Socially-smart computing to support older adults with severe visual impairments: Proof-of-concept

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T.Smith-Jackson, K.Carroll, S-J Kim, M.Suh, Y.S.Ryu. Socially-smart computing to support older adults with severe visual impairments: Proof-of-concept. Gerontechnology 2010; 9(4):472-483 doi:10.4017/gt.2010.09.04.006.00 This research describes the functionality of a Near and Far Environmental Awareness System (NaFEAS) intended to be worn as a computer-based vest undergarment to support social interaction for older adults with severe visual impairments. The system is designed to facilitate wayfinding (orientation, navigation) and object recognition. The design framework was derived from embodied cognition. **Methods** Five consultants with Severe Visual Impairments (SVIs) formed a participatory design team who worked on the first iteration of the NaFEAS prototype. We used information from the team to develop a questionnaire to elicit scenario-based information from older adults with SVIs. Data were also collected using an online questionnaire that provided a description and broad scenarios indicating how NaFEAS could operate in a party setting and the garment and material design of the NaFEAS vest. Fifty adults ages 55 and over responded. Analysis methods included χ^2 analysis of frequency data and content analysis of qualitative data. **Results** revealed important requirements for the NaFEAS system. Navigation through party environments, especially those containing stairs and balconies, was a critical need. Although relatively homogeneous in responses, χ^2 tests revealed that women considered NaFEAS to be more beneficial for introducing others and playing games compared to men. Older adults who attended social events more frequently wanted the system to support remembering names, compared to those who attended parties less frequently. The most important garment features were functionality, overall appearance, and usability. **Discussion and conclusion** User requirements centered on being able to locate key people, having to rely less on others, and having a wearable computer garment that is attractive and easy-to-use. Further implications involved the importance of designing the NaFEAS as a tool to be used with other mobility aids such as walkers and hearing aids.

Keywords: wayfinding, social computing, assistive clothing, visual impairments

The World Health Organization (WHO)[1] estimates the number of individuals with visual impairment at 314 million, of whom 45 million are blind. Adults ages 50 and over are disproportionately represented. While making up only 19% of the world population, 82% of those with visual impairments are 50 and over[1]. Congdon et al.[2] used 2000 Census data and WHO statistics to estimate the number of individuals in the USA with visual impairment indicating 937,000 Americans over 40 with blindness and 2.4 million with low vision. Using projected data, they estimated that, by the year 2020, the number of individuals with blindness in the U.S. will increase by 70%.

Given the increasing prevalence of visual impairment over the lifespan, there is a continuing need for user-centered technologies that facilitate social interaction in leisure contexts. However, designing products that are usable and intuitive to older adults remains a significant challenge. Some inconsistencies of applying user-centered approaches are apparent in the usability of products for technologically marginalized users such as older users with disabilities. Users with severe visual impairments (SVIs) of all ages experience frustration when interacting with certain assistive technologies[3-10]. Here, we are defining severe visual impairment using the definition given by the WHO, which includes a central visual acuity of 0,05 or less that cannot be overcome with corrective lenses[1]. Fleming[11] identified several weaknesses in user-centered design for older adults (and consequent problems with usability and safety) that stem from the exclusion and lack of participation in design. These include the release of products or systems that are difficult to use, hazardous, and ineffective. At a minimum, usability problems can cause minor frustration or discomfort, but they can ultimately impact quality of life.

Quality of Life (QoL)

Foundational studies have identified several QoL activities preferred by older adults. These include access to health information, opportunities for leisure and social engagement, independent living, and control over personal decision-making[12-14]. Factors such as social support and a sense of mastery or perceived control over one's life and environment are also related to QoL, and specifically, social engagement[15,16]. Jang et al.[17] demonstrated that most older adults with disabilities reported receiving some type of assistance usually provided by relatives, but a negative correlation was found between the social support they received and their sense of mastery. Thus, independence more than social support seems to be important to older adults with disabilities.

