or low-cost technology helps to reduce any financial barriers (18). Offering customizable purchasing options, such as a one-time payment setup, subscriptions, or optional technical services could help better fit individual budgets (16,26,27). Additionally, subsidized costs or more upfront costs can help users factor these expenses into a retirement plan (22,23). Making use of and repurposing technologies already present in user's homes can also help mitigate additional costs (18,31). Lastly, housing and personal support workers are additional cost considerations for older adults wanting to remain living independently (26,27).

5.4 Limitations and Biases

The study acknowledges certain limitations that warrant consideration in the interpretation of findings.

The case study approach, while providing valuable in-depth insights into the individual participant's experience, may not capture the broader diversity of perspectives and the findings may not be generalizable to a broader population. Additionally, with only one participant the study may not have captured broader social, economic, and cultural factors that influence the adoption and use of technology for aging in place.

Additionally, the participant's behaviour could have been influenced by being part of the study as they were aware that they were being interviewed and observed. This is known as the Hawthorne effect.

Self-selection bias should also be considered, as the participant chose to take part in this study, and therefore may have had pre-existing interest or comfort with such technologies. Furthermore, it is important to note that the participant in this study was relatively young within the context of aging research. The experiences and challenges faced by younger older adults may differ from those older.

Lastly, as the health-focused technologies were installed relatively late within the study timeline and considering the participant's extended time away from the HealthTech Home towards the end of the study, there is a time dependent limitation. The participant had significantly more time to interact with some technologies compared to others. Additionally, the study may not have fully encompassed the long-term effect of technology use on aging in place. Over time, the participant's needs and preferences may change and the technology's effectiveness may also evolve.

5.5 Future Study Considerations

5.5.1 Considerations for Future Tenants and Participants

When talking about their experience in the home, the participant noted several pieces of advice that could be of assistance to future tenants. They felt it was important to express all comments or concerns with researchers and push themselves to use all facets of the available technology.

> "I would [suggest to future tenants] not to be afraid of the technology and to take the time to learn one thing after the other, and there is no pressure… Be patient with yourself … Just give [yourself] the time to learn this stuff and if you forget, you ask again."

> "Do not be afraid to use the technology and maybe even push yourself a bit to use it."

The participant found that the technology's practicality and daily usage made learning easier and encouraged them to push past their normal comfort zone. Through their experience living in the HealthTech Home, the participant noted that they have changed the way they think about technology, with their increased comfort leading them to consider how they could continue to incorporate it into their everyday life.

> "[I] think that you put up a wall [against] new things, like a new technology that you don't need it, or you won't be able to learn it, and I think that being part of the condo has opened my mind [to] all that technology."

> "It has really changed [my] opinion… on technology… in a positive way."

Additionally, the participant noted that they would appreciate easy access to a quality meal preparation service, as they find cooking for one person to be a challenge and often lack motivation to do so. While

this isn't a service they employed during their time in the HealthTech Home, they did note that they would have enjoyed having this external support to encourage healthy eating habits while also saving them time.

> "I like food, but I like when it's really good food… I would [like to] have three meals a day from a caterer. This is something that I would love."

Lastly, the participant received support throughout the year from both the researchers and the BSF staff who helped make this experience as smooth of a process as possible. In the future, having a similar third party (that isn't their family) that could help a future tenant and build a rapport with them would help to facilitate the success in the new environment.

5.5.2 Move-In and Move-Out Considerations

The participant noted that a more structured move-in, where they were able to ask questions to the study and BSF staff, would have potentially mitigated several early issues. Post-move-out, the participant still had access to technology within the home, indicating the need for a more detailed close-out procedure.

> "I think it would be easier if someone is there when [the tenant] moves in… There was something I was missing the day I was moving… [the BSF staff] really thought that I would have it, but I didn't have it. I think it was the garage door opener or something. So, if somebody… would be there, those things would have been solved right away."

> "Technically, now, I'm thinking I could start the Roomba now and I'm not living there no more. So I think I should remove all the apps [from my iPhone]."

6   Recommendations and Conclusion

6.1 Recommendations

6.1.1 Upstream Opportunities (Planning and Design)

- Prior to the tenant moving in, conduct a needs assessment that includes current technology usage and confidence, mobility and accessibility needs, and desires and preferences that help to personalize the experience as much as possible
    - The number and type of technologies needed
    - the order of the technology implementation
- Choose one operating system, or consider a tool that integrates and coordinates with different operating systems, so that there is an initial level of familiarity, a single interface and one source of truth for the user
- Incorporate a multi-disciplinary team (current residents, occupational therapists, architects, IT specialists) in the initial design of rooms and technology selections
- Enlist an occupational therapist to review the room and make sure basic fixtures, safety requirements, and accessibility are also considered, along with assistive technology (e.g., grab bars)
- Incorporate a selection of products and features from each of the gerontechnology domains

6.1.2 Downstream Opportunities (Adoption and Improved Use)

- Provide the tenant with some choice as it relates to room design and technology selection to improve feelings of dignity and independence
- Incorporate technology with childproof (or pet-proof) capabilities to allow for customization and adaptability to the user's specific needs so that the user can maintain a safe environment while tailoring the system to their preferences and changing circumstances
- Conduct periodic testing of safety monitoring technology (e.g., water leak sensors, smart fire alarm & CO detector) so that the tenant is confident that these technologies will work in an emergency
- Select products that include audio-visual feedback to indicate when actions don't align with the proper use of the product or system (e.g., fridge beeping when it is left open, stove or oven signal when it has been left on) to promote user awareness so that the user can promptly correct or address any safety-related issues and prevent potential hazards
- Provide education regarding data collection and tracking abilities of the available smart technologies to increase user comfort with the technology
- Pre-schedule a follow-up tech support visit to improve knowledge translation beyond the initial set-up when learning a new system or technology, and to make the participant feel supported rather than a burden
- Gradually introduce apps to the user one at a time to facilitate better understanding by the user and avoid overwhelming them with too much new information at once
- As the user becomes more familiar with the technology, introduce more voice commands and provide additional training and resources to allow them to become a more advanced user
- Incorporate manual override options to allow the user freedom to maintain activities of daily living while turning off or not using the smart products when systems don't work as expected or optimally
- Incorporate additional support guides to help facilitate learning and re-learning of the technologies present

6.2 Conclusion

Overall, the participant reported that they had a wonderful experience living in the HealthTech Home and was very grateful for the experience. Values articulated by the participant were drawn from the interviews as a frame for the thematic analysis. Each of these themes contributes to the desired experience of dignity, meaningfulness, and freedom. These desired experience concepts are not commonly or consistently associated with and incorporated into designing products and services for seniors.

