# Implications of Participatory Design for a Wearable Near and Far Environment Awareness System (NaFEAS) for Users with Severe Visual Impairments

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**Abstract.** This paper presents experiences from a study that included five users with Severe Visual Impairments (SVIs), fashion designers, and human factors engineers. We used participatory design (PD) to develop a wayfinding and object-recognition system. The PD study consisted of three sessions and was designed to include actual users in the design process. The primary goal of the PD was to validate the system concept and to determine the attributes of system interaction. Two of the three sessions are discussed here. We obtained several insights from a technological perspective, textile and apparel perspective, and user interface design perspective. Among the results identified, users with SVIs preferred to wear assistive technology unless that was not distracting to the participant or those that came into contact with the participant. Auditory feedback was chosen as a primary modality in user interface design, and we realized that constructing a good pool of PD members is essential to transform actual users' needs and requirements into the design process.

**Keywords:** participatory design, usability, inclusive design, user interface, assistive technology, wearable technology, severe visual impairment.

## 1 Introduction

Individuals with Severe Visual Impairments (SVIs) are legally blind and have a visual acuity of 20/200 in each eye or worse that cannot be overcome with corrective lenses. Although individuals with SVIs maintain or develop very effective compensatory sensory-perceptual capabilities, they may still be challenged by tasks that require object recognition and wayfinding. Some SVIs can navigate independently in familiar places such as home since they have an internal map of the layout based upon a spatial mental model developed from past experience. However, independent wayfinding may be challenge unfamiliar places. To overcome these challenges, there are assistive technologies to support independent wayfinding tasks based on GPS (Global Positioning System), Wi-Fi (Wireless Fidelity), RFID (Radio Frequency Identification) or

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infrared technology [1, 2]. However, people with SVIs often experience frustration when they use assistive technologies, including some that are designed to be assistive [3]. The problems and frustrations associated with the use of advanced assistive technologies impose an urgency to develop a more inclusive interaction paradigm derived from human ecologies and contexts of use. This approach is known as situated design [4]. Coincidentally, the definition of usability given by ISO 9241-11 emphasizes the need to design with an understanding of the context of use, which includes users' experiences in ecologies of information (stimuli) reflecting cultural, social, and physical experiences.

This paper presents several lessons learned from two participatory designs (PD) [5, 6] sessions involving five consultants with SVIs who served as members of our participatory design team (PD members). The goal of this effort is to determine whether a garment-based wearable environment awareness system called Near and Far Environment Awareness System (NaFEAS) [7] is effective, efficient, and acceptable to users with SVIs. Here, we defined the near environment as being between 18 inches and 4 feet (48 inches) from the user. The far environment was considered to be the space that was greater than 4 feet from the user. This paper also discusses how we planned each participatory design meeting and the activities that we used to engage the team.

The presentation of this paper has four sections. In the Background section, we describe background related to PD. The Participatory Design for NaFEAS section describes our PD for a wearable environment awareness system. In this section, we describe the construction of the PD team, the objective of the 1st and 2nd PD, and procedures of each PD. The results of the 1st and 2nd PD are described at the end of each subsection. The Discussion section is devoted to describe facts (that) made our PD success, and the Conclusion and Future Works section makes a conclusion with future works.

## 2 Background

The participatory design (PD) [5] is a collection of user-centered design methods geared to ascertain user needs and validate concepts by bringing actual users to a design process and to discuss the assessment, design, and development of technological or organizational systems. It is used in many disciplines as a means of creating environments that are more responsive and appropriate to their inhabitants and to users' cultural, emotional, spiritual and practical needs. PD can be used information architecture, where tacit knowledge is elicited to capture user's needs [8]. For example, professionals in the field of architecture and urban design enhance the quality of design work with citizen involvement [9]. In software development, PD plays an important role in building up the method of scenario-based usability engineering. To solve design problems, PD uses the collective knowledge of stakeholders rather than the individual creativity of designers.

The primary reason for using PD in many disciplines is that reflecting actual users' opinion is crucial in designing systems or products. Therefore, PD is more focused on the design process rather than a design output. PD is also an extension of user-centered design. User-centered design does not automatically imply the involvement of users on the design team. PD is a type of user-centered design that is based on the

philosophy of empowering representative users to be intimately involved in the design effort. Beck [10] stated that isolated technology developments are no longer probable in well-defined communities of work since we use technology anytime and anywhere even when on the move. This gives us an important fact that the new design paradigm to develop new technology should be a partnership consisting of actual users along with researchers and developers. Another reason that we should consider PD is that the underlying hardware of our systems is advancing at a dramatic rate paralleled by our ever-shifting environment. However, the capabilities of the human user remain the same. Therefore, bringing the actual users into the design process and considering their characteristics are essential to assess the concept and functionality for them to integrate the emerging technologies.

