Technology Adoption and Learning Preferences for Older Adults: Evolving Perceptions, Ongoing Challenges, and Emerging Design Opportunities

CAROLYN PANG

School of Information Studies, McGill University, carolyn.pang@mcgill.ca

ZHIQIN COLLIN WANG

School of Information Studies, McGill University, zhiqin.wang@mail.mcgill.ca

JOANNA MCGRENERE

Department of Computer Science, University of British Columbia, joanna@cs.ubc.ca

ROCK LEUNG

Samsung Electronics Canada Inc., rock.leung@samsung.com

JIAMIN DAI

School of Information Studies, McGill University, jiamin.dai@mail.mcgill.ca

KARYN MOFFATT

School of Information Studies, McGill University, karyn.moffatt@mcgill.ca

Technology adoption among older adults has increased significantly in recent years. Yet, as new technologies proliferate and the demographics of aging shift, continued attention to older adults' adoption priorities and learning preferences is required. Through semi-structured interviews, we examine the factors adults 65+ prioritize in choosing new technologies, the challenges they encounter in learning to use them, and the human and material resources they employ to support these efforts. Using a video prototype as a design probe, we present scenarios to explore older adults' perceptions of adoption and learning new technologies within the lens of health management support, a relevant and beneficial context for older adults. Our results reveal that participants appreciated self-paced learning, remote support, and flexible learning methods, and were less reliant on instruction manuals than in the past. This work provides insight into older adults' evolving challenges, learning needs, and design opportunities for next generation learning support.

CCS CONCEPTS • Human-centered computing • Collaborative and social computing devices

Additional Keywords and Phrases: Older adults, seniors, learning, large display, smartwatches, tablets, user manuals, digital health, personal wearables

1 INTRODUCTION

The relationship between older adults and interactive technologies is evolving and presents new opportunities to explore learning preferences in this population. When mobile technologies, including smartphones, tablets, and e-readers, were first introduced, their adoption among older adults was limited, spurring researchers to consider ways of supporting older adults to learn and use them [8][17][24][28][35]. These technologies are now *mainstream* for this demographic, with a substantive proportion of older adults using them as part of their daily routines [17][38] to stay connected with their social networks and to access information online [2][17][19][38]. A *new generation* of technologies, such as smartwatches, activity trackers, and mobile health apps, allow individuals to monitor their own health and wellness (e.g., tracking heart rate, steps taken, sleep quality, and stress level), but adoption of these technologies among older adults is still nascent. As older adults realize the personal benefits of technology use, their confidence and competencies have evolved. Yet, our understanding of how older adults adopt and learn technologies is still grounded in older research based on the needs of earlier cohorts and the characteristics of older—now mainstream—technologies [8][17][24][28][35]. While that body of work provides crucial insight into supporting older adults' adoption of technologies, the proliferation of new generation technologies introduces additional questions and prompts the revisitation of old ones.

First, prior work has primarily focused on introducing basic smartphone tasks to novice users [24][38][41][46]. As older adults have become more comfortable with these simple tasks, challenges remain with more complex ones [19][45], such as those required to configure and pair mainstream with new generation devices (e.g., a smartphone with a smartwatch). It is likely that sophisticated users and tasks will require different learning support approaches. Second, next generation technologies have moved the goal post in terms of the overwhelming amount of information and built-in features that can make them challenging to learn and adopt, especially for older adults who are more likely to be retired from the workplace and have fewer opportunistic encounters with new technologies [8]. These challenges are further exacerbated by new interfaces, evolving interaction styles, and displays that are generally too small to provide effective interactive help [18][19][48]. Finally, researchers have detailed the challenges encountered by older adults when using mainstream technologies, such as attention splitting between support materials and devices [16][24][38][41][46][48]. As a result, we see recommendations for how tools can be better designed to support older adults, including improved instruction manuals and dedicated systems [16][24][48]. Despite this work, there remains ongoing challenges with using mainstream technologies; overcoming these challenges and learning how to use new generation technologies adds an additional layer of complexity for older adults that is underexplored.

Our goal was to explore the evolving relationship between older adults, mainstream and new generation technologies, and more specifically to examine the following research questions:

*(RQ1) What are the **adoption priorities and challenges** of older adults with regards to mainstream and new generation technologies?*

*(RQ2) What are the **learning needs and preferences** of older adults with regards to these mainstream and new generation technologies?*

As such, we conducted a two-phase study. Phase I began with an online questionnaire to collect baseline information and to support recruitment, followed with semi-structured interviews to understand older adults' current technology uses and experiences; their preferred methods and resources for learning new technologies; and, their perspectives on new generation devices for health management and current methods for managing personal health information. In Phase II, we designed a video prototype and used it as a design probe with a subset of our initial interview participants to gather feedback through additional interviews. Video prototypes are effective for holistically communicating use of a system [3][29][30][31], while design probes are often used in HCI as tools for design and understanding in empathetic engagements with individuals around issues of personal significance [3][29][30][43].

Given our research goal, we chose to examine older adults' technology experiences both as part of their daily routines and through their personal health management practices. Exploring daily routines enabled us to understand older adults' current use of technologies and contrast such use with prior work. Exploring personal health practices offered two unique opportunities. First, we were able to study older adults' perceptions of new generation technologies, such as smartwatches and wearables, which have not yet achieved widespread adoption amongst this group [42]. Second, it provided a context that was applicable and beneficial for older adults. Older adults today are living longer, remaining more active into older age, and more involved in preserving and maintaining their health [9][49]. As such, we might expect that the personal health management features offered by smartwatches and wearables may soon lead to greater adoption and interest, and that exploring this context can help anticipate eminent learning and adoption needs.

The contributions of our work include an updated understanding of older adults' current experiences and level of expertise with mainstream technologies, such as smartphones and tablets. We also uncover the challenges that remain with the initial adoption and setup of new generation technologies that offer personal health management features. Our design probe reveals the value in integrating multiple learning options, including remote support, instructions, trial and error, and an Internet search engine. Lastly, our work offers a set of design opportunities that consider accessible social supports and preferred learning resources in a centralized space.

2 RELATED WORK

We begin by summarizing prior work describing the factors that influence older adults' adoption and use of technologies. This allows us to see the evolution of technology adoption and expertise by older adults as technologies have become more pervasive in their everyday life. We then reflect on the techniques older adults have used when learning a new technology, setting a baseline for understanding preferred common resources used in the past. Lastly, we present research done to date examining older adults' experiences with technologies for personal health management. This helps us understand existing challenges and opportunities for designing teaching technologies to older adults.

2.1 Technology Adoption and Learning Preferences for Older Adults

Smartphone adoption among adults 65+ has almost quadrupled in the last five years and Internet usage has increased 55% in just under two decades [2]. Intrinsic motivations, such as perceived usefulness and value, play an important role in the increased adoption of technologies, while older adults' social groups (family and friends) continue to have a strong influence in demonstrating the relevance and usefulness of certain technologies [8][17][19][23]. However, what remains to be studied is a close examination of this social influence to understand whether it is mediated by support and mutual learning, or whether it involves a more negative dynamic, such as pressure to conform [19]. Prior work has also identified factors, such as usability, affordability, independence, experience, and confidence as additional determinants of older adults' adoption of technology [23]. Along with this understanding of such factors, many of the existing studies explored specific technologies, such as activity trackers [1][19][27], smartphones [8][24][33][38], and tablets [17][23][38].

Studies have examined how older adults have incorporated independent learning techniques when using new technologies, finding a preference for instruction manuals over learning by trial and error [24] even though these product instructions had poor legibility, lacked feedback, and had insufficient simple explanation of technical terms [16][18]. This resulted in older adults preparing their own customized product instructions to assist in learning. Research has also reported a general preference among older adults for learning independently to avoid long wait times from IT support or customer service [18] and to avoid interrupting or bothering family [28]. Systems have also been developed to assist older adults in learning how to use smartphones [18][24][48]. Our previous work, Help Kiosk, was based on the concept of instruction manuals and provided a self-directed learning environment where older adults could control their speed and repeatedly complete tasks as many times as needed [24][48].