The relationship between QoL activities such as social interaction and life satisfaction cannot be understated. Opportunities for social networking have been associated with positive health outcomes that, in turn, sustain older adults' continued involvement in leisure activities[18,19]. Engaging in volunteer activities also seems to enhance QoL for older adults. Besides the obvious benefits to the communities and organizations they serve, older adult volunteers benefit from the social interaction that is essential to most volunteer activities[20]. However, difficulties with independent mobility can undermine opportunities for social interaction.

Mobility

Mobility, especially in unfamiliar places, is a major challenge to individuals with SVIs. Mobility is supported by wayfinding, which is, in turn, facilitated by object recognition and performed by orientation and navigation tasks. Mobility aids are used to support wayfinding by supporting spatial orientation and navigation to a destination point. Wayfinding mobility aids can include canes, guide dogs, and walkers, but only one third of adults with blindness actually use them[21]. A number of efforts in the past ten years have focused on developing smart canes that are installed with GPS, optical electronics, and speech output functionality to provide information about location and destination points. However, recent studies have also indicated that these technologies are considered cumbersome, expensive, complex, and a source of unwanted attention when used in public[22,23]. The challenge to designers is to reframe the design space so that mobility aids are integrated with the body and the senses, such that they are less likely to be perceived as incompatible with use and context. One possible approach to support a coupling or integration with the body and the senses is to apply a design framework based on embodied cognition.

Embodiment as design strategy

The level of human system coupling is the degree to which the human is linked to or integrated with the system during system use. It is at its lowest level when the human is operating the system from a distant separate space, for example. Humans are indirectly or loosely coupled with the system through traditional displays and controls, but are not in direct contact with the system. Humans rely heavily on vision to interface with loosely-coupled systems. Several performance problems exist because of loose or indirect coupling, including reduced situation awareness by the operator[24], which may lead to human error. In contrast, haptically-controlled, robotic, and tele-operated systems with direct manipulation controls are designed on the basis of tight coupling. It is also important to note how increasing age negatively influences perceptual processing speed and body sense. Thus, device or technology coupling when designing for older adults becomes increasingly important to support overall embodiment of technology and the ongoing age-related adaptations associated with embodiment.

Consequently, our design and evaluation model uses embodied cognition as the framework, which suggests that "cognition depends on perception-action loops that bind organism and environment together in a continuous, reciprocal interaction" [25 p 124]. This system and perceptual motor coupling facilitates user interaction with objects and the environment. Design on the basis of embodiment couples the human with the system and argues that the environment cannot be independent of the knower[26,27]. Hardy and Baird[28,29] and others suggested that computer-based systems may be difficult to use by older adults, because there is a decoupling of the hardware and software interfaces, thus undermining the ability of the user to embody, collaborate with, or anthropomorphize the system.

Embodied wayfinding

The Near and Far Environmental Awareness System (NaFEAS) has a mission function to facilitate users' social interactions by supporting wayfinding tasks and object recognition. The system serves as a proof-of-concept that, based upon needs analysis and expert feedback, has been iterated to a low-fidelity prototype. The NaFEAS is predicated on the assumption that a wearable system that matches perceptual-motor capabilities of the user with feedback from the environment provides a coupled, cooperative, and intuitive interface. As an embodied system, the NaFEAS will facilitate three social actions that are necessary for successful interaction within a leisure environment – social interaction, navigation, and recognition (*Table 1*). Our design scenario focused on social interactions that would occur within a party setting or other informal social gatherings. Using Gardner's theory of multiple intelligences[30], the NaFEAS can support social interaction by providing stimuli that can enhance the user's interpersonal processing capabilities while utilizing somatosensory capabilities.

Concept and prototype design

The NaFEAS integrates sensors, a database, and multi-modal user interfaces into a garment providing a user with awareness of environmental landmarks[31] that consist of primary and secondary environmental cues[32]. The NaFEAS consists of five components: (i) A garment establishing the NaFEAS as a wearable interactive platform; (ii)) A database embedded in an article of clothing to save wayfinding data; (iii) The

