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A CO-DESIGN EXPLORATION: DESIGNING SENSOR-ENABLED EXERCISE WEAR FOR AGING.

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ABSTRACT

This paper documents an ongoing research project that investigates the possibility of design for sensor-enabled clothing or devices that augment the experiences of the independent elderly while exercising. Qualitative user-centered methods are employed to actively elicit the sensory knowledge and experience of a group of older adults. The research takes a grounded theory approach to collecting and analyzing sensory data. It structures and investigates the dynamics of co-design interaction in the initial stages of the design process, where student designers and older participants work together in this technology-oriented process. The mature participants contribute both to the initial idea generation and to the subsequent evaluation of the conceptual scenarios.

Keywords: Co-design, Aging, Wearable Computing.

INTRODUCTION

In the winter of 2011 twelve design students began to investigate older people's sensory experience while exercising in order to design assistive wearable technologies for them. They hoped to learn about their sensory capabilities and find design inspiration by collaborating with the older exercisers. The project, which was strongly influenced by a co-design approach, advanced through four stages from initial immersion to scenario development as described in more detail in the methods section of this paper.

Ethnographic fieldwork observation preceded the generative design research techniques, which enable participants to become co-designers in the early stages of the design process (Sanders,2002; Sleeswijk Visser, 2009). The highlight of the research activities took place during three parallel co-design sessions where students and mature exercisers worked together to generate basic concepts for sensor-enabled exercise-wear.

This paper explains how the structure of the project enabled the students to identify and address modest, but important, exercise issues and their design solutions. These user-centered approaches contrast with current practice in the predominantly technology-led field of wearable computing.

BACKGROUND

Researchers, designers, engineers, computer scientists, and artists In the growing field of wearable technologies have very different approaches to the design process (Barfield & Caudell,2001; Baurley,2004; Hallnäs & Redström,2006). Designing wearable technologies for older people poses a problem due to the varied declining physical and cognitive capabilities related to aging (Consolvo, Everitt, Smith, & Landay,2006). Nonetheless, exploration in wearable technologies has demonstrated the potential for enhancing older people's sensory experiences in ways that could provide emotional, cognitive, and physical support (Consolvo et al, 2006; McCann et al., 2005). According to wearable technology researcher Jane McCann (2005), innovations in design and technology should be led by the aspirations, desires, and everyday needs of the end-user. McCann's view is that that collaborative engagement with older users is essential. This approach centers on matching individual needs, desires and expectations with a set of non-restrictive, supportive and wearable lifestyle-enhancing services (McCann, 2005).

CO-DESIGN

In the co-creation generative approach, advocated by Sanders and Stappers (2008), the design researcher is at the table with the participants as a facilitator, playing a part in hands-on probing activities that engage people in telling their unique stories. As a result, it seemed appropriate to sensitize the design researcher-facilitators to their participants first through ethnographic fieldwork. This field activity provides a preliminary understanding, allowing the facilitators to prepare suitable materials to draw out their participants' innate knowledge through stories and design activities later in the project. According to Sleeswijk Visser (2009), the stories of people's experiences can inspire new design thinking because they are, ideally, developed with the designers/researchers present and bring up deep and rich understandings of the needs, emotions, and possible future opportunities. In this case, co-creation was strongly influenced by the exercisers' sensory experiences.

ANTHROPOLOGY OF THE SENSES

Anthropology of the senses is an approach within the field of anthropology. It studies the patterns of sensory experience to understand how an individual within a culture gains knowledge about their world through all of their bodily senses (Howes, 1991). Classen and Howes (1991) provide a framework of ten areas for probing into understanding the importance and position of the senses within a culture. Some of these include: the use of language relating to the senses; the role artifacts and aesthetics play in relation to the senses; the exceptions to the dominant sensory model within the community in cases such as sensory handicaps; and the inter-relation between the environment, built surroundings, and the senses.