Older adults have also reported enjoying the experience of learning collaboratively with their spouses, other family members, and those within their own social network, where observing others easily use a system enhances one's self-efficacy and perceived ease of learning [18][27]. Prior work has indicated that continued support from family, friends, and/or service providers could be instrumental in encouraging older adults to maintain higher levels of technology use [19][26][33]. While older adults have become more comfortable with basic tasks on mainstream technologies, challenges remain with the initial adoption and setup of new generation technologies (e.g., smartwatches), along with ongoing social support during setup and learning [1][38][47]. This is the focus of our work.

In our work, we re-examine many of these preferences and tendencies to document their evolution with newer cohorts of older adults. In particular, our work offers a close examination of social influences as it relates to technology adoption and learning and to probe the role family and friends play in shaping the adoption habits of older adults. We also expand on the existing exploration of older adults' use of specific technologies to contribute an updated understanding of the relationship between older adults' use of a broader set of mainstream and new generation technologies. Our research probes how learning affects use, and whether changes to the onboarding process and the offering of learning resources can positively impact perceptions towards the adoption of technologies. Additionally, much of the work done to date has had less focus on strengths of older adults (e.g. their independence), and instead emphasized their weaknesses [17][23]. We see this as an opportunity to focus on supporting new independent learning preferences identified by older adults.

2.2 Personal Health Management Routines

Recent work has revealed an increase in technology applications designed to support people in personal health management [15][42]. Research has shown that older adults have an interest in using technology to manage their personal health, and identified topics such as tracking heart rate, maintaining an exercise diary, and monitoring stressful events as important [1][21]. Personal wearables and mobile apps have the potential to be beneficial to a growing older adult population; however, such products must consider age-related changes in cognitive, sensory, and motor function when being developed for use by an older generation [1][25][27].

While researchers have explored older adults' use of dedicated health-specific devices, such as activity trackers and sleep monitoring devices [1][13][14][21][22][25], few studies have explored older adults' use of new generation devices (e.g., smartwatches and mobile health apps) for health tracking [5][14]. While there is an initial positive interest in using such technologies, maintaining use remains a challenge and social support through collaboration was identified as a primary motivator to encouraging use [21][22]. Simplifying setup, providing detailed, easier-to-use instructions, and ensuring robust syncing capabilities have also been recommended to support the use of activity trackers by older adults [1][40]. Studies have also found that some older adults with little experience with technology prefer relying on healthcare providers and caregivers for health tracking [26][40]. Educating older adults on the benefits of mobile and wearable tools for health can encourage self-care and independence while alleviating pressures on family members and caregivers.

Given this, we set out to examine how older adults perceive using new generation technologies as part of their daily routines and for personal health management. We focus on this context as it provided us with the flexibility to explore how older adults perceive using new generation technologies for supporting both daily routines and personal health management. We examine how to support older adults in learning new technologies both independently and collaboratively by investigating reactions to the ability to connect to a distributed family member while learning how to use new generation technologies.

3 STUDY METHODOLOGY

We conducted a two-phase study to investigate how to better support older adults in learning to use mainstream and new generation technologies (Figure 1). In order to maximally probe participants' experiences, we did not restrict the conversation to any particular class of computing technology. Instead, we encouraged participants to share the experiences they felt were most relevant. Our first phase included an online questionnaire and semi-structured interview. The online questionnaire at the outset served as an entry point to the research, providing a general understanding of older adults' current technology use and personal health management practices (Appendix A). The questionnaire also helped us to identify and recruit appropriate participants for the semi-structured interview, which delved further into current technology uses and experiences; preferred methods and resources for learning new technologies; and, perspectives on dedicated devices for health management and current methods for managing personal health information (Appendix B). Our second phase included the development of a video prototype, followed by interviews with a subset of the interview participants from the first phase. Here, we asked participants to expand further on their past experiences and preferences with technologies by reflecting on a video prototype that we used as a design probe (Appendix C).

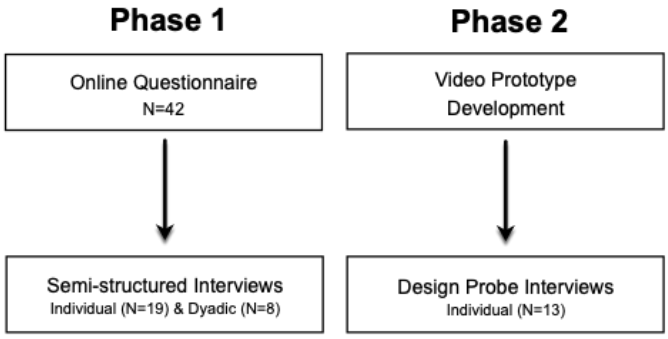

Figure 1: The two-phase design and activities of the study.

3.1 Participants and Recruitment

Table 1 details our participant demographics across both phases of our research: questionnaire (N=42), interviews (N=27), and design probe interviews (N=13). All participants resided in major cities in Canada. Initially, participants were recruited through snowball sampling (word-of-mouth), ads posted on online community forums and social media (e.g., Craigslist, Kijiji, and Facebook), and in public spaces (e.g., public libraries, recreation centers, and coffee shops) across 16 Canadian cities. As we progressed through the two phases of our research, we recruited from the previous phase's participant pool; thus, participants in both phases took part in multiple activities of the study. Ethical approval was obtained from the university's research ethics board. Informed consent was obtained from all participants for each activity of the study. Questionnaire data was collected anonymously with responses to the invitation to participate in further research collected separately; thus, it is not possible to link individual responses to the interview data.

Table 1: Participant demographics for the two phases of the study

Phase	Method	Total	Gender		Age	
			Male	Female	Range	Mean
I	Questionnaire	42	24	18	65–83	69
I	Individual Interviews	19	9	10	65–83	69
I	Dyadic Interviews	—	—	—	—	—
	Older Adults	4	3	1	66–83	73
	Family Members	4	1	3	35–65	43
II	Design Probe Interviews	13	6	7	65–83	70

According to the questionnaire data, participants (N=42) described their general health status as better (n=14) or about the same (n=20) when compared to a year ago, while some admitted to their health deteriorating (n=8). The majority of our participants indicated their general health was very good (n=17) or good (n=16). The top four health conditions affecting our participants included high/low blood pressure, high/low cholesterol, allergies, and a heart condition. Personal health information tracked included health appointments, blood pressure, weight, and heart rate.

3.2 Phase I: Online Questionnaire & Semi-structured Interviews

Over a 10-week period, participants (N=42) completed a 15-minute online questionnaire mainly focused on their general experiences with their use of various mainstream and new generation technologies (e.g., computers, tablets, smartphones, wearables, social media, and email); their preferred methods and resources for learning new technologies (e.g., instruction manuals, customer support, searching the Internet, taking a class, or asking a partner or children); their general health; and their current availability of social support (from family and friends) for learning how to use new technologies.

We then conducted semi-structured interviews (N=27) in-person and over the phone with a subset of the participants who completed the questionnaire. The interviews lasted between 45-60 minutes each. Of our 23 interviews, 19 were individual interviews and 4 were dyadic interviews with a family member and an older adult (see Table 1). Completed over a 7-week period, the interviews were semi-structured and focused on participants' experience with technologies, their motivations for adopting new technologies, and their personal health management practices. For example, we asked participants to walk us through the last time they had to learn a new computing technology, including what the new technology was, how they went about learning to use it, what learning resources they used, and what parts of the learning experience they enjoyed and did not enjoy. Dyadic interviews covered the same topics but explored more deeply the role of a family member's help; e.g., we asked them to tell us about a time when they used video chat to connect with each other and what kinds of tasks they worked on together.