Table 1. Social activities and the NaFEAS design features

Social Activities	Interpersonal Processing	Design Feature
Social interaction	Bodily-kinesthetic	Haptic and auditory signals to orient users to static and dynamic stimuli, to facilitate encoding of objects or people who are approaching or positioned in or near the human envelope (1.22m); Example: Judging distance and maintaining personal space during face-to-face conversations
Navigation	Bodily-kinesthetic, spatial	Haptic and auditory signals that establish a point of origin marker and a destination marker while providing route feedback during movement; Example: Moving from the refreshment table to a cluster of people in the room
Recognition of people and objects	Spatial, auditory	Sensory feedback using radio frequency, wireless and Bluetooth support to allow users to store environmental information in a knowledge base for later use, i.e., the signal pattern of a person they met 30 minutes ago. Example: Storing information about physical features of a person to recognize him/her later if s/he approaches again at the same party

Environmental User Interface (EUI)[33] enabling the wayfinding data saved in the database to interact with environmental contexts; (iv) Sensors that are self-activated transducers which transmit environmental contexts to the database by way of the EUI; (v) A multi-modal user interface to give the user feedback in the form of auditory signals (verbal or non-verbal) and vibration signals via a tactile device. The purpose of the garment is to integrate all components into a wearable system to facilitate the user's interactions with their environment by utilizing sensorimotor capabilities of the hands, ears, and torso.

The NaFEAS can identify RFID tagged objects, information from sensors, and condi-

