Considerations for Technology that Support Physical Activity by Older Adults

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ABSTRACT
Barriers to physical activity prevent older adults from meeting recommended physical activity levels necessary for maintaining quality of life. As technology becomes more advanced, we have the opportunity and the responsibility to address concerns faced by the aging population. We seek opportunities for technology to empower older adults to overcome barriers on their own by interviewing and learning from older adults who have successfully overcome these barriers. In this paper, we present a set of needs that technology can address, and considerations for designing technology interventions that support physical activity by older adults.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Keywords
Older adults, physical activity, barriers, technology interventions.

1. INTRODUCTION
By 2050, the U.S. population of older adults over 65 years old is expected to increase from 46 million to 108 million [26]. The quality of life of these older adults is heavily dependent on their mobility and social lifestyle, but due to decreased mobility and health declines associated with aging, many older adults leading sedentary lifestyles are at risk of developing various other health problems such as obesity, cardiovascular diseases, depression, and subsequently, lower life expectancy.

Physical activity can help curb these problems and improve quality of life [6], and outdoor physical activity, particularly, can also improve mental health [21]. It is recommended that older adults get at least 30 minutes of moderate intensity aerobic exercise five times a week, with strength training on two separate days [5]. However, despite interventions [14], there are still barriers to physical activity that prevent older adults from getting the recommended amount of aerobic and strength training exercises needed for reducing risks of aging-related health issues.

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Our research goal is to find ways for technology to mitigate barriers and to assist older adults in incorporating or maintaining physical activity in their lifestyles. There are several existing physical activity systems [e.g., 3, 7, 15, 16], but only a few are specifically created for older adults [1, 13, 19, 23] that use known effective persuasive techniques (*e.g.,* goal setting, feedback) for physical activity interventions [14]. However, given the vast literature on barriers to physical activity, we want to take a needs-based, barrier-centric approach to explore other appropriate technologies for addressing barriers.

To address this goal, we first review literature in non-technical fields on physical activity and older adults to find needs that are relatively unaddressed. We then conduct semi-structured interviews with older adults who have successfully overcome barriers to physical activity to understand how technology can support other older adults who may not have the resources to overcome barriers on their own. From these interviews, we derive four needs that technology can address in keeping older adults active, and we validate them by evaluating concept storyboards. From the evaluation, we derive design considerations for technology that support physical activity by older adults. Finally, we create and deploy one of the concepts to gain preliminary insights about how older adults use such technology in real life.

Our contributions to the field are four needs for technology to support to maintain physical activity by older adults, derived from an understanding of how older adults are able to overcome barriers on their own, and design considerations for technology interventions supporting physical activity by older adults.

In the next section, we present barriers to physical activity from literature. Then, we describe the structure of our interviews, our twelve participants, what we learned from older adults who have overcome barriers on their own, and how we derived a set of four design opportunities for technology. We discuss these design opportunities in more detail and present eight concepts, which are evaluated with eleven additional older adults through concept storyboards. From the concept evaluations, we derive considerations for designing technology that support physical activity by older adults, and we build and evaluate one of the concepts *in situ*. We conclude with limitations and future work.

2. BARRIERS TO PHYSICAL ACTIVITY
There is a vast body of literature in fields such as preventive medicine, environmental psychology, sports medicine, gerontology, *etc.,* detailing barriers to physical activity. Many people face personal and environmental barriers that disrupt plans to perform physical activity in their daily routines. The most common barrier across all adults is perceived lack of time, but for those aged 60-75, injury or poor health is the top barrier [24].

Indeed, as older adults' physical health declines, they are more likely to be physically limited and less confident in their ability to perform physical activity.

Furthermore, as their mobility is reduced and environmental barriers discourage them from going outdoors, they lead increasingly sedentary lifestyles and social interaction becomes less frequent [18]. Changes in living circumstances, such as moving to a smaller home [17], or loss of loved ones [10] also contribute to weakened social connections, which reduces the social support older adults need to stay connected and maintain a satisfactory quality of life [18].

Toscos et al. [24] provided a review of 13 studies of personal barriers, which include barriers that are:

- psychological (e.g., lack of motivation, low self-efficacy),
- physical (e.g., illness, injury),
- emotional (e.g., lack of enjoyment),
- social (e.g., lack of social support from friends and family [4])
- responsibility-related (e.g., caregiving duties, job), and
- convenience-related (e.g., perceived lack of time, inconvenience).