The evaluation supports the hypothesis that interventions, such as HealthTech Home, could support aging in place if the recommendations in this report are taken into consideration.

7 References

1. CMHC. Aging in the Right Place [Internet]. 2021 [cited 2022 Jul 24]. Available from: https://www.cmhc-schl.gc.ca/en/nhs/nhs-project-profiles/2020-nhs-projects/aging-in-the-right-place

2. Golant SM. AGING IN THE RIGHT PLACE COPING REPERTOIRES: THE SUBSTITUTABILITY OF CONNECTIVITY ALTERNATIVES. Innov Aging [Internet]. 2017 Jul 1 [cited 2022 Jul 24];1(Suppl 1):664. Available from: /pmc/articles/PMC6247150/?report=abstract

3. Golant SM. Commentary: Irrational Exuberance for the Aging in Place of Vulnerable Low-Income Older Homeowners. http://dx.doi.org/101080/08959420802131437 [Internet]. 2008 [cited 2022 Jul 24];20(4):379–97. Available from: https://www.tandfonline.com/doi/abs/10.1080/08959420802131437

4. Franke T, Attig C, Wessel D. A Personal Resource for Technology Interaction: Development and Validation of the Affinity for Technology Interaction (ATI) Scale. Int J Hum Comput Interact. 2019 Apr 3;35(6):456–67.

5. Haugan G, Drageset J, André B, Kukulu K, Mugisha J, Utvær BKS. Assessing quality of life in older adults: psychometric properties of the OPQoL-brief questionnaire in a nursing home population. Health Qual Life Outcomes. 2020 Dec 2;18(1):1.

6. Bowling A, Hankins M, Windle G, Bilotta C, Grant R. A short measure of quality of life in older age: The performance of the brief Older People's Quality of Life questionnaire (OPQOL-brief). Arch Gerontol Geriatr. 2013 Jan;56(1):181–7.

7. Franke T, Attig C, Wessel D. A Personal Resource for Technology Interaction: Development and Validation of the Affinity for Technology Interaction (ATI) Scale. Int J Hum Comput Interact. 2019 Apr 3;35(6):456–67.

8. Snowden A, Martin CR. Concurrent analysis: towards generalisable qualitative research. J Clin Nurs [Internet]. 2011 Sep [cited 2022 Sep 7];20(19–20):2868–77. Available from: https://pubmed.ncbi.nlm.nih.gov/20946446/

9. Quintanilha M. Quali Q. 2021 [cited 2022 Sep 7]. Concurrent Data Collection and Analysis: Say What? Available from: https://www.qualiq.ca/blog/concurrent-data-collection-and-analysis

10. LUMA Institute. Luma Institute. 2022 [cited 2022 Sep 7]. Heuristic Review. Available from: https://www.luma-institute.com/heuristic-review/

11. Nielsen J. Nielsen Norman Group. 2020 [cited 2022 Sep 7]. 10 Usability Heuristics for User Interface Design. Available from: https://www.nngroup.com/articles/ten-usability-heuristics/

12. Nielsen J. Nielsen Norman G. 1994 [cited 2022 Sep 7]. Heuristic Evaluation: How-To. Available from: https://www.nngroup.com/articles/how-to-conduct-a-heuristic-evaluation/

13. Lesnoff-Caravaglia G. Health Aspects of Aging: The Experience of Growing Old [Internet]. 2007 [cited 2022 Dec 8]. Available from: https://books.google.ca/books?hl=en&lr=&id=Y0d3CAAAQBAJ&oi=fnd&pg=PR1&dq=Lesnoff-Caravaglia+2007&ots=99-zWN3mhF&sig=VsseysAyIXh59Weazhheg1z_Jf8&redir_esc=y#v=onepage&q=Lesnoff-Caravaglia%202007&f=false

14. Chen K, Chan AHS. Gerontechnology acceptance by elderly Hong Kong Chinese: a senior technology acceptance model (STAM). Ergonomics. 2014;57(5):635–52.

15. Centre for Excellence in Universal Design. The 7 Principles of Universal Design [Internet]. 2020 [cited 2022 Sep 26]. Available from: https://universaldesign.ie/what-is-universal-design/the-7-principles/

16.   Choi YK, Thompson HJ, Demiris G. Internet-of-Things Smart Home Technology to Support Aging-in-Place: Older Adults' Perceptions and Attitudes. J Gerontol Nurs. 2021 Apr 1;47(4):15–21.

17.   Kim D, Bian H, Chang CK, Dong ; Liang, Margrett J. In-Home Monitoring Technology for Aging in Place: Scoping Review. Interact J Med Res [Internet]. 2022 [cited 2022 Nov 2];11(2). Available from: https://www.i-jmr.org/2022/2/e39005

18.   Elers P, Hunter I, Whiddett D, Lockhart C, Guesgen H, nat rer, et al. Original Paper User Requirements for Technology to Assist Aging in Place: Qualitative Study of Older People and Their Informal Support Networks. JMIR Mhealth Uhealth [Internet]. 2018 [cited 2022 Nov 2];6(6). Available from: http://mhealth.jmir.org/2018/6/e10741/

19.   FakhrHosseini M. MIT AgeLab. 2021 [cited 2022 Jul 24]. Some design considerations for smart home technologies: findings from C3 interviews. Available from: https://agelab.mit.edu/home-logistics-and-services/blog/some-design-considerations-smart-home-technologies-findings-c3-interviews/

20.   Couture M. Smart Environments Supporting the Ecosystem of Fragile and Isolated Seniors: The City of Côte Saint-Luc Living Lab [Internet]. 2022 [cited 2022 Jul 24]. Available from: https://cotesaintluc.org/services/public-safety/the-living-lab/

21.   Ahn R, Aghvami S. Innovative care: Using 'A day in the life' as a tool to explore opportunities for a tech-enabled home for older Canadians. Knowledge Management & E-Learning: An International Journal [Internet]. 2020 Dec 26;12(4):419–26. Available from: https://www.kmel-journal.org/ojs/index.php/online-publication/article/view/455

22.   Kim K, Gollamudi SS, Steinhubl S. Digital technology to enable aging in place. Exp Gerontol [Internet]. 2017 [cited 2022 Nov 2];88:25–31. Available from: http://dx.doi.org/10.1016/j.exger.2016.11.013

23.   Jaschinski C, Ben Allouch S, Peters O, Cachucho R, G M van Dijk JA. Acceptance of Technologies for Aging in Place: A Conceptual Model. J Med Internet Res [Internet]. 2021 [cited 2022 Nov 2];23(3). Available from: https://www.jmir.org/2021/3/e22613

24.   Gochoo M, Alnajjar F, Tan TH, Khalid S. Towards Privacy-Preserved Aging in Place: A Systematic Review. Sensors [Internet]. 2021 [cited 2022 Nov 2];21. Available from: https://doi.org/10.3390/s21093082

25.   Arthanat S, Wilcox J, Macuch M. Profiles and Predictors of Smart Home Technology Adoption by Older Adults. OTJR (Thorofare N J) [Internet]. 2019 Oct 1 [cited 2022 Nov 2];39(4):247–56. Available from: https://doi.org/10.1177/1539449218813906

26.   Narushima M, Kawabata M. "Fiercely independent": Experiences of aging in the right place of older women living alone with physical limitations. J Aging Stud. 2020 Sep 1;54:100875.