Aspects of this framework, such as the use of language and the role of artifacts in relation to the senses, can be applied to the study of the sensory worlds of the elderly in our own society. What kind of language would mature exercisers use to describe or emphasize different sensory modalities in comparison to their own past practices or those of others? Does their relationship to aids that assist with sensory changes (sight, balance, hearing, taste, touch, smell) evolve over time?

In the literature there are several examples of approaches that can be adapted to the study of the sensory experiences of the elderly. For example, Paterson (2005), building on Husserl and Merleau-Ponty, proposes a "felt-phenomenology" as a valid approach to learning about the haptic senses in the moment, as they are being lived and prior to reflective interpretation of the experience. To Paterson bodily-felt sensations include the position and posture of the body in relation to the earth, or the pressure of one part of the body on another; both are valuable approaches to understanding the sensory interactions experienced by the elderly.

Macpherson's (2009) ethnographic study of the members of a partially visually impaired walking group revealed how important touch, especially touch through the feet, was while walking. Participants she interviewed talked about how wearing thin-soled shoes on city pavement enable them to feel the variations in texture on the ground as they go along.

While anthropology of the senses can contribute to understanding the sensory worlds of the elderly it can also contribute to understanding how to design for them. Macpherson (2009) notes that in the West, the design of shoes, while protecting the feet and conveying a social message, also contributes to a loss of feeling, providing a cage of sorts that distances sensory stimulation. While we can design things that extend the body's sensory capabilities, as discussed by Merleau-Ponty (1962), it is important to become aware of how technology affects the sensorium, causing it to reconfigure.

For example, when hiking on uneven terrain, Abram (1997) admires the remarkable capabilities of the sensory system to respond to constant changes in the environment, without his conscious involvement. In comparison, he criticizes how design limits his sensory interaction with products such as washing machines. These are so functionally optimized that they repeat the exact same sequence with each use.

According to Abram (1997), this removes the element of surprise that enables the senses to continue learning and evolving by responding to a variety of challenges. Design research may clarify when it is appropriate to challenge sensory capabilities and when to assist them.

These cases illustrate the idea that it may be possible to evaluate whether designed solutions are improvements or impediments to the sensory experiences of elderly people, and how new design solutions may fit into their evolving sensorium. The investigation described here begins to address some of these issues.

METHODS

After the appropriate ethics approvals were granted from the two sponsoring universities- Concordia University and Carleton University- the research progressed through four stages; contextual framework development, activities to sensitize participants to the context of the research, co-design sessions, and scenario development. There were twelve industrial design students, mostly in their early twenties and twelve mature participants, mostly in their early seventies.

CONTEXTUAL FRAMEWORK

In the initial step the student design facilitators developed a contextual framework for their research. They identified three key areas for consideration:

- Their own assumptions about older adults exercising in fitness classes that might set up biases,
- Categories to guide their observations of mature exercisers' sensory experiences in a fitness environment such as; the interaction between the environment and physical sensations, sensory relationships with objects, activities, activity sequences, etc. and,
- Potential sensor technologies appropriate for wearable technology probes for fitness based on the relevant sensory issues such as touch, kinesthetic, dexterity, hearing, seeing, etc. and the types of sensing required for each.

These aspects were condensed into a list of observation criteria posted on a shared blog. The list set up informal guidelines for observations and interviews.

SENSITIZING

The second stage focused on sensitizing all the participants: the student designers and the mature exercisers. At this point the student designers engaged in ethnographic field studies using the criteria they had developed to guide their observations of the participants' behaviors, sensory issues, and physical interactions. Following their analysis of the observations, they identified opportunities that would be compatible with sensory-enabling technologies (see table 1).

Opportunities	Applications	Input	Output	Components
Physical	flexibility	bend sensor	vibration/buzz	socks
self-monitoring	balance	pressure sensor	lights/LED	gloves
correction	cardiovascular	accelerometer	colour change	T-shirts
feedback	strength	Heart rate monitor	sound	Shoes
		proximity		buttons
Communication		heat sensor		velcro
instruction				ribbons
guidance				

Table 1. Opportunity Chart developed after initial observation analysis.