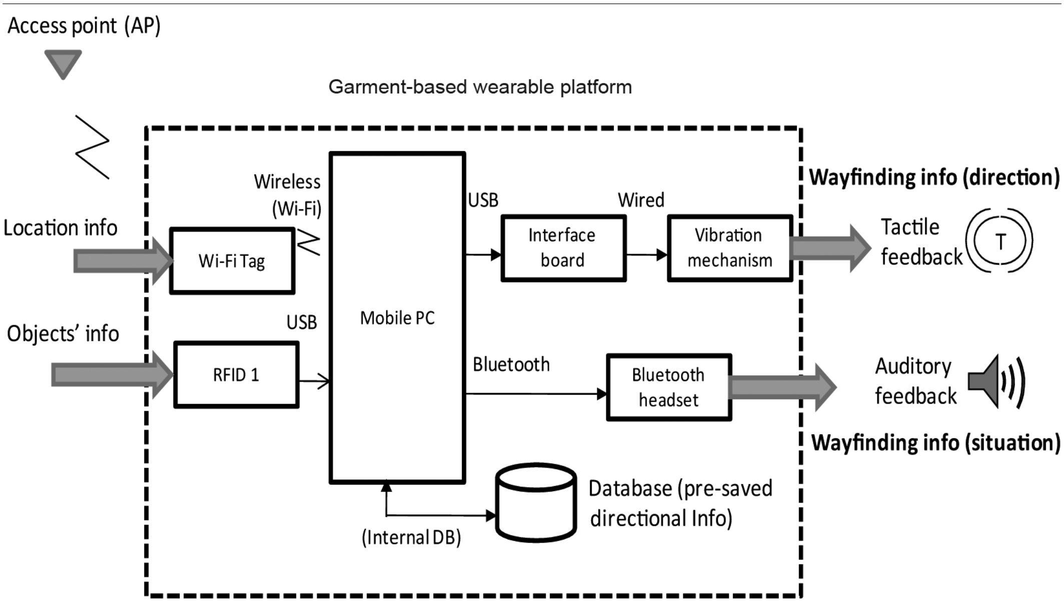

Figure 1. The overall system block diagram of the NaFEAS

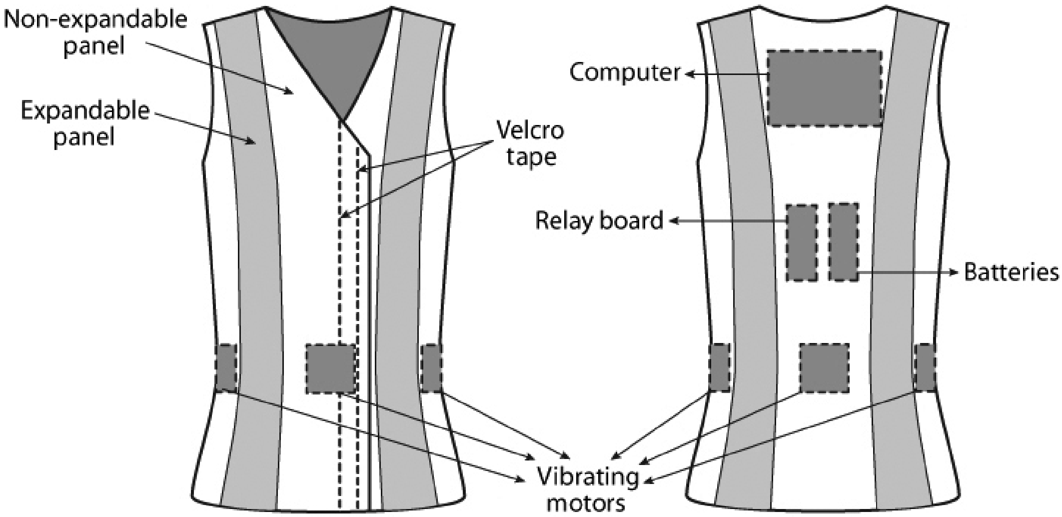

Figure 2. Expandable vest

tions in the near space, which is defined as 1.22 m (4 feet) around the human envelope or external space that can be reached by his or her arms and legs. The system can also identify the current location of the user and provide near-space auditory and haptic feedback through user interfaces embedded in clothing worn by the user (*Figure 1*).

The NaFEAS EUI module consists of a Wi-Fi positioning engine and an RFID system that jointly collects all relevant real-time environmental contexts within the category of the near and far environment (for instance, object information, number of people and their names, today's weather and schedules). Once the EUI collects all environmental contexts, the main computer compares the collected information to pre-saved wayfinding information in an internal database and provides the feedback in the form of wayfinding cues to the user for his or her activities through a multi-modal user interface. The types of user feedback are determined according to the type of information that needs to be conveyed. Directional information can be delivered to the user by a mechanism consisting of four vibration motors placed inside the garment and in contact with the torso. Situational information can be delivered to the user via an auditory interface delivered in a Bluetooth headset.

The garment is used as a wearable platform that delivers the feedback for direction and supports the wearers' embodiment of the technology. The NaFEAS prototype is designed to demonstrate the concept of wearable technology. One garment (a vest) was produced in a base size 40 (40″ [101.6cm] chest - 34″ [86.4cm] waist - 40″ [101.6cm] hip) for a male and in a size 10 (36″ [91.4cm] bust – 28″ [71.1cm] waist – 38.5″ [97.8cm] hip) for a female. The American Society for Testing and Materials (ASTM) standard measurement was used (ASTM D-5585; ASTM D-6240)[34,35] (*Table 2*).

The expandable panels were constructed to enlarge the vest size up to size 48 for male and size 20 for female. The garment is designed so that various assistive technologies can be attached to the non-stretchable panels to maintain the shape of the vest against

Table 2. Fabric specifications

Characteristic	Non-expandable panel	Expandable panel
Fiber Content	97% Cotton 3% Spandex	94% Cotton 6% Spandex
Fabric Structure	Ripstop Woven	2x2 Rib Knit
Stretch ability	~ 20%	~ 200%

the weight of devices (*Figure 2*). In addition, two sets of Velcro tape stitched vertically down the front of the vest allow expansion when the vest is closed and facilitate easy opening and closing.

As a proof-of-concept effort, NaFEAS has evolved into a low fidelity prototype. However, more work on gather and analyze requirements is needed to improve the current design for use within a leisure or party setting. The initial design upgrade from concept to prototype relied on participatory design that included five consultants with severe visual impairments, four of whom were ages 50 and over. The purpose of this research was to acquire additional user requirements for the NaFEAS system for use in parties or other social gatherings.

Method

Research design

The basic design features and functions of the NaFEAS were identified and applied to concept and prototype design by our participatory design team. Once the prototype was developed, additional requirements and needs were elicited. We used two methods to elicit user requirements: (i) a design session with consultants with SVIs and (ii) an online questionnaire of older adults with SVIs. The online questionnaire was based on information acquired from the participatory design sessions. We present the results of the online questionnaire in this paper. The questionnaire data included responses to open- and closed-ended questions (*Figure 3*).