27.   Arthanat S, Chang H, Wilcox J. Determinants of information communication and smart home automation technology adoption for aging-in-place HHS Public Access. J Enabling Technol [Internet]. 2020 [cited 2022 Nov 2];14(2):73–86. Available from: www.emeraldgrouppublishing.com/licensing/

28.   Wang S, Bolling K, Mao W, Reichstadt J, Jeste D, Kim HC, et al. healthcare Technology to Support Aging in Place: Older Adults' Perspectives. Healthcare [Internet]. 2019 [cited 2022 Nov 2];7(60). Available from: www.mdpi.com/journal/healthcare

29.   Beer JM, McBride SE, Mitzner TL, Rogers WA. Understanding challenges in the front lines of home health care: A human-systems approach. Appl Ergon. 2014;45(6):1687–99.

30.   McBride SE, Beer JM, Mitzner TL, Springman JM, Rogers WA. Challenges of training older adults in a home health care context. In: Proceedings of the Human Factors and Ergonomics Society. 2012. p. 2492–6.

31.   Tural E, Lu D, Austin Cole D. Safely and Actively Aging in Place: Older Adults' Attitudes and
        Intentions Toward Smart Home Technologies. Gerontol Geriatr Med [Internet]. 2021 [cited 2022
        Nov 2];7. Available from: https://doi.org/10.1177/23337214211017340
32.   Arthanat S. Promoting Information Communication Technology Adoption and Acceptance for
        Aging-in-Place: A Randomized Controlled Trial. Journal of Applied Gerontology [Internet]. 2021
        May 1 [cited 2022 Nov 2];40(5):471–80. Available from:
        https://doi.org/10.1177/0733464819891045
33.   AGE-WELL Industry Advisory Group. Technology and Agining At Home: The Future of Aging in
        Place. 2021.
34.   Government of Canada. Thinking about aging in place [Internet]. 2016 [cited 2022 Oct 19].
        Available from: https://www.canada.ca/en/employment-social-
        development/corporate/seniors/forum/aging.html
35.   Card Sorting: Uncover Users' Mental Models for Better Information Architecture [Internet]. [cited
        2023 Sep 10]. Available from: https://www.nngroup.com/articles/card-sorting-definition/
36.   The Safe Living Guide—A Guide to Home Safety for Seniors - Canada.ca [Internet]. [cited 2023
        Sep 10]. Available from: https://www.canada.ca/en/public-health/services/health-
        promotion/aging-seniors/publications/publications-general-public/safe-living-guide-a-guide-
        home-safety-seniors.html

8 Appendix

8.1 Definitions

Aging in Place: Having the health and social supports and services you need to live safely and independently in your home or your community for as long as you wish and are able (34). Changes to cognitive, sensory, and physical abilities over time can lead to functional impairments requiring the need for additional services and support that can disrupt aging in place. It refers to the ability to continue residing in one's own residence as they grow older, and can depend on many factors such as health, social supports, and available services.

Aging in the Right Place (AIRP): Involves supporting older adults to live as long as possible in their homes and communities, while recognizing that where an older person lives impacts their ability to age optimally and must match their unique lifestyles and vulnerabilities (1). The principle of AIRP is to enable older adults with diverse needs to maintain their independence and autonomy in later life and continue to stay socially connected in the place where they live, feel competent, comfortable, and in control (2,3).

Card-sorting: A usability evaluation method in which a participant groups words or phrases written on notecards according to certain criteria to uncover how they structure certain information (35).

Case study: An in-depth analysis of one individual experience.

Dignity: The right of a person to be valued and respected for their own sake, and to be treated ethically.

HealthTech Home: A condo in an independent living facility in Calgary, adjacent to a seniors' wellness community. The technology incorporated into the home includes smart and connected devices around lighting, smart displays, voice assistants, and more. It also includes health-focused technologies designed to support areas such as health monitoring and health management.

Heuristic Evaluation: A usability evaluation method where a system is inspected against a set of standardized design principles (i.e., heuristics) (11).

Independent living: Being able to support one's own activities of daily living, such as tasks related to mobility, personal hygiene, and eating.

Safe living: When a residence incorporates features aimed to prevent or considerably reduce the chances of being injured at home (36).

8.2 Technology and Features List

Table 2 outlines the various technologies available in the HealthTech Home, as well as the participant's personal devices that they used throughout the study. Note that this is not an exhaustive list of all the technology features.

TABLE 2. LIST OF TECHNOLOGIES PRESENT IN THE HEALTHTECH HOME AND THEIR NOTABLE FEATURES

Technology	Gerontechnology Domains	Features
Apple Watch	Home and daily living; Communication; Healthcare; Education and recreation	iOS operating system
		Health tracking (e.g., heart rate, blood oxygen)
		Fall and crash detection
		Cellular connectivity
August Smart Lock	Home and daily living	Activity monitoring
		Guest access
		Away-from-home control
		Status updates (DoorSense)
		Auto-lock/unlock
Chirp	Healthcare	Camera-free activity monitoring
		2-way voice communication
		Voice-based personal emergency response system (i.e., say "help")
Google Nest	Home and daily living; Communication; Healthcare	Watch or listen to media
		Control TVs and speakers
		Plan your day (e.g., calendar, weather, traffic, etc.)
		Get things done (e.g., set reminders, find recipes, make a shopping list, etc.)
		Manage tasks (e.g., set a timer)
		Get answers
		Control your home (e.g., lights, security camera, etc.)
		Have fun (e.g., play trivia and games)
iPad & iPhone	Home and daily living; Communication; Education and recreation	iOS operating system
		Internet connectivity and web browsing
		Dual-facing cameras
		Communication (e.g., messaging, emailing, video chat, etc.)
		Voice-controlled personal assistant (i.e., Siri)
		Download and use apps
		Touch screen
LG Smart TV	Education and recreation	Internet connectivity and web browsing
		On-demand streaming
		Casting from a mobile device
MacBook	Communication	iOS operating system
		Voice-controlled personal assistant (i.e., Siri)
		Internet connectivity and web browsing
Motion Detector Lights	Home and daily living	Detect movement to turn on lights
		Turn lights off after a set amount of time
PC Laptop	Communication	Windows operating system
		Voice-controlled personal assistant (i.e., Cortana)
		Internet connectivity and web browsing
Philips Hue Smart Lights	Home and daily living	Voice control