3.3 Phase II: Video Prototype Development & Design Probe Interviews

Our video prototype, Help Kiosk 2.0, evolved from six months of iterative sketching and design, drawing from our reflections on earlier work (e.g., [19][40]) and emergent findings from Phase I of our study. The design was intentionally broad with the goal of bringing together a variety of supports under a single umbrella for exploration. Help Kiosk 2.0 offered four different popular learning methods: Internet (via an integrated Google Search), trial and error (through feedback), instruction manuals (through step-by-step and video instructions), and remote support (through video chat). It featured a single 40" tabletop display on which users place their smart devices as a way of pulling instructions closer to the device to reduce attention splitting and making instructions clearer and more concise (We acknowledge that large tabletop displays are expensive and uncommon today. However, to explore the idea that additional screen real estate can help with the management of small devices, we asked participants to imagine that as the technology progresses, they will become more common in households.).

The video prototype featured two scenarios using Help Kiosk 2.0. The first scenario introduced Shane, a 70-year-old retiree, who lives alone and recently received a smartwatch and tablet as a gift from his family. As an independent learner, Shane has often used online web searches as a learning tool. He places the smartwatch and tablet on Help Kiosk 2.0 to learn about the basic functions, and uses the navigation menu, embedded help videos, and integrated Google search tool to find various cooking apps to install on his tablet. In the second scenario, a 76-year-old retiree, Audrey, often talks to her daughter, Jessica, who lives out of town. Audrey has basic technology skills but wants to track her steps and heart rate on the smartwatch she was gifted. She places her smartwatch and tablet on Help Kiosk 2.0 and begins tapping instructions. Confused, she taps 'Call for Help' to video call Jessica. Audrey explains what she is trying to do but Jessica requires more information. Audrey taps 'Share Screen' and Jessica is able to guide Audrey through the instructions to setup her smartwatch to sync her health information onto her tablet.

With the video prototype complete, we then conducted 30-minute design probe interviews over Skype (with a subset, N=13, of the Phase I interview participants). The goal of this phase was to examine older adults' perceptions of receiving a new device and learning to use it through two scenarios built around use of a design concept of a learning tool, Help Kiosk 2.0. During the interviews, we shared our screen and played the 7-minute video prototype (see Supplemental Material).

After each scenario, we paused the video prototype and probed participants about their initial thoughts of the design concept and the scenarios, including what they learned from the video. We also asked participants to reflect on the features of Help Kiosk 2.0, to describe any challenges they experienced, and to discuss the learning supports they felt were most useful. We reminded participants that the probe was meant to elicit reflection, rather than to test functionality and emphasized that we were less interested in feedback concerning the details of the interface (e.g., specific learning topics and font size). Instead, we asked them to focus on whether features of Help Kiosk 2.0 might inspire new possibilities for learning support.

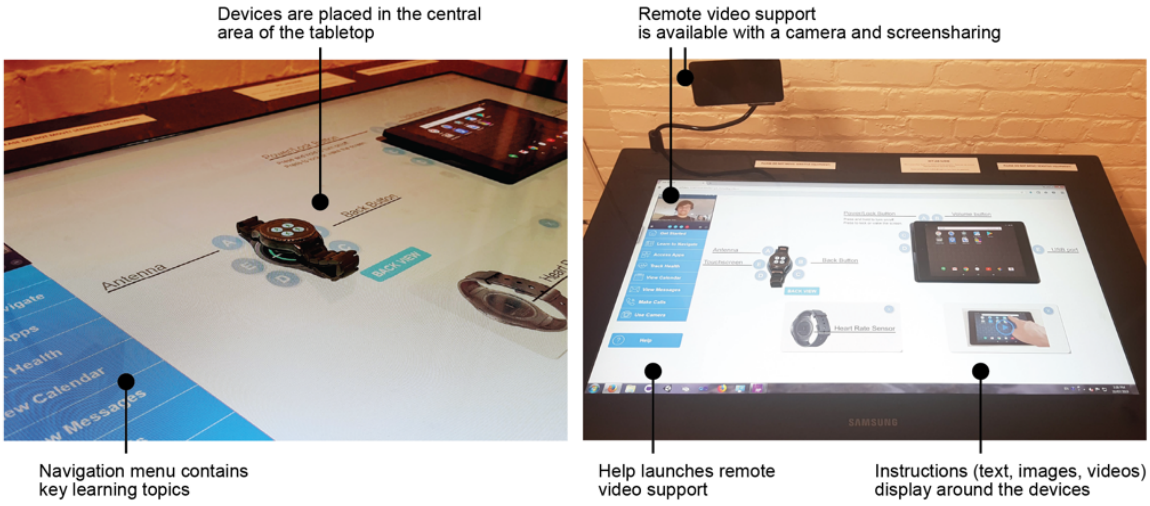

Figure 2: Design of Help Kiosk 2.0, including learning topics, remote video support, and interactive instructional information. Learning topics are listed on the left side of the screen. Devices are placed directly on the tabletop in the central area so that instructional information (including text, images, and videos) can be displayed around them. The "Call for Help" feature allows users to video chat and screen share Help Kiosk 2.0 to ask for assistance from their family members and friends.

3.4 Data Analysis

Our questionnaire primarily served as a recruitment tool for our interviews; therefore, we conducted simple descriptive statistics on the data to use alongside our qualitative results to provide additional context as needed. Along with notes taken during each interview, approximately 34 hours of audio recordings from our interviews were transcribed and analyzed by three researchers.

Table 2: Qualitative data coding layout

Themes	Sub-themes	Main Codes
Social Influences	Adopting New Technologies	Family member
		Friends' use of new tools
	Experiences with Technologies	Initial set-up (onboarding)
		Social media
		Social gatherings/functions
Perceived Value & Benefits	Mainstream Technology Use	Smartphones/tablets
		Email
		Desktop applications
	New Generation Technology Use	Mobile apps
		Fitness trackers
	Personal Health Management	Paper files
		Desktop software (Excel, Notepad)
Methods & Resources for Learning	Learning Methods and Supports	Family member
		Online courses
		Google
		Trial and error
		Videos (YouTube, forums)
		Instruction manuals

We used open coding to label our findings within the interview transcripts (Table 2). Axial coding was used to group our findings into categories, which included current technology use and experiences, adopting new technologies, learning methods and supports, and personal health management practices. Lastly, selective coding was used to identify main themes through a refinement and selection process. Main themes included social influences on the adoption of technologies, perceived value and benefits of technologies, and methods and resources for learning.

4 STUDY RESULTS

We first explore participants' experiences with technology, including their familiarity with mainstream devices such as smartphones and tablets, and new generation devices, such as smartwatches and wearables. We then describe participants' challenges with technologies before sharing the learning methods and resources older adults employ to support their learning goals.

4.1 Technology Adoption Priorities

Overall, our participants were sophisticated users of smartphones and tablets, but much less familiar with wearables, including smartwatches and activity trackers. 86% of questionnaire respondents rated themselves as intermediate or advanced with computers, 74% with smartphones, 69% with tablets, and 90% with email, while a full 60% indicated they had no or very little experience with wearables. Interview participants similarly had very little experience and knowledge of smartwatches and were relying on a number of traditional tools to help manage their personal health.

4.1.1 *Traditional tools used for personal health management*

Often times, various non-digital and mainstream digital tools were used to track and manage participants' personal health, including physical calendars, Excel spreadsheets, and scanned reports in file folders. P2 (Female, 66 years old) used a combination of such tools, where she used her smartphone to track steps and exercise, her computer to record her weight, and a notebook to detail other health-related information. P4 (Male, 72 years) tracked his blood sugar levels in a booklet. P8 (Male, 73 years old) kept records of his weight, blood pressure readings, and doctor's notes in an envelope at home.