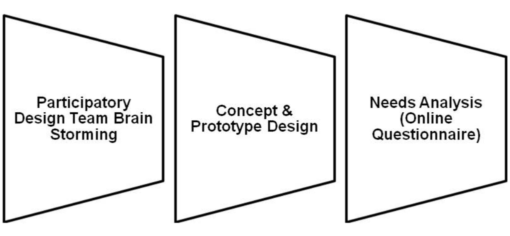

Figure 3. Research flow model

Online questionnaire

The online questionnaire was developed on the basis of feedback from the participatory design team. Questionnaire respondents (participants) were recruited using listservs and advertisements. The questionnaire consisted of forced choice, checklist, and open-ended questions and elicited information in the following categories:

Personal information – Snellen measure of visual acuity (if known), self-reported level of impairment (mild, moderate, severe), cause of vision loss, age, gender, geography, country.

Social Activities –Frequency of attending social events, types of social events attended (checklist format).

Party Scenario - We described the current system capability and then asked participants to select activities with which they felt the NaFEAS would be of benefit using a checklist format.

Wearable Computing Garment Design - Requirements regarding design of the clothing. Respondents were asked to consider five aspects of clothing and to comment on importance in clothing development. These five aspects were: Functionality (type of assistance given); Appearance (aesthetic appeal); Usability (donning, doffing and wearing); Comfort (thermal comfort control and tactile quality); and Psychological effect (appropriateness for situations).

Procedure

This research was reviewed and approved by the Virginia Tech Internal Review Board for Human Subjects Research. The online questionnaire was administered using survey.vt.edu and was anonymous. Consent was implied when participants submitted their answers. Instructions and an estimated time for completion (15 minutes) were given at the beginning of the questionnaire. Once completed, participants were thanked for their participation.

Results

A total of 50 participants ages 55 and over responded. The majority of the participants

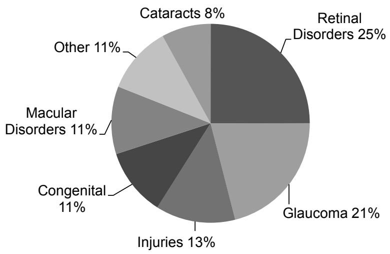

Figure 4. Causes of visual impairments among respondents

self-reported the level of visual impairment as severe (88%); 8% reported the level of impairment as moderate, and 4% as low. The mean age was 63.8 (SD=8.7, n=47), and ranged from 55 to 85 years of age. Ninety percent (90%) of the participants lived in the United States. The gender distribution in the sample was 63% women and 31% men; 6% did not respond. Most of the respondents reported living in a suburban area (50%), followed by an urban area (35%), and a rural area (14%); 1 person did not provide geographic information. The causes of SVIs reported by participants varied, and included both age-related and congenital causes (*Figure 4*).

The questionnaire elicited the types of social events routinely attended by participants (*Figure 5*). The most frequent social events were gatherings with family and friends and civic gatherings. The category 'other' included social events associated with learning environments, volunteering, travel, and health and sports clubs.

42% reported attending social gatherings at least five or more times per month, 28% two to fourtimes per month; 14% once per

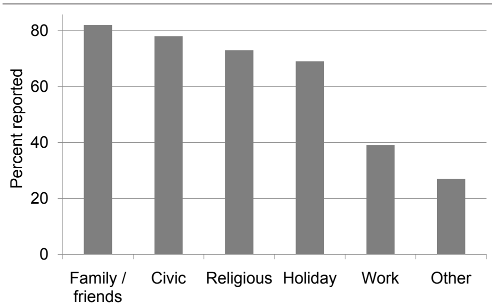

Figure 5. Types of social events attended by respondents

month and 10% less than once per month; 6% did not respond. Participants reported the functionality needs using an item that referred to the usefulness of the NaFEAS in helping to socialize at a party. Participants were asked to select each social action that could be supported by the NaFEAS (*Figure 6*).