		Dimming and RGB lighting
		Light recipes for daily tasks
		Timers and sleep automations
		Away-from-home control
Phyn Smart Water Sensor	Home and daily living	SMS and app leak notification
		Audible alarm
		Flashing LED alarm
		Customizable alarm for temperature and humidity
		Low battery alert
ReJoyce	Healthcare	Upper limb exercises representing activities of daily life
Roomba	Home and daily living	Automated vacuuming/sweeping
Smart Fire Alarm & CO Detector	Home and daily living	Sends notifications to your smartphone
		Alarm flashes red and verbally informs what is happening

8.3 Individual Technology Experience Breakdown

Each individual technology experience breakdown includes a description with unique comments or thoughts provided by the participant on the product and its use, as well as an experience map, which notes how many user celebrations and violations were mentioned in each interview. The columns in the experience map represent the different periods (i.e., T1, T2, T3, T4) and each period is separated by the end-of-term interview that was held. Each column is a different width to represent the duration of each term (e.g., T1 was only a few weeks, making it relatively short, but T3 was many months, making it relatively long). The rows represent the number of celebrations (shown in green), or violations (shown in red) mentioned about the item. Each item starts neutral at zero and is then placed on the graph when the first positive or negative comment is made about it.

Additionally, two card-sorting activities were conducted in the T3 and T4 interviews. The participant rated if the product was a 'need,' 'nice to have,' or 'could do without' item, as well as the usefulness of the product on a scale of 7, with 1 being not useful and 7 being very useful. The averages across the T3 and T4 interviews are shown below.

8.3.1 Apple Watch

Usefulness rating: 7/7

The Apple Watch used in the study was the participant's personal device. The participant expressed a deep appreciation for the Apple Watch, and they specifically noted the fall detection and reorientation feature, praising how it could be used both inside and outside the home, whereas Chirp was restricted to at-home use. It provided them with peace of mind by providing immediate health data, such as blood oxygen and heart rate, when they were experiencing anxiety which helped ground them. Additionally, the movement rings encouraged the participant to be more active. The participant considered the

technology a need and recommended that all future HealthTech Home participants or tenants have an Apple Watch.
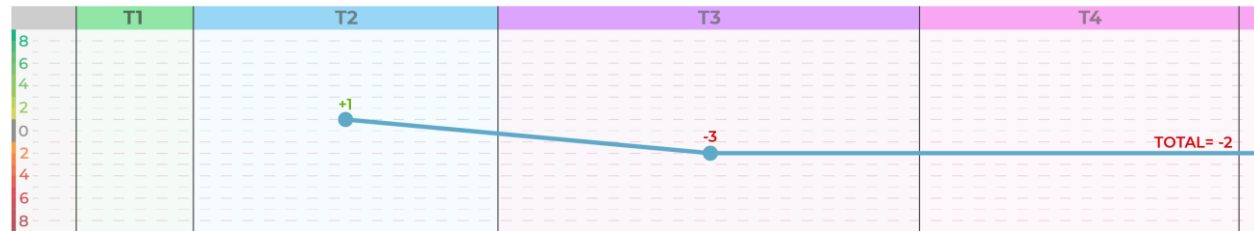
Apple Watch
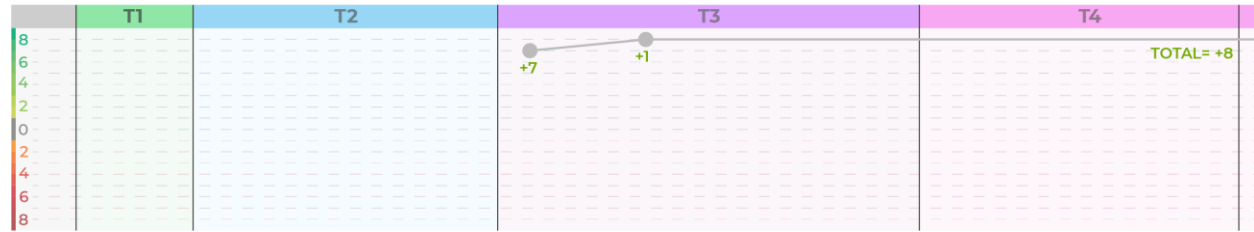
8.3.2 Bidet
Usefulness rating: 5/7

The participant was unable to address several issues with the bidet, such as the spray orientation and cold-water temperature, but suggested that if there was a better version installed it would be classified as a need. They stated that they plan to look for one with warm water that sprays in their desired orientation for their current house.

Bidet

8.3.3 Chirp
Usefulness rating: 7/7

The participant found that while Chirp was nice to have, they likely would not purchase it for themselves. The Apple Watch's fall detection feature fulfilled the same purpose both in and out of the home, making it of greater value to the user as Chirp is limited to in-home use. Additionally, the participant struggled to set up their care circle for Chirp, which may be a limitation of the device. Due to this, the user considered Chirp a nice to have but a fall detector device to be a need.

Chirp
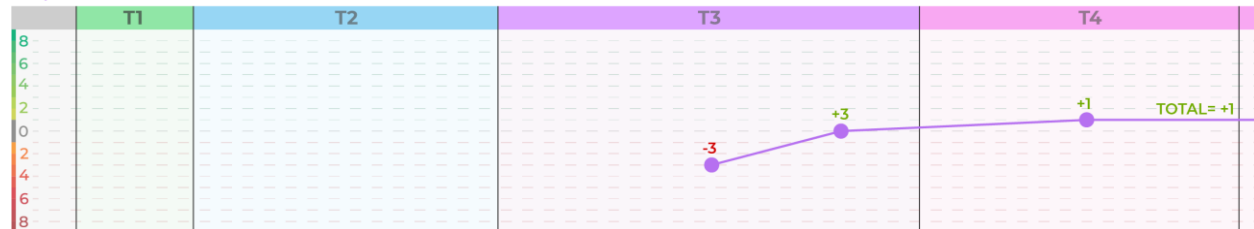
8.3.4 Grab Bars

Usefulness rating: 7/7

While there were several issues with installation, the participant found the grab bars to be incredibly useful. The participant categorized them as a need, expressing plans to install them in their current home. However, grab bars were only installed in the Master Ensuite bathroom to assist entry and exit from the shower but were never installed in the secondary bathroom to assist entry and exit from the bathtub.