Few participants used mainstream technologies for health monitoring, and of those that did, most adopted them for basic tasks, like step counting, that did not necessarily require configuration with other devices. Participants were unaware that smartwatches could be used to support close monitoring of one's health conditions. While some had concerns with aspects of this, participants were open to learning more about how such devices could be used to help manage their health. P7 (Female, 66 years old), despite being concerned with privacy in having her steps tracked, considered using a smartwatch to monitor her heart rate, given its relevance to her health condition. P6 (Male, 66 years old) regularly biked outdoors in his neighborhood and indicated that tracking distances and routes would be of no use to him; however, he felt tracking his blood pressure was important and would consider using a device to help him with this. These two data points reflect careful attention to tradeoffs between value and privacy; in both cases, participants were reluctant to compromise privacy for general wellness tracking (step counts, distances and routes), but were willing to reconsider in the context of tracking a more explicit health concern.

While the majority of participants did not have experience with smartwatches and wearables, two participants found value in using a wearable and mobile app to manage their health.

> "Originally when I got [Fitbit], I didn't really pay that much attention to it, but recently I, I'm trying to lose weight. So, I actually found, started to very recently to actually use it where I log in my meals and the exercise. Like I've, I've used it before, I didn't use the app, I just used it as a step counter. But now I'm doing, I'm logging calories and you know." – P28, Female, 65 years old

While some participants expressed interest in using a technology to help manage their health information, we learned that others preferred not to closely track any health conditions, despite the serious nature of them. For example, one participant (P18, Male, 67 years old) had a heart attack two years ago but chose not to wear a heart rate monitor on his wrist as he did not want to get constant notifications. We delve further into these perceptions and challenges with technologies next.

4.2 Technology Adoption Challenges

As we saw earlier, our findings suggest older adults have become more familiar and comfortable using mainstream technologies over time, though some still resorted to non-digital tools to help manage their health information. When it came to new generation technologies, such as smartwatches and wearables, we saw mixed views across our participants. Next, we summarize these technology adoption challenges uncovered throughout the two phases of our study.

4.2.1 *Perceptions of new generation technologies*

While our participants were fairly unfamiliar with the features available through smartwatches and wearables, we found there was a general interest amongst participants to learn more about smartwatches and its capabilities. Some older adults, such as P25, were impressed and could see the potential for smartwatches. P2 (Female, 66 years old) thought tracking technologies could help save time with inputting health data and sharing tracked health information with her family and doctor.

> "Say if you look at the Siri thing, Siri actually sort of changed my life. I found it extremely useful, so I can only imagine that a smartwatch could be really useful." – P25, Male, 65 years old

Yet, we also saw strong negative views on new generation technologies as well. Despite the available features on smartwatches, several participants described them as being redundant to smartphones and perceived them as "new toys" and "unnecessary gadgets".

> "Again, I get all that information from my iPhone. There's a distance monitor on it and it counts the steps as long as you keep the phone in your pocket I guess, and I have this other gadget that I can put on to get my heart rate. A smartwatch or another wearable would just be too much." – P16, Male, 74 years old

There were also concerns expressed for the cost of purchasing new generation technologies. Several participants noted they were retired and on a strict budget, thus, they would only consider using a smartwatch if they were gifted one by a family member. Many participants also noted that the small screen size of smartwatches was worrisome and was a reason in itself not to explore using it.

> "I haven't looked more into them simply because of how much it would cost, and another main thing is the size of the screen. Because I am not a young person, my vision is not perfect. The smaller the screen is, the more uncomfortable I am with it, even when I can enlarge or maximize. Because when you enlarge or maximize, you're only seeing the center of it, and then you have to scroll to the right and scroll to the left and up and down." – P20, Female, 70 years old

4.2.2 Technology setup and onboarding has been challenging

Our study results showed common challenges remain even with mainstream technologies. Participants in our interviews spoke especially of frustrations associated with acquiring a new device. For example, when a phone or laptop was being replaced with a newer model, older adults still often relied on others (e.g. store technicians, family members) to complete the setup process. At times, participants expended substantial effort in trying to set up a device before turning to help, only to find that a small oversight or misunderstanding was the root cause.

> "And I tried to set it up and I ... I eventually went to a local iPhone store and got them to set it up for me. No, it was two different stores. It took forever. It was really confusing and really hard, but I really needed support to do that. I couldn't figure it out." – P25, Male, 65 years old

While the setup and onboarding challenges described in the above quote are well documented in the prior literature [24][40], the quote also reflects a greater willingness to invest effort and perseverance to overcome barriers that suggest new opportunities for designing independent setup and onboarding supports.

Some participants also described a preference for having the setup and onboarding process completed for them as it was an infrequent event, thus there was no need for them to learn. Others felt that they probably could have done it themselves, but that assistance got them going faster.

> "I guess if I was alone and I really needed it, I would've tried it over several days and probably maybe at the end I would have understood, but I needed them to print that day. And sometimes you run out of patience." – P15, Female, 65 years old

4.2.3 *Ongoing challenges supported by remote family members*

Results from our questionnaire revealed that 64% of the participants encountered a problem with a technology about once a month and would contact a family member for help. For example, despite overall gains in technology proficiency, tracking and managing passwords remained a problem. Both older adults and remote children discussed how this caused frustration and posed a stronger barrier than the accessibility of the applications themselves. Remote children described needing to track passwords for their parents as back-up and frequently having to help step them through the login process; older adults often resorted to writing passwords in a notebook, despite knowing this was not secure.

Similarly, participants described ongoing challenges with using the camera and sharing and editing their photos afterwards. They were able to tap the camera icon on their smartphone or tablet, yet, struggled with centering the focus of the photo and getting a stable, unblurry photo. They often took a series of photos and did not know how to get them off their device(s) and on to their computer. Participants described needing to email them one-by-one to themselves as a work around to this challenge. Remote children expressed wanting their parents to learn how to use the camera in order to take and share photos with them.

4.3 Technology Learning Preferences

It was common for our participants to need to learn something new with computer technology: 31% of questionnaire respondents indicated this occurred at least once per week, and a further 38% learned something new at least once a month. In both the Phase I questionnaire and interviews, we asked participants about their preferred methods and resources for troubleshooting and learning supports. We learned that when older adults encountered problems with technology, they preferred resources that were easy to access (convenient, readily available) and easy to understand (clear, simple language). Many of our participants were also active learners; for example, P3 (Male, 68 years old) and P16 (Male, 74 years old) indicated that learning was part of their hobbies and that they regularly take courses and attend webinars.

4.3.1 *Independent learning preferred and tried first*

Our study found that participants had a preference towards adopting more independent learning supports. Forty-five percent of questionnaire respondents noted they often first searched the Internet for help and would then try to work out any issues themselves through trial and error (Figure 3), suggesting a departure from past cohorts who were reluctant to engage in these behaviors, preferring more structured learning supports like instruction manuals [16][18][24]. Interview participants similarly described preferring trial and error, noting that interfaces have improved to the point they can randomly tap on icons and see what would happen. If unsuccessful with trial and error, they then turned to searches on Google. Similarly, our Phase II design probe interviews revealed that participants enjoyed the independent learning approach Help Kiosk 2.0 offered. This was especially appreciated by those who preferred the trial-and-error method and those who felt they were more knowledgeable with technologies. The Google search feature was identified as an important tool to help with looking for additional online resources. This was a common approach to learning and troubleshooting technologies that participants had described in earlier interviews.