We conducted a χ^2 test of association to determine whether there were differences between age categories and user needs related to support during social interaction. To balance the groups, we used a median split (61 years) to divide the sample into 'young old' and 'old old' categories. No significant associations were found (α=0.05; two-tailed).

Additional tests were conducted to explore the heterogeneity of users in terms of their needs and preferences. A 2x4 χ^2 test was conducted to determine whether frequency of social interaction was associated with types of support for social interaction. No significant differences were identified, although one social interaction need approached significance. Proportionately more of the participants who reported the highest amounts of social interaction (five or more times per month) selected a need for

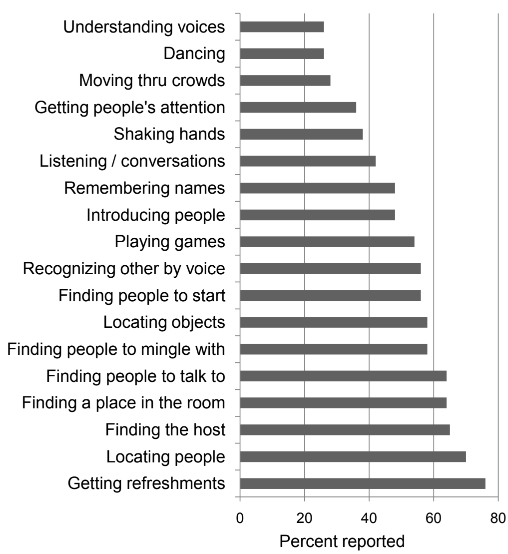

Figure 6. Social activities that respondents thought could be enhanced by the NaFEAS support

the system to support their efforts to remember names, ($\chi^2(3)=7.02$, $p=0.07$).
Several gender differences were identified using a 2x2 χ^2 test of association. Proportionately more women wished to have the system support their ability to find the host or hostess at a party, ($\chi^2(1)=4.07$, $p<0.05$). Proportionately more women also reported using the system to play or join games, ($\chi^2(1)=11.97$, $p<0.01$). Another association was found between men and women and the use of the system to assist with introducing people. Proportionately more women selected this social interaction as one that would benefit from the NaFEAS support, ($\chi^2(1)=4.85$, $p<0.05$).

In addition to the needs reported, the majority of users (82%, n=41) said they would use a vest that vibrated their sides and back to provide information about their environment.

In considering the wearability aspects of the vest, at least 50% of respondents considered all five aspects to be equally important considerations in the design of an assistive garment. 72% of respondents considered comfort and appearance to be 'important', 'very important' or 'most important'. In response to assessing the functionality of garments, respondents gave a variety of suggestions, ranging from general affirmation to very specific requests; 58% regarded functionality as 'slightly important' or 'mostly important'. Two respondents were interested in having the garment function in conjunction with existing assistive technology (hearing aids and canes). Specific responses included a need for pockets for a mobile phone and other articles, especially if a walker is used. Some respondents specified activities with which they would like the garment to give assistance, such as being able to mingle at social events and find people who they know. Two respondents raised the issue of security at airports and hospitals, and were concerned whether the device would impede progress through such security measures.

Responses about comfort tended to focus on the fabric and fabric attributes, rather than the design of the garment. The last aspect was the psychological effect of the potential garment, and participants discussed the psychological aspect of having an assistive garment that is visible to others. Even though they do not want to stand out in a crowd, having a garment they know is going to work would be more important than worrying how it would appear to others; "If it could be made to appear discretely fit with other clothes, I would feel more confident in wearing it, but functionality is still key".

Discussion and conclusion

Our sample provided a profile of social activities and preferences among older adults with SVIs. The majority of our respondents (70%) reported attending social gatherings at least two times per month and some up to five or more times per month. The majority of respondents reported attending holiday, religious, and civic gatherings as well as with family and friends as their major events for social interaction.

The variability in the types of SVIs that were reported by the questionnaire respondents is useful in our efforts to design an inclusive system that enhances accessibility for the widest range of users. However, there were surprisingly few differences based on demographic groupings such as age or gender, although a few interesting gender differences were found. Women, for example, were more likely to need a system that would assist with finding a host or hostess, introducing people, and joining in party games. These types of interpersonal skills are critical factors in impression management and indicate active engagement in the social environment[47].