For older adults, personal barriers also include mobility impairments resulting from physical health declines such as poor balance, reduced strength, and bone degeneration [6]. When combined with environmental barriers, mobility impairments also cause older adults to avoid physical activity because they are afraid of falling [2]. Environmental factors such as pleasantness, safety, and convenience are primary concerns. Environmental barriers [12, 25] include:

- weather (e.g., ice, humidity, rain),
- street characteristics (e.g., uneven sidewalks, high curbs, lack of sidewalks),
- safety (e.g., air pollution, traffic, crime, inadequate lighting),
- aesthetics (e.g., lack of trees and grass, litter), and
- facilities (e.g., public transportation, gyms, stores).

Green, accessible, safe, and lively neighborhoods foster physical and social activity, reduce stress and blood pressure, and improve mood and self esteem [21].

Although these barriers are covered comprehensively in literature, it is relatively unknown how older adults have adapted to living with these barriers. As part of our needs-based approach, we conducted interviews with older adults to reveal needs that they were able to fulfill that allowed them to overcome barriers to physical activity.

3. QUALITATIVE INTERVIEWS

In order to further probe what we found in the literature, we recruited 12 older adults from a lifelong learning center that allows older adults to further their education by taking classes at local universities. We chose this program because we wanted to recruit older adults who were more likely to be physically active, as education is positively correlated with physical activity [25]. We emailed a screener survey to the mailing list (75 responses) and chose 12 respondents that represented a wide range of ages, barriers, reported physical activity levels, and residential area. Table 1 lists our participants by gender, age, and main barriers they experienced, many of which are specific to older adults.

The interviews lasted between 1-2 hours and were audio recorded. We asked participants to walk us through a typical day and the day before the interview and describe both their indoor and outdoor activities. When they mentioned a specific outdoor activity, we probed them further about their reasons for engaging in the activity, barriers to performing the activity, and factors that facilitated the activity. We asked about recent precipitating events that might have changed their physical activity levels (*e.g.,* retirement), whether and how they retained their physical activity level, their hobbies, family, and technology use. Detailed field notes were taken during the interviews and from the audio recordings, and were coded for ways in which the participants have overcome barriers to physical activity. These codes were then grouped together in an affinity diagram to form themes of how our participants have overcome barriers to physical activity.

Gender	Age	Barriers
F1	67	Spinal arthritis, degenerative scoliosis
F2	82	Lack of motivation, inconvenience, humidity
F3	65	Recent death of husband, lack of activity partners
F4	85	Balance problems, fear of falling, arthritis, osteoporosis, spinal stenosis, lack of motivation, lack of time
F5	63	Recent relocation to smaller home, noise pollution, traffic, fear of falling, uneven sidewalks, ice, humidity
F6	61	Noise pollution, traffic, hills, knee injury, lack of motivation
F7	63	Lack of motivation, hills, lack of sidewalks, lack of facilities and stores, extreme weather
F8	72	Parkinson's disease
M1	67	Snow
M2	67	Lack of sidewalks, inclement weather
M3	90	Lack of time, depression
M4	72	Health declines

Table 1. Interview participants by gender, age, and barriers.

These interviews were critical in illustrating how active older adults have overcome barriers to outdoor physical activity by themselves.

4. INTERVIEW FINDINGS

The interviews provided insights as to what older adults are able to do on their own, and what needs technology could address for older adults who do not have the same resources as active older adults. We found four recurring themes across our interviews regarding successful personal interventions: awareness of personal limitations, social motivation, establishing and adapting to routines, and finding enjoyable activities. We did not find age-related differences among the themes.

4.1 Awareness of personal limitations

There is a known gap between older adults' perceived and actual ability in literature, where older adults overestimate their ability before a major event causing an accident, and often underestimate their ability afterwards [11, 20]. Older adults from our interviews

who successfully adapted to their mobility limitations did so by telling others during activities what they can and cannot do, or finding alternative activities that accommodate their physical limitations. Older adults who are more aware of their limitations and their actual ability are more confident in choosing the right activities for their ability level, and less fearful of falling or inconveniencing others with their pace.