> "I will Google it. I will look it up on YouTube. I mean really, I ask questions. I go all over the place, online looking, but very often I end up with trial and error. I'll try something, it doesn't work, and I'll say, 'Yeah, but in that other technology...' It's like an extra bit of understanding what the possibilities could be."– P20, Female, 74 years old

"Yes, we ... yeah I Googled it. When you can't figure it out yourself, and you just need to get something done... the answer is just usually gotten by googling it. We googled it. Whatever instructions we got just didn't work." – P18, Male, 67 years old

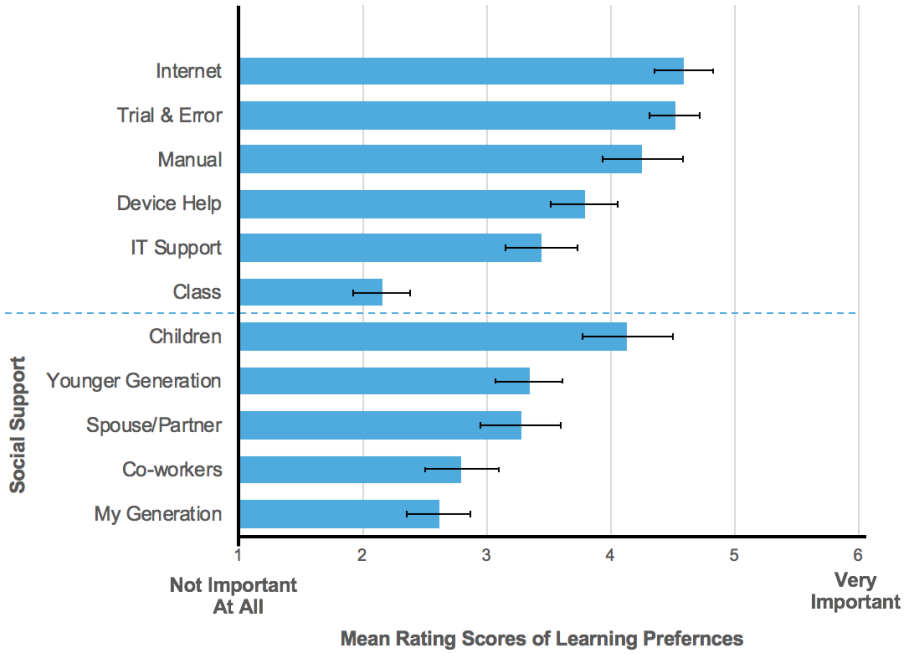

Figure 3. Mean rating scores on the preferred learning methods and resources for technologies.

When asked about instruction manuals, many participants noted that they were often not included anymore with new devices or if they were, they were not useful as the language was too complex. P2 (Female, 66 years old) noted that some manuals have more information than necessary and preferred general information about the device, rather than every single feature. Plain language is desirable not only for manuals, but for video tutorials and in-person technician support as well. P8 regarded their technical language as "a new form of literacy" and expressed that he would like to see instructions written from a general user's point of view, and not a technician's view. Often with online tutorials or company instruction manuals, participants would need to make their own notes to remind themselves of how to do something. Participants preferred concise, step-by-step instructions or a simple one-page (cheat sheet) that outlined the basics.

Our design probe interviews also revealed that participants valued step-by-step instructions; however, expressed concerns with the topics included in Help Kiosk 2.0. Given that all our participants had experience with tablets, several learning topics appeared too basic (e.g., Getting Started, Learn to Navigate). Participants were curious about the smartwatch, likely given their inexperience with it. This tension speaks to the need for instruction-based approaches that can grow with the user and adapt the content offering as tasks are mastered.

Videos were identified as helpful but needed to be brief so participants could follow along and remember the steps easily. Following our design probe interviews, participants' opinions on the video instructions embedded in Help Kiosk 2.0 [see Figure 2 (right)] were mixed. Some felt they were more suited for beginners. Others appreciated having the relevant videos embedded with the step-by-step instructions for each device and learning topic. One participant

described wanting the video to automatically sync (play and pause) to the pace of her attempts to follow along on the device. Another participant appreciated the relatively low speed of the videos and that it was viewed in context to help with learning. Participants emphasized that videos needed to be short but also appropriately paced so that they can follow along.

> "I like [the] speed of the videos. I could follow it on my own. I think the instructional videos are effective and step-by-step instructions are useful. Everything seems to have a context and a meaning." – P8, Male, 73 years old

4.3.2 Personal support, both in person and remote, was helpful and sometimes used

In general, participants described often becoming aware of new generation technologies and features through their social network (e.g., family members and friends) [17][36]. During the interviews, participants reflected on when they first started using their smartphone and tablet and the challenges they faced at that time. Through the years, they became more comfortable with basic tasks such as making phone calls, sending text messages, checking email, downloading eBooks, reading news, and watching videos and movies. More advanced tasks, such as using video chat and installing specialized apps (e.g., social media, hobbies, transit) were relatively new for most participants. Remote children were either the initiator or were asked to demonstrate how newer features worked.

> "My brother told [mom] how to use Facebook. My brother, when he was having fun with her, one time, he just downloaded it on her phone and her iPad, and she asked him, 'What's this?' So, my brother showed her how it all worked and even created an account for her." – P9, Female (Family Member), 36 years old

> "I learned about Siri through my oldest child, then I started to just integrate it in my general life. So, for instance, I can use Siri with voice commands to send an email or to send a text now, and I can use Siri to make appointments, to send [an item] to my grocery list. There's a lot you can do with Siri, actually." – P25, Male, 65 years old

Participants identified various *technology support persons* they would (at times, with reservation) turn to for assistance. This included family members (spouse or children), friends, or instructors and/or technicians at the store. However, participants were cautious of using this resource as they felt they were troubling others with their questions, especially if they had to ask the same questions multiple times.

> "Well, it came with no instructions, which isn't very helpful. I didn't know how to answer the phone. As simple as that, […] I asked a friend to show me, and he actually had to show me twice because he showed me and then I forgot, and I couldn't do it again. Then I asked another friend who is about my age but is also very much involved with technology. She explained some basic things to me, and then the rest I figured out for myself." – P26, Male, 76 years old

Remote children also described their preferences for being able to see their parents as it offered additional information beyond just hearing their voices on the phone.

> "It is still a big improvement actually being able to see how they're looking, and sometimes because over the phone they can hide certain things, and then you can't see their facial expressions. With the video you can actually see what's going on, most of the time." – P9, Female (Family Member), 35 years old

However, video communication did not work for everyone. This quote highlights the importance of also considering the constraints and challenges of family.

> "My daughter who lives out of town – she has two children, one is 8 years old, the other 5. I tried to initiate Skype with her so I can see them and talk. It didn't really work… she always feels too time stressed to take on anything different like that. So, I just phone her. I call every Sunday morning." – P14, Female, 70 years old

From our design probe interviews, participants described the collaborative learning support depicted in the second scenario as a valuable and relatable feature in Help Kiosk 2.0. They appreciated that a single "call for help" button could immediately connect them to their technology support person through video chat.

> "My impression is that I could stop at any moment and have access to the person — my help resource person. I like the fact of having a visual person available for me and being able to, say if the buttons don't work, the person can respond to my needs. This is a big plus; this would take away any frustration." – P12, Female, 65 years old

4.3.3 Screen sharing seen as beneficial

Screen sharing was deemed as facilitating communication of what the participant was seeing and guidance from the personal support. Participants valued being able to share their screen so that they could receive personalized, relevant instructions. They also valued being able to see the support person's screen and how to interact with it, as it helped interpret instructions.

> "It's just easier for me. I think over the phone is more confusing. Because when somebody actually shows you physically, 'You press this and then your finger goes there, and here's the dropdown menu and you click this,' it's a lot easier. It just sticks better." – P25, Male, 65 years old

> "Occasionally, when I get confused about things on my computer, my older son, we speak by phone and he teaches me stuff. But he is at home and I am over here. The screen sharing feature on [Help Kiosk 2.0] helps get to the specific issue fairly quickly." – P26, Male, 76 years old

> "Screen sharing is very important for anybody who doesn't or can't follow the instructions individually. I know that many people in this age group who would really need that extra visual input." – P20, Female, 74 years old

Participants with remote children were already using video to share artifacts, whether it was invoices they had questions about or if they needed to be shown how to do something on a device. Our interviews also revealed three participants used screen sharing software (e.g. Skype, TeamViewer) with their technology support persons when they encountered an issue. This included a friend in a different city, a technician from the Apple Store, and an adult child who lived in a different country. Participants appreciated being able to hand over control of their computer to a technology support person to outsource a tedious task.