Grab Bars
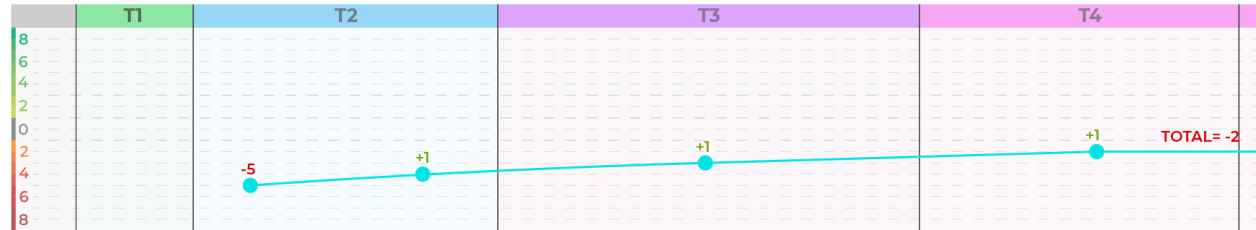
8.3.5 Google Nest

Usefulness rating: 5.5/7

The participant appreciated the Google Nest's voice recognition features and how it could be used to create a welcoming environment. The participant initially considered the device a need and selected it as one of their top three favourite devices, though several capabilities overlapped with their iPhone and laptop, so the participant stated that they do not plan to buy the device for their current home, making it a nice to have.

Google Nest
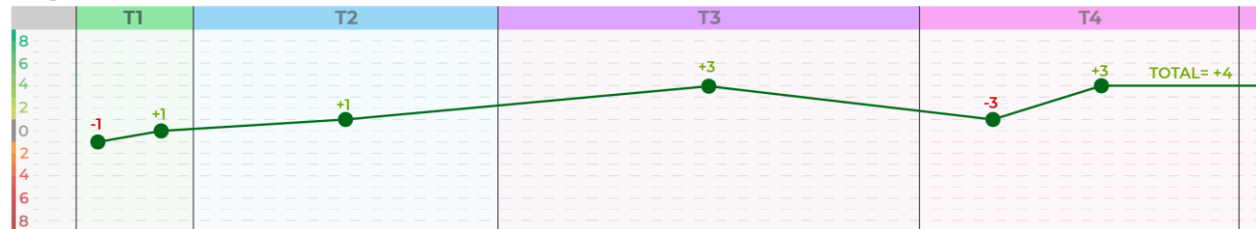
8.3.6 iPad

Usefulness rating: 6/7

While initially categorized as a need, the participant found several redundancies with the iPad, as their iPhone was able to fulfill a similar role in the HealthTech Home. These redundancies led them to reclassify the device as a nice to have; however, the participant noted that the iPad was required to change the settings within some apps, and this could not be completed with the iPhone. They also appreciated the flexibility of having both the iPad and iPhone to control the various HealthTech Home apps, as they could use whichever device was closer or more convenient at any given time.
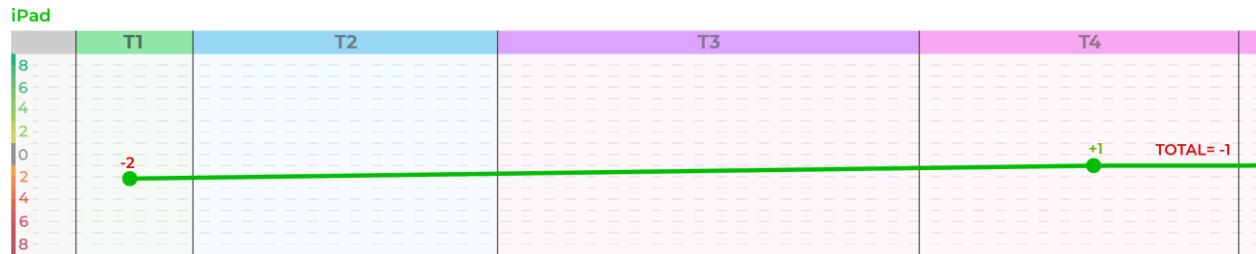
8.3.7 iPhone

Usefulness rating: 7/7

The iPhone used in the study was the participant's personal device. The participant appreciated the flexibility as they were able to download and operate all the apps used to control the HealthTech Home onto their iPhone. The user felt that the iPhone apps completed all tasks the same as the iPad, although they mentioned that some app settings had to be adjusted on the iPad. Overall, the participant found the iPhone incredibly useful and would consider the technology a need for their everyday life.
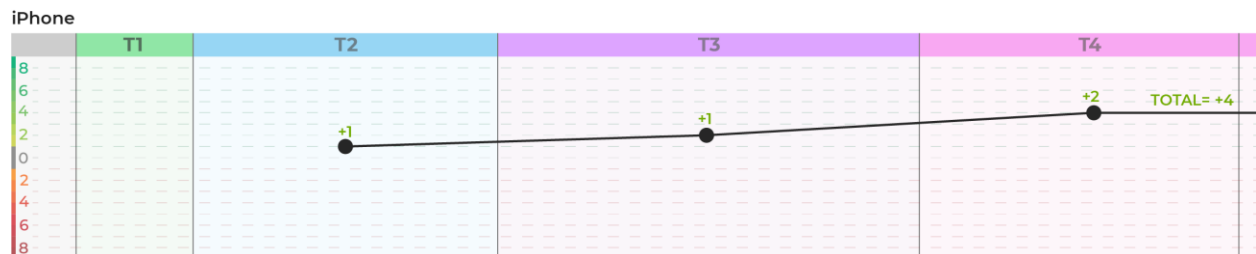
8.3.8 MacBook