4.2 Social motivation

Literature has shown that an active social life and adequate social support is important to older adults' quality of life [9]. In our interviews, we found that this social support can manifest in several ways to support physical activity. It can come from family and friends who are activity partners or cheerleaders in their loved ones' health, but also through social comparison or social collaboration. For example, M3 is proud that, at 90 years old, he can do a lot more than his friends can do. Similarly, F6 has "a little bit of a competitive streak" and "[takes] pride that [she's] the only one out [walking in snowy and bad weather]." F7 is not competitive, but a team sport or a collaborative goal among residents of her neighborhood would motivate her to perform physical activity. An example would be a neighborhood program where the most active street would have flowers planted along their sidewalk.

In the case where older adults are not as physically active as they would like, lack of social support or activity partners is a primary reason for not doing an activity. Loss of family members or moving to a new location is a common occurrence that means losing activity partners, but F3 and F5 overcame these barriers by making the extra effort to include other family and friends in physical activities, and relocating to a walking-friendly neighborhood, respectively.

While support from friends and family is important, social interaction with strangers in public spaces where older adults frequent provide an added incentive for being outdoors. For example, M4 enjoys greeting people and their animals that he meets on his walks, while F2 meets people who stop and talk to her when she walks her daughter's dog. In a neighborhood where walking outdoors is common among residents, seeing other walkers can be socially motivating.

4.3 Establishing & adapting to routines

Most of the older adults we interviewed had the advantage of living in the same area for several years, and so were familiar with road conditions in their neighborhood. This allowed them to establish pleasant, walkable routes that became an important part of their daily routines. Routines allowed the interviewees to have stability and predictableness, and develop ingrained habits of physical activity. It was also a way to keep track of their physical abilities, as several participants were able to identify when they were no longer able to continue existing activity habits, or track how much activity they have done.

Disruptions in routines occurred for all of the older adults we interviewed, usually through a major life change that altered their physical activity levels. For many, it was retirement, social status changes (e.g., married, widowed), relocation, or general age-related physical declines. Normally, these changes in routine may disrupt existing physical activity, but many of our interviewees used the opportunity to incorporate physical activity into their new routines. For example, M1 found a different daily one-mile route after he retired. M4 goes to a senior citizen center in the winter and uses the exercise bike there instead of biking on the streets. Fear of becoming immobile or boredom also drove F6 to stay active after retirement despite inclement weather.

4.4 Finding enjoyable activities

From the interviews, we learned that even though some of the older adults did not perform any regular physical *exercise* (i.e., going to the gym or walking a one-mile route), all of them have busy schedules and are very involved in volunteer work or serve on various boards and committees. In other words, despite mobility impairments or other personal barriers, the older adults we interviewed found enjoyable activities that provided them with social and physical activity that took the place of structured physical exercise. For example, F2 enjoys going to outdoor music and art shows, admiring nature, and looking at architectures of homes. F5 sets small goals for herself to accomplish on foot, such as errands or chores.

For older adults, having access to amenities that facilitate walking with a purpose (e.g., grocery stores, coffee shops) really makes physical activity more enjoyable. Several interviewees mentioned that they wanted a destination or purpose in mind when they go out for a walk, rather than walk just for exercise. F7, who lives in a suburban area with no sidewalks, stores, or amenities nearby, hopes to move to an urban area so she can have a purpose for walking.

5. CONCEPT GENERATION

Figure 1. M1, 94, organizing the concepts in his apartment's common space.

In order to validate whether or not these needs will encourage older adults to be more physically active, we generated eight concept storyboards illustrating various ways technology might fulfill these needs. We accomplished this by revisiting each theme, sketching two to three technology solutions based on specific things participants mentioned or did in each theme, and then choosing eight final sketches that depicted more probable uses of current technology. We evaluated these concepts with a different group of 11 older adults, which we recruited from the same lifelong learning program, as well as Craigslist, to get feedback from both active and inactive older adults. There were six female participants (F1-F6) aged 64 to 80, and five male participants (M1-M5) aged 79 to 94. We interviewed three married couples together, and all but two participants were interviewed in their homes. To compare different responses to the concepts, we noted how much and how often participants participated in physical activity, and whether or not they were motivated to do physical activity. For the remainder of the paper, the participants referred are concept evaluation participants, not those from the first round of interviews.