PD was used in the assistive technology area of designing a wheelchair convoy system. [11]. Wu et al [12] conducted PD with people with anterograde amnesia who had difficulty storing new memories. Using PD, they analyzed their cognitive deficit unrelated to memory and designed a tool called a Personal Digital Assistants (PDA). Similar to this research, PD was used in a study about adapting and combining traditional design methods to design assistive technology especially for people with cognitive disabilities and their family caregivers [13]. To support individuals with aphasia, a handheld hybrid desktop system was developed using PD [14]. In this research, PD was employed to include speech-language pathologists into the design process as proxies to target population. PD has been utilized to explore the accessibility of the World Wide Web for individuals with SVIs especially those with novice computer users [15]. The motivation of this PD method was to ascertain alternative modes of feedback mechanisms through auditory and tactile interactions, page as a screen reader, reading the content on a screen aloud for SVIs is required to undergo extensive training. Recently, distributed PD [16] has emerged because of ubiquitous infrastructures that make our interactions seamless. We use computing technology along with wireless networks to send and receive information anywhere or anytime. Distributed PD is a design approach and philosophy that supports the direct participation of actual users and other possible stakeholders in design work and its analysis. The reason is that the possible stakeholders would like to create environments that are more responsive and appropriate while the majority of design teams are distributed to join the PD. As a result, distributed PD also aims to facilitate understanding between people from different backgrounds by giving them an opportunity to engage their background in the design process.

## 3 Participatory Design for NaFEAS

Near and Far Environment Awareness System (NaFEAS) is a garment-based wayfinding system consisting of wireless devices embedded in a garment. It is used to support people with SVIs in wayfinding and navigation with a goal of ensuring that these tasks can occur independently while receiving appropriate near and far environmental information. The primary reason that we use a PD method in designing NaFEAS is to bring users with SVIs into the design process and as proxies for target populations. SVI participation is necessary to integrate the needs and capabilities of actual users, and thus finally to remove any bias caused by developers or researchers.

The main objective of our PD is to ascertain primary design factors, features and guidelines of NaFEAS and to analyze the fundamental interaction process of people with SVIs in wayfinding tasks.

Table 1 shows our PD consisting of three sessions, and the results reported here came from the first two PDs. Five participants called consultants with SVIs participated in this study to serve as members of our participatory design team (PD members). A total of 10 research members consisting of Human Factors, Textile and Apparel and Human Computer Interaction participated in this study. Each PD session was limited to one and half hours and focused on understanding and finding fundamental interaction factors of people with SVIs in wayfinding tasks. Each session was recorded using audio and video devices and transcribed for further analysis. As seen in table 1, the first PD session was designed to discuss the overall concept of wearable NaFEAS and to validate its concept. The rest of the two PD sessions were designed to discuss user feedback modalities and to give experience to the consultants with SVIs about the low fidelity of NaFEAS components and discuss their insights.

**Table 1.** The outline of the three design meetings

| | 1st PD | 2nd PD | 3rd PD |
|---|---|---|---|
| Purpose | NaFEAS concept Evaluation | Interaction analysis (near environment awareness) | Interaction analysis (far environment awareness and user feedback modality) |
| Team Composition | 5 consultants with SVIs. 10 research members | 5 consultants with SVIs along with 10 research members | 5 consultants with SVIs with 10 research members |
| Study Type | Discussion | Experience and discussion | Experience and discussion |
| Task | Open-ended question | Finding objects' name and purpose | Finding/ understanding tactile feedback for direction |
| Duration | 1.5 hours | 1.5 hours | 1.5 hours |
| Data Collection | Audio/video | Audio/video | Audio/video |
| Status | Conducted | Conducted | Scheduled |

### 3.1 PD Member Recruitment and Team Composition

The PD team consisted of two groups: consultants and research group. The consultants group consisted of five individuals with SVIs and they joined our study from the Roanoke Alliance for the Visually Enabled (RAVE) supporting SVIs in the Roanoke Valley, Virginia. The research group consisted of 10 members that were divided into three teams according to their unique goals and interests. The three teams' configurations were Human Factors (4 people) with focus on analyzing SVIs' interaction process, Human Computer Interaction (4 people) with focus on designing user interfaces, and Textile and Apparel (2 people) with focus on designing functional garments. The reason for including the three teams as a research group was to analyze the mental

model and interaction process of people with SVIs in terms of cognitive science, user interfaces and wearable platforms and thus provided them with an unbiased wearable assistive technology. Another reason that we constructed the three teams within the research group was to reflect different insights coming from each unique discipline to the design process of NaFEAS. Table 2 below shows the final PD team composition.