Usefulness rating: 6.5/7

The MacBook used in the study was the participant's personal device. Upon move-in, the participant used their MacBook until it broke, in which they used the HealthTech Home's PC laptop to continue to complete their activities of daily living, such as responding to emails. The user noted they had an easier time with and preferred the MacBook user interface but were still able to operate the PC laptop. They considered their MacBook to be a need and when it stopped working the PC laptop was a sufficient replacement.
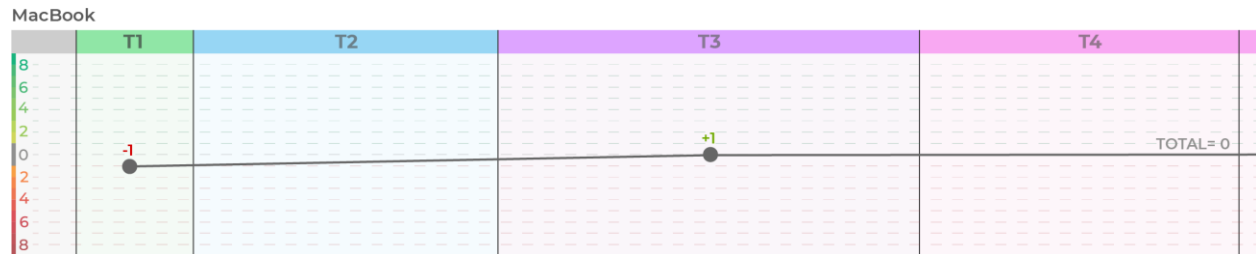
8.3.9 Motion Detector Lights

Usefulness rating: 4.5/7

While the participant noted several glitches with the motion detector lights, when corrected, they marked this device as a need. While they did not feel the technology was necessary at this time, the participant noted that it would possibly be more useful in the future as they aged.
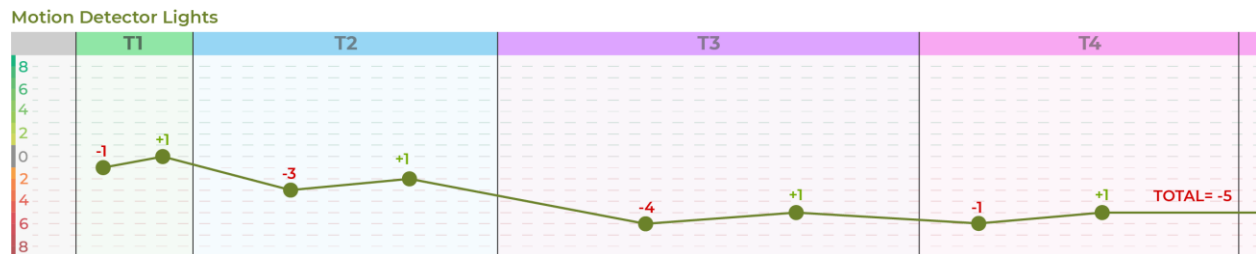
8.3.10 PC Laptop

Usefulness rating: 4/7

The provided PC laptop was slightly redundant and went largely unused by the participant, who already owned a MacBook. The user preferred the MacBook interface to the PC. They did not consider the PC a need as they preferred their MacBook, but without access to a MacBook the PC laptop became a need item.
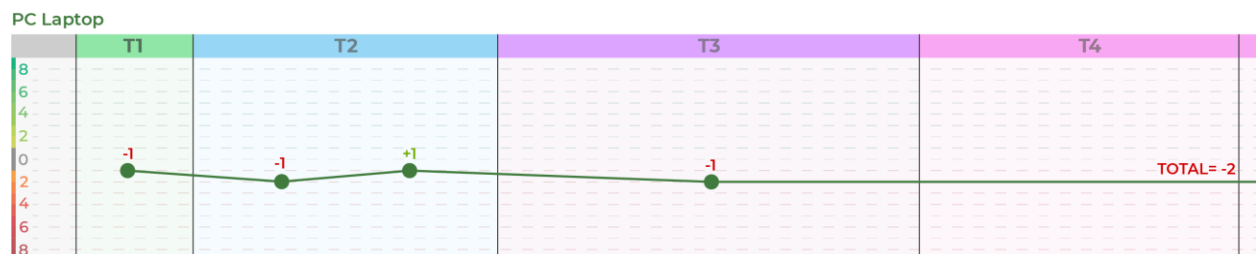
8.3.11 ReJoyce
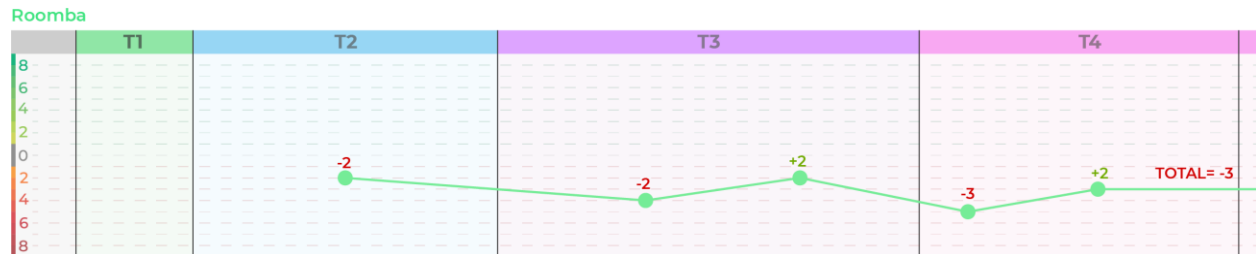
Usefulness rating: 7/7

The participant really enjoyed the ReJoyce, stating that they wished it had been provided earlier so they would have had more time with it and that if they could keep any device from the study, it would be this one. While they really liked the device, the participant stated that it was not something they would likely purchase after the study, due to financial constraints, making it a nice to have.

ReJoyce
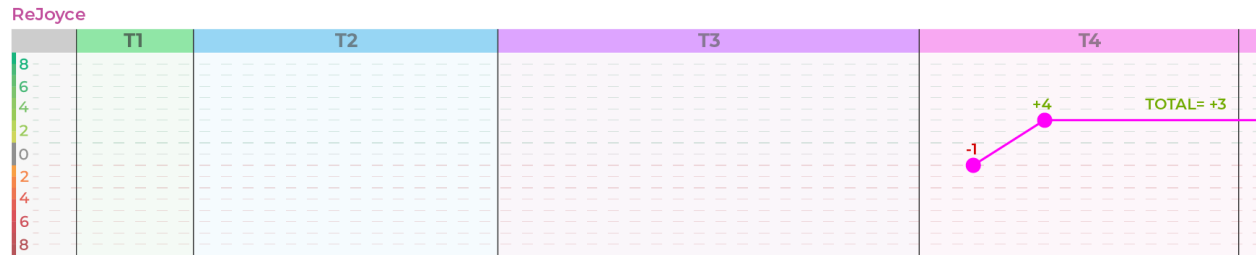
8.3.12 Roomba

Usefulness rating: 6/7

After pet-proofing the Roomba and removing rugs to prevent the device from getting stuck, the participant found that the Roomba ultimately became one of their top three favourite devices from the HealthTech Home. The participant considered the Roomba to be a need, though they were unsure about buying one for their current home.