During the semi-structured concept evaluation interviews, we asked about participants' brief life history, existing physical activity levels, technology use, and used the speed dating technique [8] to evaluate each of the concepts, which were printed in color on 11"x17" paper. We asked participants to think aloud as they went through the concepts, asked whether or not each technology would be useful for themselves and others, and any concerns or worries they had with the concept. At the end of the think aloud session, we asked participants to rank the eight concepts based on what would be most to least useful for them (Figure 1). We audio-recorded the interviews and took detailed field notes from the recording. We grouped the feedback by concept and coded the interviews for comments on how the participants would use the concept, suggested alternatives to the concept, positive and negative reactions, and concerns. In the next section, we describe the concepts and results from the evaluation.

6. CONCEPTS & EVALUATION RESULTS

6.1 Activity monitor

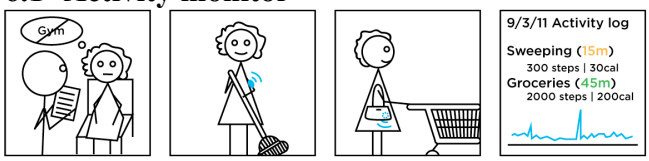

Figure 2. 1) Mary's doctor suggests that she get more physical activity, but she can't get motivated to go to the gym. 2-3) Mary wears a sensor that tracks her physical activity level as she's doing everyday chores. 4) Mary sees that she's actually getting an hour of physical activity a day, and is no longer so worried about not getting to the gym.

Four people said that the activity monitor (figure 2) would be useful because it could help them be more aware of how much activity they are currently doing, and if they had a goal, it could show them their progress. The participants who did not find it useful already knew how much they were doing (F2), or did not think it would be useful without a specific goal (F1). F2 plotted out 1-3 mile routes and after a while learned the landmarks, so she does not need a pedometer to tell her how much activity she has done. M3's exercises are defined by repetitions, not step count. Several people remarked that chores such as sweeping or shopping should not be counted as physical activity because they were not strenuous enough. One person had a concern about the accuracy of the activity monitor. She likened it to pedometers requiring you to enter your stride distance, which can be difficult to estimate. Two participants did not want to wear a monitor because "it's like being in jail and they put something on your ankle." (M2)

6.2 Finding safe routes

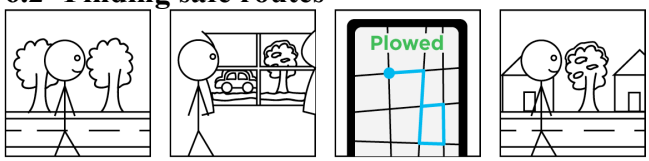

Figure 3. 1) John walks the same route every evening. 2) One day, it snowed several inches in the morning. John wants to go for his walk at night but his normal route is still mostly unplowed. 3) His mobile device suggests a new route that is well-lit, safe, and already plowed. 4) John is able to take his walk and enjoy a change of scenery.

This concept (figure 3) was useful to several participants in that it would help them sustain existing activities during undesirable conditions, but also introduce variety into everyday routine. For example, "if you continue to do the same thing all the time, it gets to be a real bore. It'd be nice to say, I want to do a 3 mile walk today, pick one for me… that would be fun." (F3) The ones who did not find it useful said it was because they already know their neighborhood, having lived there for at least a decade, but it would be useful while traveling in new places. Three participants mentioned that snow was not the problem, ice was, because they were afraid of slipping and falling. Four expressed concerns about the accuracy of the device, based on their previous experiences with GPS or uncertainty about how the device would get the updated information about street conditions.

6.3 Finding activity partners

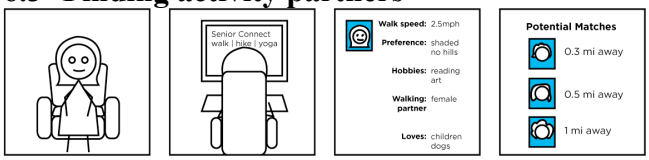

Figure 4. 1) Martha would go for walks more often if she had others to go with. 2) She joins an online social network especially for connecting seniors for activities. 3) Martha indicates that she would like to find someone else who walks at the same pace and have the same street preferences as she does. 4) The website shows her several potential matches within a mile from her.

About half the participants thought that a way to find activity partners (figure 4) was a wonderful idea, and described specific activities they would like a partner for. The other half were not looking for activity partners, because they preferred walking on their own (walking was quiet time to relax), already had activity partners, or were just not motivated to find activity partners. This concept showed us that social motivation is more effective for some older adults than others, for example older adults who are more social, or only prefer certain activities to be social. The biggest concern was privacy, because "[you] wonder who you're meeting, there's always crazies out there" (F5), and "you never know who would be picking that stuff [personal information] up" (F3). This concern partly comes from reading stories about "terrible things happening to people and people who were abusing that information" (F2), but also people who are private to begin with. Additionally, F4 was dubious that anyone else would want to walk with her, because she stops often while walking.