> "Actually, we use the same thing when I reach out to [my friend] for help, it's called TeamViewer and it's not an Apple product. That is to me just fantastic because the Apple guy goes through all kinds of things which I don't even want to know about. This technical stuff. Basically, what I want is fix it, make it work… It's free. It's mostly the technician going around and checking this and checking that […] and I'd say he's gone [after] 10 and 15 minutes." – P16, Male, 74 years old

Participants did not express any concerns with privacy and security when handing over control to a remote technology support person. This included providing access to family, friends, and technicians who could help with troubleshooting and fixing their technology issues.

4.3.4 Participants valued seeing large visuals and integration of supports

Despite concerns about the practicality and cost of having a large tabletop display at home, participants valued the large screen size and the ability to interact with a large surface. They liked that it made it possible to have large visual images and to be able to zoom in and watch the videos on a large screen. Participants appreciated how integrating the visual elements into one space would help them to apply supporting information to tasks at hand.

> "The teaching system is easy to follow and looks straightforward to everyone, especially it allows you to place devices on the screen." – P3, Male, 68 years old

> "[It] allows people to put their devices there and tells them what they need to do right away. It saves their time, and they don't have to search any instructions on the internet. I can see that [it] can be extremely helpful for those who don't use technology and give them a great boosting to use whatever technology they want." – P15, Female, 65 years old

Participants also noted that having both devices on Help Kiosk 2.0 simultaneously could be too complex to absorb and process all the information at once. This feedback suggests more work is needed to determine how to best support paired tasks while hiding away that complexity when it is not needed.

5 DISCUSSION & CONCLUSION

Through this two-phase study, we explored the experiences, challenges, and learning preferences with technologies for older adults. As part of this work, we presented Help Kiosk 2.0, a design concept that incorporated: (1) a collaborative learning option through which older adults can receive remote support; (2) integrated learning resources for multiple technologies, notably a smartwatch and a tablet; (3) access to a flexible range of learning approaches, including trial and error, and; (4) integration of these supports into a single visual space, a 40" tabletop display. We now discuss the main implications of our research for the design of future learning support technologies.

5.1 Learning preferences have shifted, yet challenges remain with personal support

Our findings reveal that participants' learning preferences have shifted such that older adults are now more comfortable with first trying independent approaches (e.g., Google, trial-and-error) when learning a new technology. Failing that, older adults reach out to a technology support person. This would typically be a spouse, adult child (who preferably lived in town), a friend, or a specialized technician. However, despite the desire for one-on-one support, older adults expressed reservations for reaching out to family members. As has been reported in prior work [28], older adults shared concerns that their adult children were busy with their own lives and that they did not want to intrude with technology questions until their children visit. Older adults in our study also felt like they were slow learners and had to sometimes ask their technology support person the same question repeatedly, leading to a lack of confidence and hesitation to reach out. To address this, future work could explore ways of automatically recording customized videos of specific help segment sessions that the older adult could replay, reducing the need for repeat questions and encouraging independent learning.

5.2 Augmenting current technologies is preferred over general-purpose wearables for health monitoring

We saw that some older adults would prioritize non-digital tools (e.g., notepad, paper calendars) over digital tools to track their health information due to comfort, familiarity, and availability. During our Phase I interviews, it was evident that older adults had minimal knowledge of how new generation technologies, such as a smartwatch, could support monitoring one's personal health. From our Phase II interviews, we saw a similar set of strong concerns around cost, redundancy (with existing devices, such as smartphones and tablets), and wearing an additional device, despite the potential value and benefits afforded by a smartwatch for health monitoring [21][22][25]. Yet, following the probing facilitated by our video prototype, we observed more awareness and curiosity in learning how digital tools could be used for health, should the appropriate level of support be available. This suggests that although adoption of new generation technologies, including smartwatches and other wearables, may not be prioritized for the reasons above, there exists opportunities for the design of simpler, less intrusive devices that can augment current mainstream technologies that older adults are already comfortable using. Moving forward, we should explore smaller, embedded sensors as part of everyday objects familiar to older adults. This could include articles of clothing, eyeglasses, and shoes that can be used as part of (or in conjunction with) one's smartphone or tablet when developing technologies for health monitoring.

5.3 Emerging design opportunities for learning supports

5.3.1 Rethink instruction manuals and amount of information

While prior work showed older adults preferred manuals over trial-and-error [24], our results reveal a preference for the trial-and-error method as participants considered it to be the most natural immediate approach with any task. Participants described manuals as overly complex and required them to write annotations or step-by-step notes to remember how to do something. Despite recommendations for best practices in manuals [16][18][24][36], many technologies today no longer come with manuals, and this change seems to be accepted by older adults, as expressed by our participants. Instead, we see a need for online, easily searchable minimal manuals [6] and mechanisms to intelligently tailor and deliver concise instructions to limit information overload.

5.3.2 Support independent setup and onboarding

Challenges faced by older adults especially emphasized the onboarding process. Past research has shown that even tech-savvy older adults receive support from other people during the initial phases of new device ownership [38][40]. Similarly, although our participants had initially expressed their preference for wanting to hand over the onboarding process to a technology support person, the design probe interviews revealed nuance to that view. For example, many participants appreciated having basic information about the devices, such as descriptions of functions for buttons and icons that are required to assist with the onboarding process. Though others felt these could be too introductory, there was interest in possibilities where learning topics would evolve with the user. Our results suggest that older adults may be willing to tackle the onboarding process independently if the right resources and instructions were made available to walk them through the process. Learning support technologies could include a model of continuous incremental updates and learning topics to adapt to individual user preferences and progress. Doing so would also provide older adults with encouragement and learning opportunities through practice and reinforcement.

5.3.3 Integrate easy access to Google, videos, personal support, and screen sharing

Many of the older adults in our study identified instruction videos as a valuable learning support for their technology challenges. Our results showed that older adults preferred communicating with technology support persons in real-time, using video chat, phone or instant messaging. Older adults valued incorporating video chat and screen sharing into the

tabletop, as they perceived it would make calling for help seamless and easy. This feature offered older adults immediate support at a time when they encountered an issue tailored guidance with technologies. To support such synchronous support, future platforms can draw inspiration from research in related areas [7], such as online status indicators to help convey if a person is online and available for a real-time conversation. Simple solutions to support older adults' preferences for these learning methods could involve going beyond trial-and-error (which can lead to frustration), manuals (which can be overly complex), and integrating Google search (which requires divided attention).

5.4 Value of dyadic interviews and using video prototypes as a design probe with older adults

In Phase I of our research, we conducted dyadic interviews with older adults and their family members (i.e., adult child). Given that recruiting older adults is a known challenge within this research space [11][12], we realized two benefits to conducting dyadic interviews. First, it increased our ability to recruit a greater diversity of older individuals as coordinating the study could be facilitated by a family member. We note that in our study, older adults in dyadic interviews were older than those who participated individually (e.g., mean age of 73 vs. 69). Second, it offered the opportunity to explore two different lenses on a particular area — one from the older adult and another from the secondary person. Dyadic interviews provided a format in which a conversation was created between the two participants. We encourage other researchers to leverage our experience and add this method to their toolkit.

In Phase II of our research, we employed a video prototype as a design probe rather than a more typical user study of a (working) prototype. While prototypes can be of different levels of fidelity and take varying forms, such as a sketch, storyboard or functional system, our selection of methods matched the characteristics of our research study. Our use of a video prototype as a design probe served three key roles: (1) relative to an in-person user study, it allowed us to access a larger sample of geographically dispersed older adults who could participate in the study from their home; (2) relative to the Phase I interviews, it impacted our participants' thinking, enabling them to go beyond their past experiences and reflect more proactively on their future needs, and; (3) relative to a working prototype, it enabled us to efficiently explore a greater range of possible design features.