Building on the knowledge gained from the applied fieldwork, sensitizing kits (see figure 1) were developed. The kits drew from the work of Gaver, Dunne and Pacenti (1999), Mattlemaki (2006), and Sleeswijk Visser (2009). The kits included simple reflective exercises, including journaling and picture taking, to introduce participants to the theme of the research- the older participants' daily routines related to exercise. Prior to the generative design sessions they were given to the twelve older participants who had been recruited. The older participants then had a week to work with their individual kits and return the cameras for developing before the Co-design session.

Figure 1. The sensitizing kits included a diary with daily exercises, a camera with an assignment sheet, and a pedometer (as a gift).

CO-DESIGN SESSIONS

The third stage required several weeks of preparation, including gathering workshop materials, designing activities for the two-hour parallel sessions, scripting the sequence of co-design activities, rehearsing (twice), and building demo prototypes of potential sensor behaviors as illustrated in figure 2. The sensor behavior kit consisted of a variety of input and output sensors that could easily be attached to an arduino board and battery and reconfigured. The electronics were sheathed in fabric to minimize their technical look.

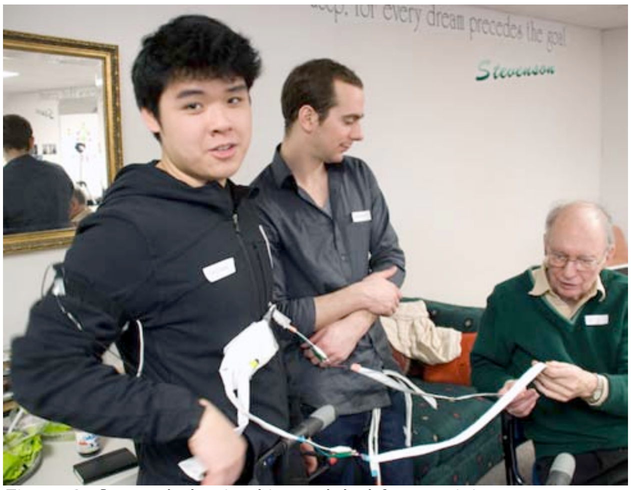

Figure 2. Sensor behavior kit modeled for participants. Photo by Jane Marusaik

Six weeks after the project began, the twelve student designer-facilitators and twelve older adults participated in three parallel two-hour co-design sessions at the seniors' Community Recreation Centre. The sessions consisted of scripted activities, beginning with introductions and consent form signatures, followed by a large group warm-up activity as an icebreaker and bridge from their homework. The activity focused on mapping (identifying) the body parts that need exercise, which was an activity that the participants had already done in their sensitizing dairy at home (see figure 3).

Figure 3. Body Mapping Activity. Photo by Jane Marusaik

Over lunch one student volunteer modeled the sensor prototypes showing how sensor inputs can provide simple sensory outputs (see figure 2). Participants then split into three groups- either balance, strength, or flexibility- for a wearable crafting activity. In the groups facilitators began by showing prepared samples of how to indicate sensor placement on various types of clothing. The participants talked and made rough prototypes of sensor-enabled exercise wear as in the example in figure 4. The activity ended with a final all-group debriefing. All of the parallel sessions were recorded on video.

Figure 4. Demonstrating pants with flex sensors to measure bend photo by Jane Marusaik

SCENARIOS

In the fourth stage of the research activity the student design participants analyzed the videos and applied many of the ideas generated in the co-design sessions. They developed concept scenarios for wearable sensor-enabled gear to augment mature exercise experiences. At the end of this stage they presented their scenarios to an audience of the older participants (see figures 5,6, & 7). The audience consisted of a majority of those who had taken part in the co-design sessions, the primary fitness instructor, and several other curious older people. In turn each student, or team, presented their scenario to the assembled group and asked for people's comments. Their feedback led to future research directions outside the scope of this paper.