6.4 Augmented neighborhood

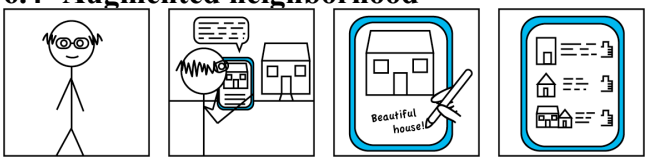

Figure 5. 1) Archie likes history and architecture. He does not like going for walks without a purpose. 2) He goes for walks with his tablet computer, which he can point at houses in his neighborhood and learn about their history and how they were built through a short audio clip. 3) He sees a house he especially likes and writes a nice note on his tablet for the owner. 4) He looks for other places that have positive comments from other people.

The goal of this concept was to give people a purpose for walking outdoors, and inspired by the participant who enjoyed looking at architecture of houses. Although many participants thought this

concept (figure 5) was a good idea because it would get some people walking outdoors, most participants would not use it because "getting information about what I'm seeing is not my priority [when walking]" (F1). Participants preferred enjoying their surroundings, interacting with their activity partner, or left to their own thoughts. Two participants compared it to museum audio tours, and thought it would be more appropriate in other situations, such as traveling, when walking was a casual activity rather than exercise. Five participants thought the commenting system was a nice gesture because they have approached others to comment on their house or garden, or had others admire theirs. They liked making personal connections, and thought this kind of technology could have lots of other applications that encouraged exploration (M2). Among the participants who would use it, two cited cost of the technology and lack of in-person instruction (e.g., a class) as barriers to using the technology, and one did not want to carry anything "heavy" or "cumbersome" while walking, especially something that was potentially valuable to others who would want to steal it. Two participants were concerned about the security of the device, and would not want their location or what they were doing to be tracked by marketers or thieves.

6.5 Finding daily flexibility

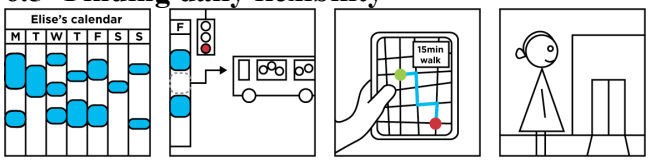

Figure 6. 1) Elise is a very busy woman. She doesn't have time to exercise. 2) Her electronic planner notices that the bus she would take to her next meeting is running late and already full. 3) It suggests that it only takes her a 15 minute walk on even ground instead of a 30 minute wait for the next bus. 4) Elise decides to walk, and arrives on time to her meeting.

Several participants from the first interview remarked that they did not have time to exercise because they were involved in many activities. This concept (figure 6) shows a system that could suggest activities, particularly exercise, in daily routines that do not already include it. Participants had separate reactions to the bus notification and the schedule suggestions. Three participants found the bus notification useful because they have been in situations where they wondered whether or not the bus would come on time, and having a bus notification would provide "useful information that you can apply" (M3). Those who did not find the bus notification useful already chose to walk or drive rather than using public transportation. Two people said they would like the schedule suggestions. For example, F5 thought it would help her see opportunities to get more things done when she was in a certain neighborhood. Others strongly preferred scheduling their own time (F3: "Why would we need it? We know what we want to do with our time."), or did not have enough fixed appointments for the feature to be useful. There were few concerns with this concept, including safety of the suggested route and uncertainty in being able to walk for the time estimated by the system.

6.6 Finding alternative activities

Three participants thought it would be useful to know alternative exercises (figure 7) that could help them sustain or increase physical activity. F6, who was quite adamant throughout the concept evaluation about not being motivated to exercise at all, was open to an activity monitor providing suggestions for physical activity after recounting previous bad experiences with a personal

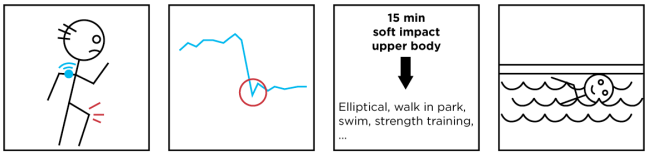

Figure 7. 1) Alan used to run a lot until he developed knee problems. 2) His activity monitor notices the change in his mobility. 3) Based on what he's able to do, it suggests alternative activities. 4) Alan tries out the suggestions and finds a new activity that he likes.