Roomba

8.3.13 Shower Head & Mount

Usefulness rating: 7/7

The participant noted that they appreciated having a detachable shower head and the additional mount to make it within arms reach, however, the mount was not adjustable and did not direct the water where the participant wanted. The participant liked the idea of these products and considered them a need, but not with the specific models chosen.
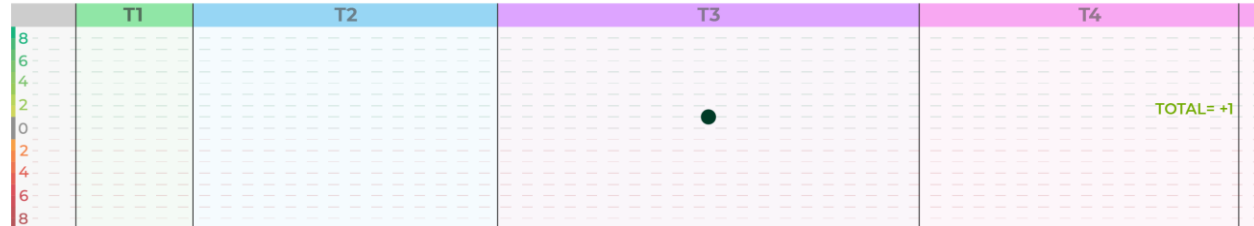
Shower Head & Mount
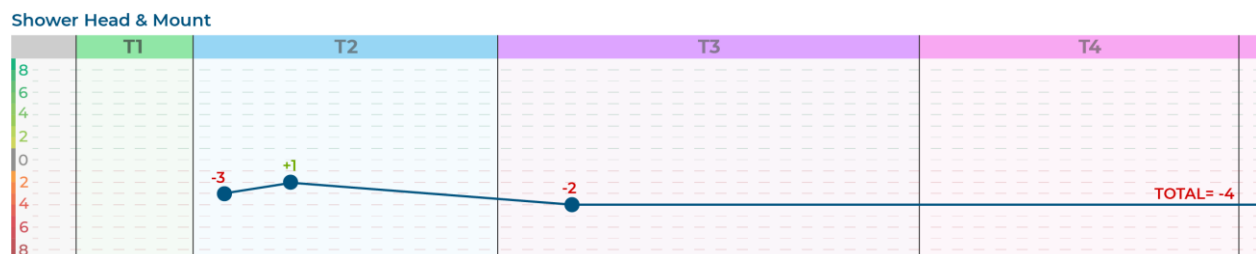
8.3.14 Smart Fire & CO Detector

Usefulness rating: 7/7

The smart fire and CO (carbon monoxide) detector was never set off, so the participant was unaware as to any differences between smart and standard versions. Despite this, the participant continually ranked the device as a need.

Smart Fire & CO Detector

	T1	T2	T3	T4
				TOTAL= +1

8.3.15 Smart Light Bulbs & Switches

Usefulness rating: 5.75/7

Despite several glitches with the lights turning on and off at unexpected times, as well as initial confusion over how to control the various lighting options, the participant ultimately appreciated the technology and stated that they plan to incorporate smart light bulbs in their current house. The participant noted they would consider the technology a need if no glitches were present.

Smart Light Bulbs & Switches

|	T1	T2	T3	T4
	-3	-3 +1	-2 +2	-3 TOTAL= -8
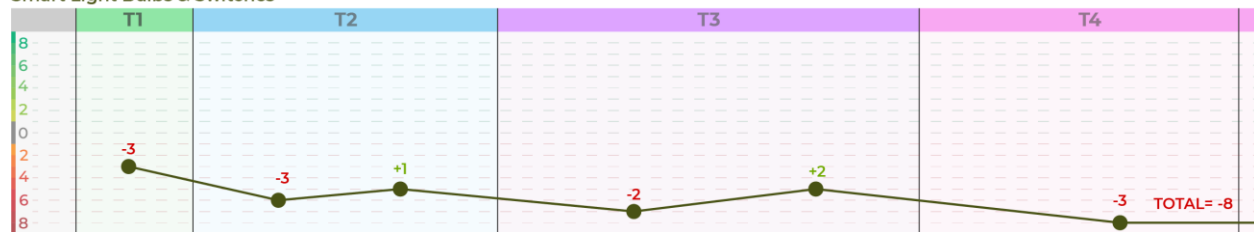
8.3.16 Smart Lock

Usefulness rating: 7/7

The participant heavily favoured the smart lock, categorizing it as one of their top three favourite devices and stating that they planned to install it in their current home. The device was deemed a need with the participant citing that, if they forgot their keys or were not home, their phone could be used to lock and unlock the doors. This feature also gave the participant a sense of security as they were able to check the status of the door lock when they were away. However, this sense of security was threatened as the device did not always lock consistently.
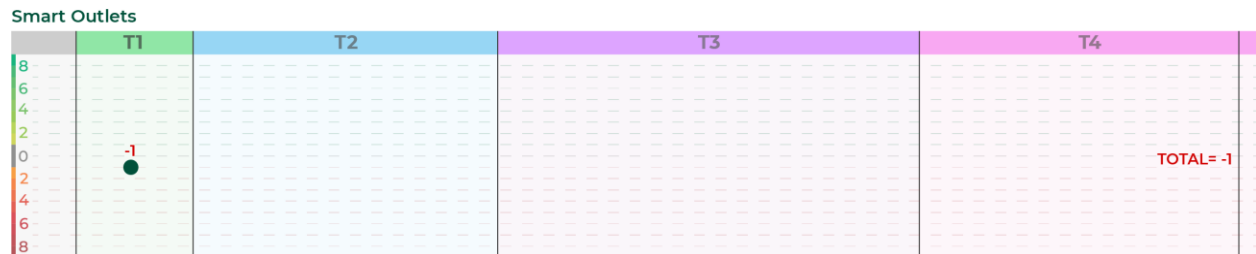
Smart Lock

|	T1	T2	T3	T4
	+1	-2 +3	-3 +3	-1 +3 TOTAL= +4
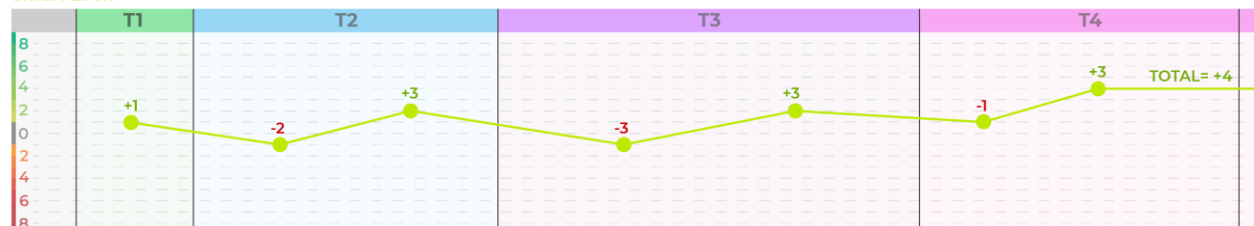
8.3.17 Smart Outlets

Usefulness rating: 5.5/7

While the participant noted minor aesthetic flaws with the smart outlets during their stay in the HealthTech Home, they ultimately deemed the device a need and expressed a desire to buy them for their current house.