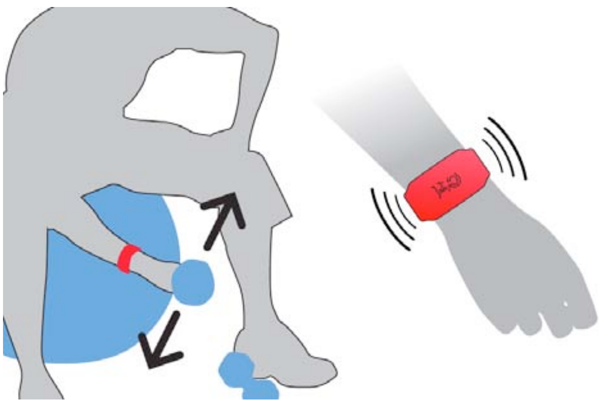

Figure 5. Wrist Band Scenario for monitoring & providing feedback about weight lifting speed, weight amount, & posture by Teddy Luong.

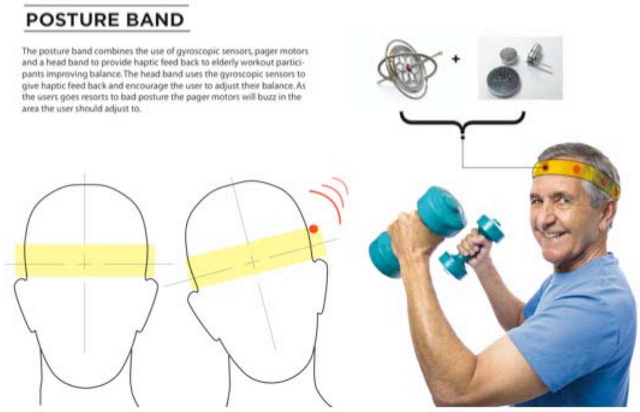

Figure 6. Posture band provides haptic feedback for adjusting balance by Mark Fromow.

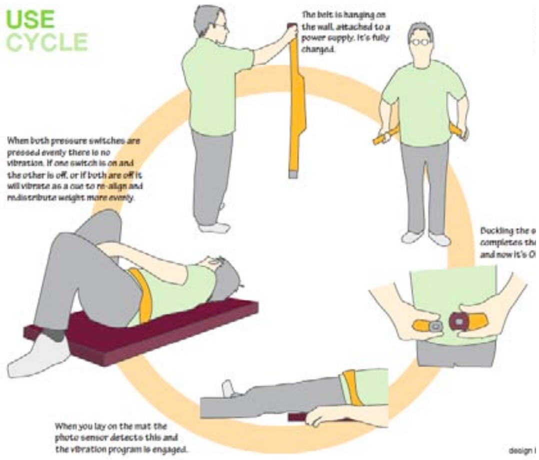

Figure 8. Feedback belt helps with body awareness and spinal alignment by Jane Marusaik.

FINDINGS

Triangulation of the data occurred through comparing information from ethnographic observations, co-design sessions, and informal interviews with the older participants. In addition, the co-design process was subject to observation, reporting (blog and paper), and informal interviews, which were also analyzed. The data can be grouped into two categories: findings related to older people's body experiences while exercising and findings about co-design as a process.

BODY

From this initial analysis we found that these seniors had a sense of their bodies, especially those parts, which needed fitness, care. They were, for the most part, willing to discuss their aches and pains, and the histories of their bodily changes, notably mostly "downhill", with some down and up again. The body parts most frequently mentioned were the spine, knees and joints, and legs and feet. Attention to posture and balance also came to the fore. In one co-design group, a particularly animated and articulate woman demonstrated how she and many fellow exercisers find their shoulders up around their ears while concentrating on certain exercises. She inspired her group to develop the "Shrug Buster" idea. According to Felix Lorisgnol, the facilitator in her group,

> *The "shrug buster" is a concept for a posture corrective system that notifies the exerciser if he or she is not relaxing their shoulders. One way of measuring this is simply an earring-like accessory that measures the proximity of the shoulders.*