trainer who pushed her too hard. M2, who is a retired doctor, thinks it would be especially useful for older adults living alone, as they do not have a spouse to point out any health declines. Those who did not find the concept useful had other ways of monitoring declines by experience, memory, and body signals. When F3 has knee problems, "I know I need to lift my weights more. I know I need to be on the elliptical instead of pounding on the treadmill. I know that already." M2 mentally compares his gym performance to previous weeks. "I don't need an apparatus to tell me when my activity has dropped. The pain tells me," he says. The two concerns about this concept were whether or not the activity suggestions would be effective, and having the suggestions backed up by a doctor or physical therapist.

6.7 Robot dog

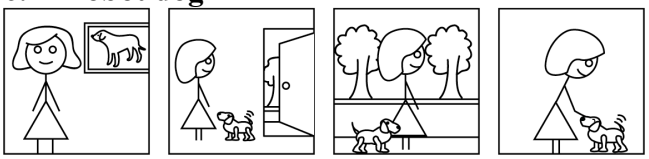

Figure 8. 1) Sally loves dogs, but she's unable to take care of one herself. 2) She has a robot dog that wants to be played with and taken for walks a couple times a day. 3) The robot dog responds to her like a real pet, and follows Sally during walks. 4) Sally grows attached to her robot dog as if it were a real pet.

Opinions about the robot dog (figure 8) were mixed, with strong negative reactions to people growing attached to a robot. Nevertheless, this concept was greeted with smiles, chuckles, and amusement. Those who were open to owning one thought it would be fun, entertaining, and could act as a conversation starter. F6 says, "I might take it for a walk because everybody would stop and talk to me and ask about it. They'd be very inquisitive…I would have to put fun in what I'm doing. I would have to make it entertaining for me." F4 thinks that the novelty of the idea would get her walking, and that people on the streets or at her workplace would "get a kick out of" seeing her with a robot dog. Two participants thought it would be appropriate for older adults living in nursing homes who wanted something to take care of. For example, F2 related a story about buying a realistic baby doll for her mother, who wanted a baby to hold while she was going through mental declines.

6.8 Informative art

The other seven concepts are mostly feasible with current technology, so we designed the last concept (figure 9) to be more far-fetched and exploratory than the others. It was inspired by a participant who loved being visually stimulated with colors and "light [falling] on things, gardens, buildings, and colors". All but one participant thought the concept was "interesting," "wonderful," "fascinating," "imaginative," or "fun," and could be

Figure 9. 1) Bob loves art and he finds physical exercise boring. 2) Throughout the day, Bob wears a monitor that tracks his movements, their intensity, and his general location. 3) The art frame in his house creates an abstract but aesthetically pleasing representation of his daily activity. 4) Bob likes looking at the art he's generated, and tries out other kinds of physical activity to see new effects.

effective in encouraging physical activity. Because there are few other experiences they can compare it to, they were unsure if it would work, but were curious enough to want to try it. However, F6 could not "understand how an art frame could motivate [anyone] to do something." F3 thought it would be fun if she could compare her painting with her husband's (M4). Some speculated that it might eventually become boring. Concerns included privacy issues with being tracked and the possibility of the device hurting the user. For F4, whose mobility is limited to only short amounts of walking, she was unsure what other activities she could do to make different effects, and for F5, the form factor was a concern because she had limited wall space in her cluttered home.

7. DESIGN CONSIDERATIONS

In addition to validating the four themes gleaned from our interviews, the concept evaluation was also used as a probe to learn older adults' attitudes towards technology in the context of physical activity interventions. Based on the results of the concept evaluation, we propose that older adults' attitudes towards physical activity, their values, and their preconceived notions about technology must be taken into consideration as future physical activity systems are designed.