Smart Outlets

|	T1	T2	T3	T4
	-1 ●			TOTAL= -1

8.3.18 Smart Scale

Usefulness rating: 5/7

The participant ranked the smart scale, which was their personal device, as a need and appreciated the ability to see a trendline of their weight over time.

Smart Scale

	T1	T2	T3	T4
			+1 ●	+1 ● TOTAL= +2
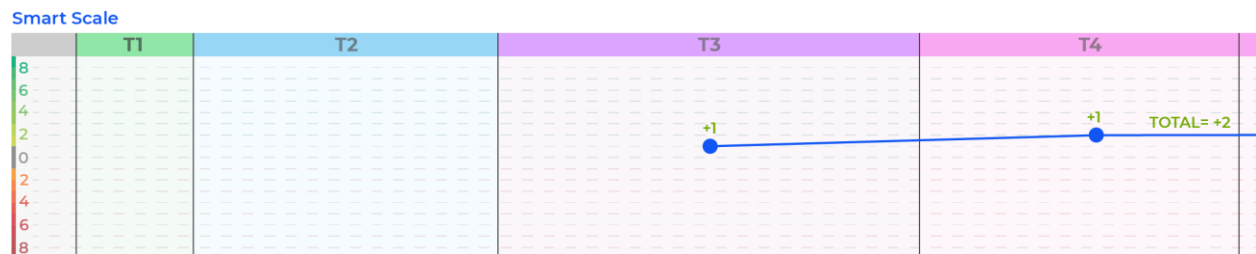
8.3.19 Smart Toothbrush

Usefulness rating: 3.5/7

While the participant initially enjoyed the smart toothbrush, which was their personal device, they ultimately found it unnecessary and at times overwhelming, ranking it as the least useful of all the devices.

Smart Toothbrush

|	T1	T2	T3	T4
			-1 ●	TOTAL= -1
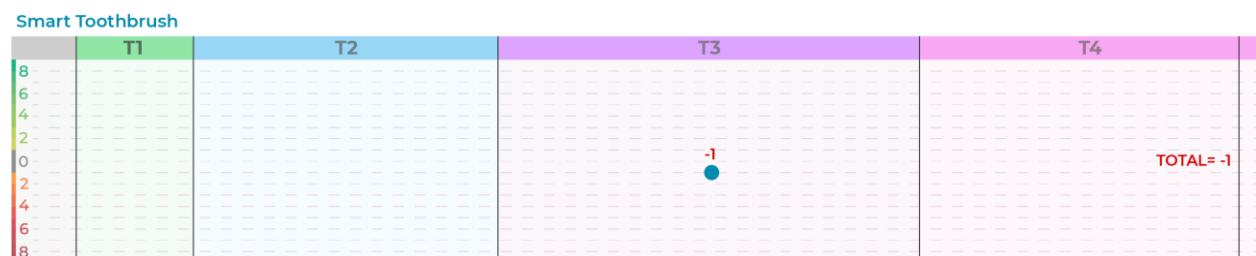
8.3.20 Smart TV

Usefulness rating: 6.5/7

Though the participant had gone about 15 years without a TV, their positive experience in the HealthTech Home solidified the device as a need. In particular, the participant appreciated that they were able to cast from their phone onto the larger screen and stated that they plan to purchase a smart TV for their current home.


Smart TV
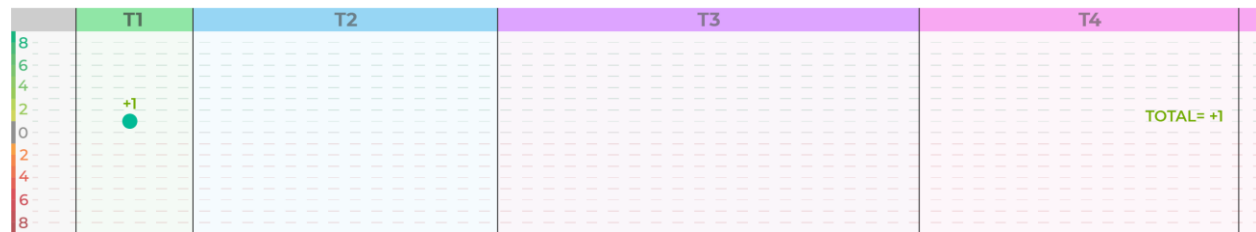
8.3.21 Soap Dispenser

Usefulness rating: 6.5/7

The participant appreciated the soap dispenser and how its placement catered to their reduced range of motion and lowered their fall risk. This device was considered a need and extremely useful, despite it not being 'smart technology' and the participant expressed plans to buy one for their current home.

Soap Dispenser
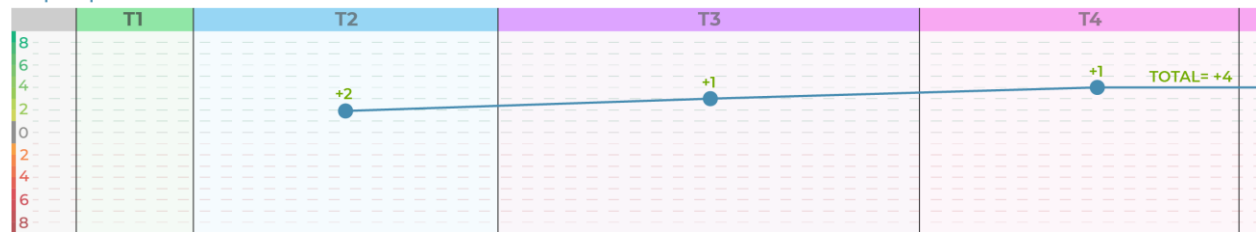
8.3.22 Water Leak Sensor

Usefulness rating: 7/7

While never actually used in the house, the water leak sensor and instant notification system were crucial for the participant, giving them comfort when away from the home.

Water Leak Sensor