Figure 8. Discussing the "shrugbuster" photo courtesy of Jane Marusaik & Tamara Phillips

The idea of an earring solution for exercising is in line with the attire of this group of people. They wear casual everyday clothes for exercise- not sports or exercise attire- and keep their jewelry, watches, bracelets, earrings, and glasses on throughout their class time. When asked, people frequently commented that they would dress for the day and they would wear the same clothing to class. This often included orthotic, or similar, footwear and in two cases, nylon stockings. However, two seniors, who were somewhat younger than seventy, wore name brand exercise clothing. One of these was the only person to wear a heart rate monitor to class. This relates to another notable finding; in two of the co-design groups people did not want to take a wearable technology home with them. According to student-facilitators Phillips and Lorsignol, they were interested in the design of detachable products that could be applied to existing equipment and used at the Centre.

The exercise classes were notably social. In the co-design session there were ten older women and two older men. This reflected the demographics of the exercise classes we had observed. Although in some, there were no men at all. That did not seem to isolate the problems by gender. For example, in two of the three co-design groups, including the one with the two men, feet were the focus of the wearable design activity. In the words of student-facilitator Caleb Hill,

> *Most of the participants were adamant about a pair of shoes which could help correct how you walk, as freedom of mobility is a critical issue in old age. We then established key areas of the foot that should have sensors, and decided that vibration outputs would be useful for indicating which part of the foot needs attention (i.e. walk with more weight on the right toe of your foot). It was also discussed that vibration devices would be useful for a foot massager, and to help increase circulation to the extremities.*

The findings from this session inspired two different footwear solutions at a later stage in the project.

CO-DESIGN SESSIONS

Getting ready for the sessions was labor intensive. The students frequently remarked that they wanted to be better prepared, especially in the ethnographic fieldwork phase. At least three students noted that, while they knew what they wanted to observe, they wished they had prepared a short description of what they were doing or formulated their observation criteria into casual questions to encourage discussion. All of the students reported excitement about the co-design session day. So did the two seniors who were interviewed afterwards. One noted, "I think the enthusiasm really swept everybody off their feet; those kids were so enthusiastic". The buzz at the Recreation Centre drew in additional participant-reviewers at the final presentation two weeks later, not just those who had participated in the sessions.

Ten of the mature participants in the co-design sessions had taken the time to work on the Sensitizing Activity Kit to prepare for the session. One participant had been invited along at the last moment, and the other had asked to attend just the day before and neither did any prior preparation. According to Ruby Ho, one of the student observers,

> *In our group of four participants, three of them completed the sensitizing kit and were quite involved in the discussions. However, one participant had been invited by a friend, last minute and did not get a chance to be exposed to the kit. She, in particular was not as involved. This is probably due to a lack of understanding of the design session. She also ended up leaving early.*

Prior to the co-design sessions, the student facilitators had struggled with the idea of introducing the sensor-technology to the older participants. They devised a plan to build a sort of lego-kit of different input and output sensors and show them to people before the collaborative design activity. At the first session rehearsal three mock participants were recruited from a nearby design studio. These pretend participants could not understand what the facilitators were trying to explain about the sensors. This led to a second iteration of the technology demos in which the sensors would be modeled on Thomas Lee, a student, as seen in figure 2. According to him, “It was a very good idea to go around to each participant with the demo sensors on because once they felt the flex sensor and the vibration output they immediately either sparked an idea or had a smile of excitement on their faces”.