7.1 Attitude towards physical activity

We noticed that older adults who were motivated to perform physical activity but were not already active (and had no severe impairments) found the concepts to be most useful. Older adults who were already active (and thus already motivated), and older adults who were neither active nor motivated found fewer of the concepts useful. Specifically, the five participants who were active and motivated found zero to four of the concepts useful. The two somewhat active and motivated participants found six or eight concepts useful. Two inactive and motivated participants found seven and two (M3 had severe mobility impairments that required him to use a walker) concepts useful, and the two participants who were neither active nor motivated found one or two concepts useful. The inactive and unmotivated participants found the Alternative Activities, Robot Dog, and Interactive Art concepts useful, indicating that perhaps unmotivated older adults need to find ways to make physical activity fun and playful, or, in the case of F6, nudges to perform physical activity need to be carefully communicated and executed. Therefore, technology interventions may be best suited to those who are currently inactive, but motivated to change.

7.2 What older adults value

Our participants expressed the importance of preserving social connections. For example, M1 wanted the Augmented Neighborhood concept to be more about people than houses. F4 reflected that older adults prefer "the old way" to doing things because it "strengthens social bonds." Several participants who had trouble learning new technology preferred social learning instead of a manual, and two participants specifically mentioned a person in their apartment complex that they could go to for help with technology. Therefore, technology interventions may have the highest adoption and retention rate when social connections are also taken into consideration.

Participants also valued their independence strongly. F2 wanted to decide her schedule herself instead of having an electronic planner suggest activities for her. Older adults want to keep their independence by making decisions for themselves, but they are open to using technology if it was practical and "removed blindness" (M3) by providing personally relevant information outside of their control (*e.g.,* informing whether the bus is running late or whether streets are icy).

7.3 Preconceived notions about technology

We also noticed that participants' preconceived notions towards technology played an important role in their reactions to the concepts. Complex technology may cause older adults to shy away from engaging with it because they do not "want to feel stupid, that they can't do it and it's beyond them" (F4). As M3 puts it, "technology should advance your life, not complicate it." The complexity is compounded by lack of awareness at how technology can help improve older adults' lives. F5 believes that "if [older adults] were more aware, they'd probably use it more. I think that the biggest problem is letting people know the potential and what technology can do for them so it is worth the effort to learn it, and it isn't so complicated sometimes."

Therefore, technology interventions must be easy to use, and not stigmatizing. To reduce barriers to using technology, M2, a retired doctor, suggests that technology interventions could be embedded in known assistive devices, or reusing certain technologies that have been effective for others. For example, a cane could double as an activity monitor and provide feedback about its user's step count or pulse rate. Game developers could create more Nintendo Wii games that are geared towards older adults. While the concepts we proposed may be more appropriate for older adults in the next couple of decades, modifying everyday objects that current older adults interact with may be the best way to create technology interventions for the current generation of older adults.

7.4 Summary

Throughout our work, we encountered several research themes central to designing technology for older adults, such as privacy concerns and social implications. These issues are known from the literature [*e.g.,* 9, 11], but the particular considerations we highlighted and described above are especially salient when designing technology that specifically encourage physical activity for older adults.

Overall, concepts that supported needs related to awareness and social connection were considered most useful. Concepts that helped with adaptation to routines were not valued as much by older participants who were already active and thought they were aware of changes in their abilities. The robot dog and informative art concepts provoked some uncertain reactions about their usefulness, but also curiosity and amusement, which could be enough to elicit actual use. Because they were the most deviant from the technology that the older adults are used to, and to further validate one of the concepts in light of our design considerations, we decided to build a system as a probe to elicit feedback about

this type of technology. We built the Spark system, which tracks and visualizes physical activity as an informative art piece [22], and ran a 3-week in-home deployment study with three older adults.

8. SPARK SYSTEM & DEPLOYMENT

Spark is a web application that uses the Fitbit activity monitor and its API to gather step count data from users. It visualizes the data in five-minute increments using Raphaël, a JavaScript visualization library, and HTML5. Spark can run in a web browser on any tablet, but we used the 7" Archos 70 internet tablet running Firefox on Android 2.2.1 for our study due to its low cost, built-in stand, and low profile.

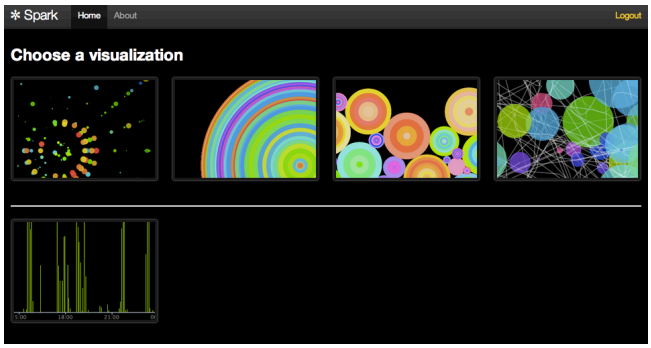

Figure 10. Spark's main screen, which allows users to choose from among five visualizations (4 abstract and 1 bar graph). The visualizations are, starting from the top row, from left to right, Spiral, Rings, Bucket, Pollock, and Column.