Our video prototype served as a valuable communication tool that demonstrated scenarios and context of use [3][29][30][31]. This was beneficial in helping older adults imagine how, when, and where a learning system could be accessed when facing technology issues at home. During our Phase I interviews, participants shared their preferences for having the onboarding process completed on their behalf. However, following our video prototype, interviews conducted during Phase II revealed a new interest in participants in tackling the initial setup of a new technology if they had the learning supports available to them. This finding was only possible through the use of our video prototype as a design probe. Second, using our video prototype as a design probe allowed us to involve our target users early in the process and to generate new design ideas. Based on prior work and Phase I interviews, we chose a large tabletop display to provide maximum screen real estate, a common challenge expressed by older adults due to legibility. Yet, during our Phase II interviews, participants expressed concerns around cost and logistics of having such a display in their homes, prioritizing those concerns over legibility. As a result, we are rethinking new modalities for future versions of our design concept. Lastly, our video prototype was a standalone artifact that was completely portable, viewable by individuals on their own devices, at a convenient time and place. This made it easier to recruit participants who may face mobility issues and find it challenging to physically meet at a research lab. At a time when remote studies have become a necessity due to a global pandemic, we suggest the use of video prototypes as an alternate methodology when in-person meetings are restricted.

5.5 Future Work

We focused on the use of new generation technologies on a large tabletop display and emphasized the futuristic nature where such a display was commonplace. Future work may consider other devices specific to personal health management, such as a heart rate or blood glucose monitor that can be made with cheaper components to only provide the functionality needed. It could also be valuable to explore a custom health application that consolidates personal health records. Finally, rather than building a system with full functionality, our participants watched a video prototype depicting a design concept and did not have the opportunity to interact with an actual system. Though there were advantages to this approach as discussed above, directly engaging with a working prototype is likely to provide different insights and perspectives.

ACKNOWLEDGMENTS

We thank Samsung Electronics Canada Inc. for their support in provisioning devices used in this research. This work was supported by the Natural Science and Engineering Research Council of Canada (NSERC RGPIN-2018-06130) and AGE-WELL NCE (AWCRP-2020-10).

REFERENCES

[1] AARP Real Possibilities Project. 2015. Building a better tracker: Older consumers weigh in on activity and sleep monitoring devices. American Association for Retired Persons. Retrieved from: https://www.aarp.org/content/dam/aarp/home-and-family/personal-technology/2015-07/innovation-50-project-catalyst-tracker-study-AARP.pdf

[2] Monica Anderson & Andrew Perrin. (2020, May 30). Tech Adoption Climbs Among Older Americans. Retrieved September 02, 2020, from https://www.pewresearch.org/internet/2017/05/17/tech-adoption-climbs-among-older-adults/

[3] Jakob Bardram, Claus Bossen, Andreas Lykke-Olesen, Rune Nielsen, Kim Halskov Madsen. 2002. Virtual video prototyping of pervasive healthcare systems. In Proceedings of the 4th Conference on Designing Interactive Systems: Processes, practices, methods, and techniques (London, England, 2002). http://dx.doi.org/10.1145/778712.778738

[4] Michel Beaudouin-Lafon and Wendy E. Mackay. (2012). Prototyping Tools and Techniques. In The Human Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications (3rd ed.), Julie A Jacko (ed.). CRC Press, Boca Raton, USA, 1081–1104.

[5] Jomara Binda, Hyehyun Park, John M. Carroll, Natalie Cope, Chien Wen (Tina) Yuan, and Eun Kyoung Choe. 2017. Intergenerational sharing of health data among family members. In Proceedings of the 11th EAI International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '17). Association for Computing Machinery, New York, NY, USA, 468–471. https://doi.org/10.1145/3154862.3154895

[6] John M. Carroll, Penny L. Smith-Kerker, James R. Ford, and Sandra A. Mazur-Rimetz. 1987. The minimal manual. Hum.-Comput. Interact. 3, 2 (June 1987), 123–153. https://doi.org/10.1207/s15327051hci0302_2

[7] Camille Cobb, Lucy Simko, Tadayoshi Kohno, and Alexis Hiniker. 2020. User Experiences with Online Status Indicators. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20). Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3313831.3376240

[8] Mario Conci, Fabio Pianesi, Massimo Zancanaro. 2009. Useful, social and enjoyable: Mobile phone adoption by older people. In: Gross T. et al. (eds) Human-Computer Interaction – INTERACT 2009. Lecture Notes in Computer Science, vol 5726. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-03655-2_7

[9] Sara J. Czaja, Walter R. Boot, Neil Charness, Wendy A. Rogers. (2019). Designing for Older Adults: Principles and Creative Human Factors Approaches.

[10] Jennifer L. Davidson and Carlos Jensen. 2013. What health topics older adults want to track: A participatory design study. In Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '13). ACM, New York, NY, USA, Article 26, 8 pages.

[11] A.C. de Barros, S. Rêgo, J. Antunes. (2014) Aspects of Human-Centred Design in HCI with Older Adults: Experiences from the Field. In Human-Centered Software Engineering. HCSE 2014. Lecture Notes in Computer Science, vol 8742. Springer, Berlin, Heidelberg.

[12] A. Dickinson, J. Arnott, and S. Prior. 2007. Methods for human-computer interaction research with older people. Behav. Inf. Technol. 26, 4 (July 2007), 343–352.

[13] Julie Doyle, Niamh Caprani, Rodd Bond. 2015. Older adults' attitudes to self-management of health and wellness through smart home data. In 2015 9th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth) (20-23 May 2015). http://dx.doi.org/10.4108/icst.pervasivehealth.2015.259279

[14] Julie Doyle, Lorcan Walsh, Antonella Sassu, and Teresa McDonagh. 2014. Designing a wellness self-management tool for older adults: Results from a field trial of YourWellness. In Proceedings of the 8th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '14). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), ICST, Brussels, Belgium, Belgium, 134-141.

[15] Evidence and Impact on Human Health and the Healthcare System Institute Report. (2017, November 7). The Growing Value of Digital Health. Retrieved September 06, 2020, from https://www.iqvia.com/insights/the-iqvia-institute/reports/the-growing-value-of-digital-health

[16] Mingming Fan and Khai N. Truong. 2018. Guidelines for Creating Senior-Friendly Product Instructions. ACM Trans. Access. Comput. 11, 2, Article 9 (June 2018), 35 pages.

[17] Vicki L. Hanson. 2010. Influencing technology adoption by older adults. Interacting with Computers, 22, 6 (2010/11/01), 502-509. https://doi.org/10.1016/j.intcom.2010.09.001

[18] Tatsuya Ishihara, Masatomo Kobayashi, Hironobu Takagi, Chieko Asakawa. 2013. How Unfamiliar Words in Smartphone Manuals Affect Senior Citizens. In: Stephanidis C., Antona M. (eds) Universal Access in Human-Computer Interaction. Applications and Services for Quality of Life. UAHCI 2013. Lecture Notes in Computer Science, vol 8011. Springer, Berlin, Heidelberg.

[19] Sunyoung Kim, Krzysztof Z. Gajos, Michael Muller, and Barbara J. Grosz. 2016. Acceptance of mobile technology by older adults: A preliminary study. In Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '16). ACM, New York, NY, USA, 147-157.

[20] Bran Knowles and Vicki L. Hanson. 2018. The wisdom of older technology (non)users. Commun. ACM 61, 3 (February 2018), 72-77. https://doi.org/10.1145/3179995

[21] Anastasia Kononova, Lin Li, Kendra Kamp, Marie Bowen, R V Rikard, Sheila Cotten, & Wei Peng. (2019). The Use of Wearable Activity Trackers Among Older Adults: Focus Group Study of Tracker Perceptions, Motivators, and Barriers in the Maintenance Stage of Behavior Change. JMIR mHealth and uHealth, 7(4), e9832. https://doi.org/10.2196/mhealth.9832

[22] Byung Cheol Lee, Junfei Xie, Toyin Ajisafe, Sung-Hee Kim. 2020. How are wearable activity trackers adopted in older adults? Comparison between subjective adoption attitudes and physical activity performance. International journal of environmental research and public health, 17, 10 (2020), 3461. http://dx.doi.org/10.3390/ijerph17103461

[23] Chaiwoo Lee, Joseph F. Coughlin. 2015. Perspective: Older adults' adoption of technology: An integrated approach to identifying determinants and barriers. Journal of Product Innovation Management, 32, 5 (2015), 747-759. http://dx.doi.org/10.1111/jpim.12176

[24] Rock Leung, Charlotte Tang, Shathel Haddad, Joanna Mcgrenere, Peter Graf, and Vilia Ingriany. 2012. How Older Adults Learn to Use Mobile Devices: Survey and Field Investigations. ACM Trans. Access. Comput. 4, 3, Article 11 (December 2012), 33 pages.