In spite of being held to a tight timeline, these were very social activities, including a casual sandwich-making lunch in between activities. The casual lunch provided an opportunity for discussion, revealing other relevant issues. Ruby Ho notes that a valuable discussion took place,

> *During lunchtime when we got to casually converse with our co-design participants. Two of the women I talked to had a history with exercise. One was a dancer and one was just very active in the outdoors. They both noted that they had issues in balance. Which is why they were sitting at the at the balance table. They stated that they had to walk a lot slower because even on slightly uneven ground, they did not feel like they had the confidence to take a step forward.*

Lastly, the sessions were arranged so that there were four older participants and two students at each worktable. These quickly broke down in all three groups to smaller groups of two elders and one designer. According to one older participant,

> *I was rather intrigued by the young blond guy… He never stopped sketching the entire time… I was fascinated because it was happening so quickly. Whatever I was saying was immediately getting written [sketched] down. There was a lot of interchange going on which was beneficial on both sides.*

DISCUSSION

One issue that arises from this research is the importance of positioning co-design activities appropriately within a research project. Had the students not taken the initial time to familiarize themselves with the older participants, their activities, and their fitness environment, the sensitizing kits and the session activities would have been more challenging to prepare. The seniors were open to the idea of this research after having the students visiting classes for observation and informal interviews. According to one senior,

> *I think it was very good that they came to the classes first because without that they wouldn’t have realized the level of exercises that we do, just vastly different than the exercises their age group do, and different parts of the body that are brought out by the different exercises.*

More than twelve members of the exercise classes were also curious enough about the students’ research to volunteer for the mysterious “arts and crafts” workshop to design fitness clothing, although the timing did not work for some interested people. In this case the sensitizing phase was clearly as important for the design research facilitators as well as the mature participants. On the part of the student designers, the majority expressed their feelings that in their four-year program they had never come this close to the "users" before. Although one student expressed concern that this would only work for niche markets, presumably because it is so time intensive.

In truth, it may have been possible to design scenarios and working prototypes for older seniors wearable fitness gear without the interaction with the seniors. This is a situation that occurs with some frequency in the area of wearable computing, with experts making the design decisions (Walker, 2007; McCann et al, 2005). The involvement in this project taught the students that working with an older population, with much life experience and acute awareness of how their bodily capabilities have changed provides an exciting opportunity to learn firsthand about issues that may be important for design. The older exercisers were for the most part, articulate, curious, and open to collaborative activities. In addition, the opportunity for the participants to spend what resembled social time together seemed to contribute to the positive outcome of the co-design sessions. As noted by an older participant,

> *Hopefully they [the students] went away with the feeling that old people are not all old and doddering- in wheelchairs. It didn't appear that that had entered their minds.*

The older participants were eased into the very social process of making rough prototypes with the students through the preliminary body mapping activity, casual conversations, sandwiches and cookies, and a wearable crafting workshop assignment with a tight timeline (constrained by the arrival of the para-transpo bus). Student Teddy Luong observed that,

> *Things got interesting as the seniors began to build the prototypes. However this had to be heavily encouraged by the students. It seemed it wasn't something that the seniors were used to doing and needed to be eased into it.*

One of the older participants commented that initially it was not clear from the word "design" if they would be creating tops, pants, and shoes. She said that once she became "aware it was not the design fashion end of it, but the practical application of the electronical and the physical ways of fitting things into your clothes" that mattered, then things went "zip, zip all the way through".

ACCEPTANCE OF TECHNOLOGY

In support of the literature, we found seniors accept the idea of sensor technology embedded in exercise gear, with some concerns (Östlund, 2007; Park et al, 2007; Czaja, 2006). In spite of the fact that the senior participants were a diverse lot, the overriding messages in each session were the same- keep it simple and don't give us anything new to take care of. So much for the student designers' desire to propel the elders into bionic perfection! Student Lorsignol noted that,

> *The work that we did has enforced my perspective that technology should be appropriate. In many cases, the simplest solutions are the best, however, when it comes to sensor technology that will be integrated with something as organic as the body, there requires a tremendous amount of testing in later stages.*

As a result, two weeks after the co-design sessions, when the students returned to the center to present their simple scenarios the feedback from the mature participants was essential. One participant at that presentation commented that,

> *To pick up suggestions and see the end result, roughly, that was very exciting. Everything was a surprise. It was a surprise to me that they could possibly think through all our wooly ideas and come up with something as simple and practical, something that would obviously work.*