**Table 2.** PD team composition

| Group | Team | Members | Role |
|---|---|---|---|
| Consultants with SVIs | Consultants with SVIs | 5 | Analyze the concept and features of NaFEAS |
| Research group | Human Factors | 4 | Analyze cognitive factors |
| | Human Computer Interaction | 4 | Analyze user interactions and feedback modalities |
| | Textile and Apparel | 2 | Analyze wearable design options |
| Total | | 15 | |

### 3.2 The 1st PD

• Objective: the primary goal of the first PD was to discuss the overall concept of NaFEAS and validate it. Three objectives were established listed below.

1. Inviting individuals with SVIs as consultants into NaFEAS design meetings as long as possible in the design process of the overall system.
2. Interacting directly with the consultants with SVIs to discuss and validate the concept of NaFEAS.
3. Engaging the consultants with SVIs to control design decision.

• Procedure: Once we obtained the informed consent form on the site of RAVE, we introduced the purpose of the first study and read an anecdotal scenario of NaFEAS. A part of the anecdotal scenario is listed below.

> *…… Now imagine a system that can detect and give you feedback on where you are going, what is around and in front of you by using something on your body and/or a mobile device you can carry in your pocket or your hands. This is the goal of Portable Awareness Clothing (PAC), which is the name we are giving to a system that will help individuals with severe visual impairments to walk around spaces independently and be able to get information about obstacles such as buildings, people, trees, etc. …… This system will also learn, so that everything you encounter or tell it to mark or store will be stored in a database. The next time you encounter that object, the system will recognize it.*

After the scenario, we asked the consultants with SVIs several open-ended questions to evaluate the scenario and to ascertain how they imagine the system. Some of the questions that we asked were: How would you imagine this system to operate? If this system needs to go with you wherever you go on your body, what's the best way to make this happen? How do you expect this system should look?

• Lessons: We obtained a few design implications. First, the consultants with SVIs did not want the system to replace their canes. Second, the consultants with SVIs primarily wanted a wearable system unless it is noticeable and would be a distraction to her or himself or to others. This implied that they were concerned with their appearance and to be seen as ordinary people while wearing NaFEAS. One PD member suggested an attachable device such as a wrist band or fanny pack, and this implied that they do not want any additional devices that dominated their body. This means that the consultants with SVIs wanted to have the freedom to remove assistive technology from their body when it was not in use. Third, the function to turn the entire system on and off was desired to secure users from being disturbed unnecessarily by technology. Fourth, most research team members were surprised that finding a trash can in a room was the most difficult task that the consultants with SVIS confronted in their daily living. From a technological perspective, they wanted precise near environment information such as where items in a room are. They remembered unique landmarks in a room to find specific items in their homes and to navigate independently.

### 3.3 The 2nd PD

• Objective: The second PD was aimed at demonstrating a low fidelity NaFEAS near environment awareness component to the consultants with SVIs and then discussing their experience. It was to validate and determine the attributes of interactions of NaFEAS. Below are two objectives established in the second PD.

1. Giving a technological experience to the consultants with SVIs
2. Discussing their experience and analyzing the attributes of interactions of NaFEAS

To demonstrate the near environment awareness of NaFEAS, four objects: a bottle of cold medicine (syrup), an allergy relief medicine (tablet), a blue shirt (checkered) and a pink shirt (unicolor) were selected and they were tagged by RFID tags. The four objects and the RFID tags are shown in Fig. 1.

**Fig. 1.** Four objects used in the 2nd PD. An allergy relief (tablet) and a bottle of cold medicine (syrup) (left), a blue shirt (checker) and a pink shirt (unicolor) (middle), RFID tag samples embedded in the four objects (right).

• Procedure: We introduced the objective of the second PD that was a technological experience for the consultants with SVIs. The technological experience consisted of two experience sessions described in table 3. As shown in the table, all the consultants

with SVIs have attempted to recognize the four objects twice: without NaFEAS and with NaFEAS. This gives them a technological experience at the onset and then an opportunity to discuss the experience of the NaFEAS technology. The rationale for this approach is that we prepared two similar box type medicines and two articles of clothing in order to add difficulty to the tests. We also would like to better understand how the consultants with SVIs recognize medicine and clothing that are very important to their health and their appearance.