[25] Joanna E. Lewis & Mark B. Neider. (2017). Designing Wearable Technology for an Aging Population. Ergonomics in Design, 25(3), 4-10.

[26] Junde Li, Qi Ma, Alan H. S. Chan, S. S. Man. 2019. Health monitoring through wearable technologies for older adults: Smart wearables acceptance model. Applied Ergonomics, 75 (2019/02/01), 162-169. https://doi.org/10.1016/j.apergo.2018.10.006

[27] Lin Li, Wei Peng, Kendra Kamp, Marie Bowen, Shelia R. Cotten, R.V. Rikard, and Anastasia Kononova. 2017. Poster: Understanding Long-Term Adoption of Wearable Activity Trackers Among Older Adults. In Proceedings of the 2017 Workshop on Wearable Systems and Applications (WearSys '17). ACM, New York, NY, USA, 33-34.

[28] Siân E. Lindley, Richard Harper, and Abigail Sellen. 2009. Desiring to be in touch in a changing communications landscape: Attitudes of older adults. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '09). ACM, New York, NY, USA, 1693-1702.

[29] Wendy E. Mackay. (1988). Video prototyping: A technique for developing hypermedia systems. In Conference Companion of ACM CHI '88, Conference on Human Factors in Computing. Washington DC.

[30] Wendy E. Mackay and Anne Laure Fayard. 1999. Video brainstorming and prototyping: Techniques for participatory design. In CHI '99 Extended Abstracts on Human Factors in Computing Systems (CHI EA '99). Association for Computing Machinery, New York, NY, USA, 118–119. https://doi.org/10.1145/632716.632790

[31] Fran Marquis-Faulkes, Stephen J. McKenna, Alan F. Newell, & Peter Gregor. (2005). Gathering the requirements for a fall monitor using drama and video with older people. Technology and Disability, 17(4), 227-236.

[32] Todd Matthew Manini, Tonatiuh Mendoza, Manoj Battula, Anis Davoudi, Matin Kheirkhahan, Mary Ellen Young, Eric Weber, Roger Benton Fillingim, and Parisa Rashidi. (2019). Perception of Older Adults Toward Smartwatch Technology for Assessing Pain and Related Patient-Reported Outcomes: Pilot Study. In JMIR mHealth and uHealth, 7,(3) e10044. doi:10.2196/10044

[33] Ronald E. McGaughey, Steven M. Zeltmann, Mark E. McMurtrey. 2013. Motivations and obstacles to smartphone use by the elderly: Developing a research framework. Int. J. Electron. Financ., 7, 3/4 (2013), 177–195. http://dx.doi.org/10.1504/ijef.2013.058601

[34] Tracy L. Mitzner, Cara B. Fausset, Julie B. Boron, Anne E. Adams, Katinka Dijkstra, Chin Chin Lee, Wendy A. Rogers, and Arthur D. Fisk. (2008). Older Adults' Training Preferences for Learning to Use Technology. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 52(26), 2047–2051.

[35] Tracy L. Mitzner, Julie B. Boron, Cara Bailey Fausset, Anne E. Adams, Neil Charness, Sara J. Czaja, Katinka Dijkstra, Arthur D. Fisk, Wendy A. Rogers, Joseph Sharit. 2010. Older adults talk technology: Technology usage and attitudes. Computers in Human Behavior, 26, 6 (2010/11/01), 1710-1721. https://doi.org/10.1016/j.chb.2010.06.020

[36] Barbara Barbosa Neves, Rachel L. Franz, Cosmin Munteanu, Ronald Baecker, Mags Ngo. 2015. "My hand doesn't listen to me!": Adoption and evaluation of a communication technology for the 'oldest old'. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (Seoul, Republic of Korea, 2015). http://dx.doi.org/10.1145/2702123.2702430

[37] Anne Marie Piper, Ross Campbell, and James D. Hollan. 2010. Exploring the accessibility and appeal of surface computing for older adult health care support. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10). ACM, New York, NY, USA, 907-916.

[38] Anne Marie Piper, Raymundo C. Garcia, and Robin N. Brewer. 2016. Understanding the Challenges and Opportunities of Smart Mobile Devices among the Oldest Old. International Journal of Mobile Human Computer Interaction (IJMHCI), 8(2), 83-98.

[39] Mackenzie Pryor & Anne Collins McLaughlin. (2018). Developing Video or Multimedia Instructions for Older Adults. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 62(1), 1739–1743.

[40] Brendan Strahm, Colin M. Gray, and Mihaela Vorvoreanu. 2018. Generating Mobile Application Onboarding Insights Through Minimalist Instruction. In Proceedings of the 2018 Designing Interactive Systems Conference (DIS '18). ACM, New York, NY, USA, 361-372.

[41] Mart Tacken, Fiorella Marcellini, Heidrun Mollenkopf, Isto Ruoppila, & Zsuzsa Széman. (2005). Use and acceptance of new technology by older

people. Findings of the International MOBILATE Survey: 'Enhancing mobility in later life.' Gerontechnology, 3(3), 126-137.

[42] Emily A. Vogels. (2020, August 14). About one-in-five Americans use a smart watch or fitness tracker. Retrieved September 04, 2020, from https://www.pewresearch.org/fact-tank/2020/01/09/about-one-in-five-americans-use-a-smart-watch-or-fitness-tracker/

[43] Jayne Wallace, John McCarthy, Peter C. Wright, Patrick Olivier. 2013. Making design probes work. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Paris, France, 2013). http://dx.doi.org/10.1145/2470654.2466473

[44] Collin Wang, Carolyn Pang, Karyn Moffatt, Rock Leung, Joanna McGrenere. (2019) Supporting Older Adults in the Use of Smart Devices for Personal Health Management. In Proceedings of the 21st International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '19). ACM, New York, NY, USA, 2 pages.

[45] Jing Wang, Deidra Carroll, Michelle Peck, Sahiti Myneni, & Yang Gong. (2016). Mobile and Wearable Technology Needs for Aging in Place: Perspectives from Older Adults and Their Caregivers and Providers. Studies in Health Technology and Informatics, 225, 486-90.

[46] Shengzhi Wang, Khalisa Bolling, Wenlin Mao, Jennifer Reichstadt, Dilip Jeste, Ho-Cheoi Kim, Camille Nebeker. Technology to Support Aging in Place: Older Adults' Perspectives. Healthcare 2019, 7, 60.

[47] Xiying Wang, Tiffany Knearem, Fanlu Gui, Srishti Gupta, Haining Zhu, Michael Williams, and John M. Carroll. 2018. The Safety Net of Aging in Place: Understanding How Older Adults Construct, Develop, and Maintain Their Social Circles. In Proceedings of the 12th EAI International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth '18). ACM, New York, NY, USA, 191-200.

[48] Zachary Wilson, Helen Yin, Sayan Sarcar, Rock Leung, and Joanna McGrenere. 2018. Help Kiosk: An Augmented Display System to Assist Older Adults to Learn How to Use Smart Phones. In Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '18). ACM, New York, NY, USA, 441-443.

[49] World Population Prospects: The 2017 Revision | Multimedia Library - United Nations Department of Economic and Social Affairs. (2017, June 21). Retrieved from https://www.un.org/development/desa/publications/worldpopulation-prospects-the-2017-revision.html