At the final session, in particular, the most often repeated question was, "when will we find these things on the market"? Many seemed to be disappointed to know that the project was coming to an end at the concept stage. Student facilitator Phillips commented,

> *They were very interested in the solutions and could even see that there were many applications for the concept products, not just for the elderly. The hard part was the fact that they would like to see these products developed beyond the concept stage. Did they really know or understand this from the beginning that the outcome would be just ideas and concepts that perhaps many of these ideas would never materialize? It did make me wonder how to approach this in the future.*

That points to the significance of publishing. According to another student, Yasaman Sheri,

> *Through documentation in the format of published papers and blogs, the ideas can circulate around design students, professors, practitioners and thinkers. This opens doors for more designers and companies to adopt concepts such as co-design with elderly and wearable computing.*

ADDRESSING SENSORY ISSUES

The concepts that were developed primarily addressed posture, balance, and core strength, with some attention to cognitive challenges. Six of the concepts used flex or stretch sensors as input opportunities to sense misalignment, as in the concern expressed about shoulders up around the ears as in the example in figure 9. In most cases, the designers included more than one type of feedback- haptic (vibration) feedback and sound (buzzing) were the most popular.

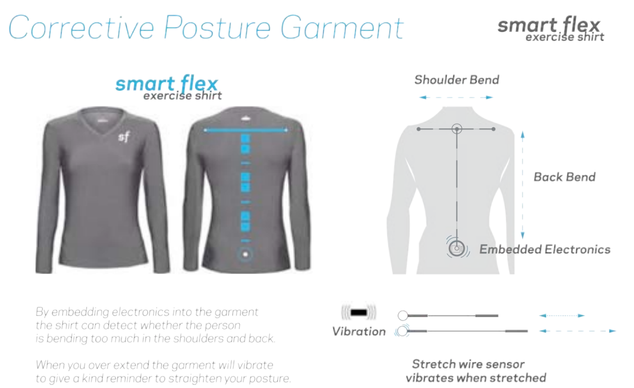

Figure 9. This garment uses stretch and flex sensors to monitor posture and provides haptic feedback to help with alignment by Min Dao.

Three students developed two different design concepts incorporating sensors into shoe insoles. One of the concepts was for massaging the feet while exercising (see figure 10) and the other was for vibrating in specific locations when sensing unequal weight distribution. These students had been facilitating and documenting the balance co-design group that worked on solutions for feet and shoes in their session.

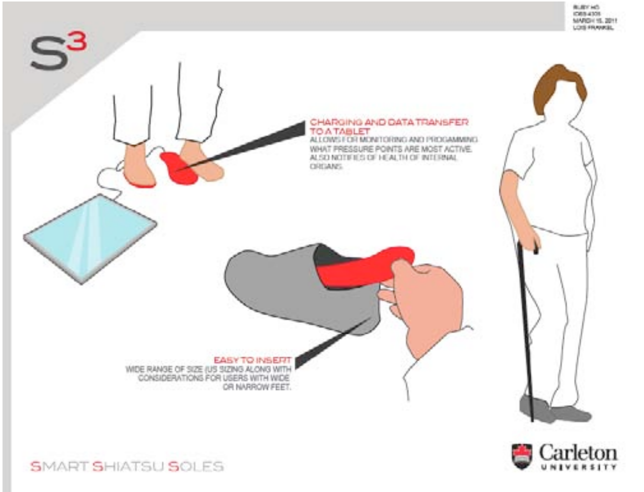

Figure 10. Shiatsu soles for massaging pressure points and shock absorption by Ruby Ho.

Half of the students seemed to concentrate on taking the design concepts initiated by their particular co-design group forward. The technology demonstrators, who were not working as closely with the senior participants in the collaboration sessions, designed more sophisticated and complex shirts with flex, and stretch input sensors and lights and vibration for output as in figure 11.