We created four abstract visualizations, each more abstract than the last (figure 10). Each visualization animates over the course of a day, using circles of different colors and sizes animated in different ways to represent the passage of time. The size represents step count in a five-minute period, and the color represents intensity of the steps (casual walking, brisk walking, or running). In Spiral, the circles animate outward in a spiral such that steps taking earlier are on the outside of the spiral. In Rings, a circle grows, adding more concentric rings for each five-minute period of activity. In Bucket, circles are created for activity, and falls from the top of the screen, filling up the screen over the course of the day. In Pollock, which is based on Jackson Pollock's artwork, a white line randomly draws around the screen, bursting into color when there is activity.

We recruited three older adults from the lifelong learning program, aged 58-71, including a male (P1, walks a lot), and a married couple (P2 female, exercises at least an hour a day, P3 male, exercises at least 30 minutes a day). The couple already owned a Fitbit, and we provided P1 a Fitbit to use for the study. The participants displayed the tablet showing Spark in their homes in a common area that they frequently pass by. The couple placed their tablets in front of their office computers, which are side by side, whereas P1 placed it on a coffee table in the living room. Both deployments took place for about three weeks. We were mainly interested in their experiences with the display, and did not measure any behavior change due to the short study.

8.1 Deployment results

All participants reacted favorably to Spark. P1 found it much more engaging than viewing a chart of his activity because it showed him what he could do, rather than what he had done. He was mainly motivated by trying to fill up the screen on the tablet, and would walk back and forth in his house to get more steps. For him, Spark was primarily a fun and aesthetic experience, and secondarily, something that made him more aware of how much walking he does on a daily basis.

P2 and P3 had a little competition going on between them. *"she likes to gloat over me...that hers was fuller than mine, prettier than mine, so I switched mine to a different mode [Pollock]."* They preferred the more abstract visualizations because they were more fun and effective at showing cumulative totals for the day. Before the study, they checked the Fitbit website for their statistics irregularly, perhaps once a week, and the Fitbit tracker a few times per day. While using Spark, they glanced at the tablet multiple times every day, which gave them the opportunity to do more each day, and a better interface for comparing their progress with each other. P3 also showed Spark to guests when they visited.

The variety of visualizations and their colorful animations increased the engagement for all participants, because no two days' visualizations would be alike. Not only did Spark provide them with more awareness of what their activity was, it added a visual reward that they looked forward to getting. In the case of P2 and P3, it also added some competitive excitement into their interactions with each other surrounding the Fitbit. Despite technical issues with the tablet, the participants all wanted to continue using Spark after the study, and suggested that it might work better as a screen saver or a larger display hung on the wall.

9. LIMITATIONS & FUTURE WORK

For the first round of interviews, we recruited older adults who are already physically active in order to learn how technology could help others who are not as active. As the concept evaluation suggested, older adults who are not at all active and not at all motivated to be active may have different needs to be addressed, and it is quite possible that the most effective interventions for them are not technology-based. Future work will aim for a deeper understanding of their personal barriers and determine the most effective intervention strategies for them.

We evaluated paper sketches of concepts that were helpful in getting preliminary feedback about whether or not the concepts represented needs that technology could fulfill. However, some of the participants had trouble with relating to the concept, understanding how it worked (and thus, what it would require of them), or focusing too much on the exact story and not the need (*e.g.,* Daily Flexibility concept). Our sample sizes were also small, which limited our ability to draw strong general conclusions. In addition, more prototypes and a long-term deployment can provide a more complete view of how technology that supports physical activity can fit in older adults' lives.

10. CONCLUSION

In this paper, we gained an intimate understanding of how barriers to physical activity affect older adults and learned from active older adults to help those who are less active. We contributed four validated needs for technology to support physical activity by older adults, and considerations for designing such technology. We also created and deployed a robust prototype to further validate one of the concepts. By addressing needs related to awareness, social connection, routines, and enjoyment, we can support physical activity by older adults and help improve their quality of life through better health throughout the aging process.

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