The most predominant needs reported by all respondents were locating people, finding the host/hostess, and getting refreshments. Only a few participants were interested in using the system to tag and recognize voices, dance, get the attention of other people, or position the body to shake hands. It is possible that users prefer to maintain full control of these functions rather than rely on an assistive device. This finding might indicate a user requirement that supports giving the user a choice to disable or enable specific functions in the NaFEAS. Although functionality such as gyroscopic inputs for dancing may not be important to many users, the functionality could still be made available. The NaFEAS could assist in helping a user maintain a specific spatial envelope to ensure they exercise safely within group exercise classes such as aerobics.

The responses related to the garment provided important user requirements. The respondents viewed the garment as something more than a platform for the technology, which goes beyond the scope of this study. When garments move from the realm of function and basic needs and become ‘stylish’ and/or ‘fashionable’, they take on a new complexity of increasing self-actualization for the wearer.

As stated, the goal of this research was to elicit user requirements for the NaFEAS. We used the results of this research to extract preliminary requirements (*Table 3*).

Limitations and future work

This study relied on a convenience sample of participants, but the sample was variable to the extent of being an acceptable representation of the population of older adults with SVIs to support preliminary work. Respondents either had access to the Internet or had access to someone who could read the questionnaire to them and input their answers. Since online administration was used, this sample may be somewhat biased toward those with higher incomes, or those who use computers.

One observation in our data was the limited reference to the need for mobility aids along with the NaFEAS or concerns about interference with mobility aids (only two respondents). Although we did not elicit further information about mobility aids, most users may have perceived the NaFEAS as an alternative to their existing mobility aids or as an additional component of a more complex mobility system. The use of NaFEAS as the sole mobility aid is the functional mission of this technology, although it has not yet achieved this functionality. This finding supports a rationale to pursue a comparative usability study between the NaFEAS and traditional mobility aids to answer the question

Table 3. User requirements table

Element	Space	Function
Haptic & auditory interface	Social space	Navigate doorways, stairs, balconies
		Locate key people, host / hostess
		Locate key objects, tables, chairs, refreshments
	Social interaction	Have less reliance on others for assistance
		Recognize the gender of other party attendees
		Participate in party games
		Support memory for names
Garment form & function	Appearance	Fashionable
		Attractive
		Discrete / inconspicuous
		In context with activity
	Comfort	Assist in heat control for wearer
		Fabric should be lightweight and soft to the touch
	Usability	Easy to put on and take off
		Easy to use/learn how to use
		Low in complexity

of which technology most facilitates the accessibility of social events.

The NaFEAS prototype design will be further iterated based on the results of this study and our continuing work with the participatory design team. Also, empirical studies that focus on performance data using the NaFEAS need to be conducted. We are preparing to implement a usability test that involves the collection of performance data such as time to destination, deviation from trajectory, and accuracy of object detection and recognition. These variables will provide more information on the effectiveness of the NaFEAS and will support improvements in the prototype. There are additional criteria that must be met, such as affordability, customizability, and compatibility within a larger social context and public arena.

Social interaction within a party environment will likely require accessible 'smart spaces'. In other words, the system will require that objects be tagged with RFIDs for example, and coupled with Bluetooth devices. We also envision people being tagged with discrete RFIDs, and perhaps supported by a smart garment industry that is focused on integrating older adults and those with disabilities by developing smart garments that can be worn by younger people and those with no visual disabilities. Essentially, the NaFEAS will be most helpful if smart accessibility systems are developed to support it. Just as accessibility aids such as curb-cuts or talking cross-walk signals have been internalized as beneficial to society, the same transformation will be required as assistive devices become more necessary in an ever-expanding older demographic. As with any research and development efforts that are compatible with gerontechnology practice[36], the challenge remains to synchronize design with emerging technologies that will coexist and possibly complement what is being developed. But, most importantly, the implications for such designs as NaFEAS reflect the importance of the social model of disability[37], which would support more inclusive design in social environments as a means to minimize the stigma and criticality of aging by fully integrating older adults with disabilities into the social mainstream.

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