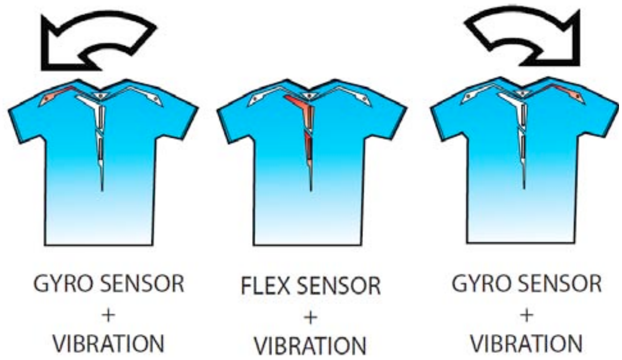

Figure 11. This shirt for monitoring posture and providing feedback was more complex than other solutions by Jordan Palmer.

Nine out of the twelve students designed sensor-enabled gear that could be put on when exercising and in six of those cases, left at the recreation center for others to use, as requested by the older exercisers. Of those two of them addressed cognitive issues- in one case sensors would keep the count on first left and then right sides when lifting weights. This was presented as an opportunity to keep track of count, should the exerciser be interrupted by a friendly social visit and want to return to the fitness activity (see figures 12 & 13).

Figure 12 & 13. Intelligent exercise grip by Felix Lorsignol.

Overall, in this project visual feedback took a back seat to haptic and auditory feedback. One student cleverly used gyroscopic sensors in a headband to determine posture alignment, with haptic feedback to assist the wearer to lean more to one side than another (see figure 6). However, it is difficult to assess how much the students' knowledge of sensor technologies affected their design choices. To offset their wide range of experience with technology they were given a choice to build a working circuit or to make a video, along with their final scenario presentation. Five students made videos and seven students made working circuits.

LIMITATIONS

The limitations to this research included a semester-related scheduling constraint that required the cancellation of second set of parallel co-design sessions planned to take place after the initial student-designer scenarios were developed. This may have been a more productive way to get feedback instead of the presentation format. Another issue, although addressed thoughtfully by the student designer researchers, was how to introduce technology to the older exercisers so that they grasped the capabilities of the simple electronics. An alternative to modeling the potential underlying input/output structure as in figure 2 might be to employ simple sensor-enabled prototypes, or what may be called "technology probes", during fitness classes by way of sensitizing the participants earlier on. Lastly, so as not to overwhelm the mature exercisers, pairs of student observers attended a wide range of classes for their ethnographic observations, which may have diluted the interaction between the two sets of participants. A focus on observing only one or two specific classes may have allowed for greater interpersonal interaction between the student facilitators and the older exercisers. This may have set up a more comfortable understanding of the issues and expectations prior to the co-design sessions.

CONCLUSIONS

This paper has described the initial stages of a co-design research project about designing sensor-enabled exercise wear for aging. The lessons learned from this project fall into two categories:

SENSORY AND OTHER ISSUES IMPORTANT FOR THIS GROUP OF SENIORS

This group of older exercisers were most interested in focusing on assistive wearable solutions for balance and posture. They were particularly interested in solutions that addressed the position and use of the spine, knees, joints, legs, and feet. Shoe inserts that provide feedback to correct balance were of great interest. The older participants were open to the idea of sensor-enabled exercise wear, but preferred to design things to be used at the recreation center, not at home. They were excited by the idea of simple sensory inputs and outputs that would help them in their fitness classes. The overriding message was to keep the concepts simple to use and to understand.

CO-DESIGN ACTIVITIES FOR ELICITING SENSORY KNOWLEDGE FROM OLDER ADULTS

It was found that four phases provided a strong foundation for stimulating design idea generation in the front end of product development. These phases include, in order: developing a **contextual framework** for the design researchers, **sensitizing** design research facilitators as well as potential co-design participants through ethnographic fieldwork, preparing for and facilitating **co-design sessions**, and developing **scenarios** of use based on the triangulated analysis of the data gathered in the previous three phases.

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