**Table 3.** NaFEAS technological experience

| | Four Objects | | | |
|---|---|---|---|---|
| | Cold Medicine | Allergy Relief | Blue Shirt | Pink Shirt |
| Without NaFEAS | Experience Session 1 (the all consultants with SVIs) | | | |
| With NaFEAS | Experience Session 2 (the all consultants with SVIs) | | | |

In the first experience session, each PD member was asked to recognize the four objects by themselves without any technological help as shown in Fig. 2 (left) and then the team discussed their experience. After the first session, the second experience session followed with the same procedure except that a RFID based object awareness system was used as shown in Fig. 2 (middle). A RFID reader was attached to the lower arm close to the wrist as shown in Fig. 2 (right). In the second session of experience, the consultants with SVIs were assisted by the technology as they were trying to recognize the four objects. The consultants with SVIs received a headset in order to receive only audio information from the objects. As in the first experience session, discussion followed the experience.

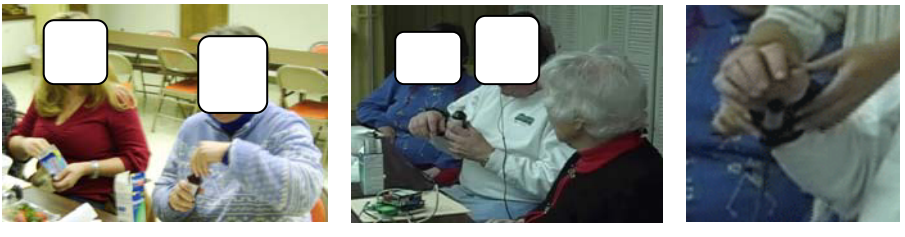

**Fig. 2.** Snapshots of NaFEAS technological component experience. Object recognition without NaFEAS (left), Object recognition with NaFEAS (middle), A RFID reader mounted close to the wrist (right).

• Lessons: The second PD was also successful as it gave the team many insights from a technological and a garment design perspective. The first lesson was when the consultants with SVIs use NaFEAS how to organize information. For instance, which information is most beneficial and how to convey the information effectively? Actually, the consultants with SVIs most like to know about the dosage of the two medicines. They were also interested in knowing the color of the clothing. They

commented that expiration date and cooking instructions are also important for them. We realized that NaFEAS should provide them with appropriate information depending on the specific item. Another lesson that we obtained was how to physically attach the component of NaFEAS technology to users with SVIs. An arm band was not sufficient to attach a RFID reader on a lower arm and this led us to speculation about a pocket that can be closed after inserting the RFID reader. Velcro or a magnetic button was preferred for stability and ease of use. Since we are in preliminary stages of testing the feasibility of NaFEAS, further investigation will follow as to the feasibility of embedding the receiver into the woven structure of a garment.

## 4 Discussion

A PD approach with the consultants with SVIs allowed us to refine the efficient design of NaFEAS, even though the 3rd PD has yet to be completed. The PD has shown itself to be a viable solution to the research members in the design process of NaFEAS. In this section, we discuss a few things that made our PD successful.

First, one should consider a design boundary in a PD. We wanted to cover not only issues regarding the concept or features of NaFEAS, but also how the technological components benefit users with SVIs or how the system will be utilized in the real world. We wanted the consultants with SVIs to have the ability to decide what should or could be done and what trade-offs need to be made.

Second, PD team composition is a key to draw the needs and requirements of actual users. From the two PDs, we conclude that a group composition is very important to lead successful PD. Including actual users who can act as proxies to the target population are crucial for team success. Other members are also important to analyze the results of PD. Since we are dealing with a wearable assistive technology for SVIs, we have included experts in Textile and Apparel, Human Factors, and Human Computer Interactions. As a result, we realized that constructing a PD team that is relevant to the study and proxies to interact directly with users are crucial in PD.

Third, how to engage actual users into a PD is also an important factor. If the actual users are not fully engaged in the PD, there will be no insights that will be gained for future design processes. In our study, we configured our PD from discussing the concept of NaFEAS to experiencing the low fidelity of NaFEAS technological component in order to engage them to NaFEAS. We discussed the concept of NaFEAS in the first PD and assessed the efficacy of the NaFEAS technological component in the second PD. In fact, the technological experience session in the second PD helped the consultants with SVIs understand the concept of NaFEAS better as they realized how the system worked and how to properly use it.

Finally, questions or discussion topics are foundations of PD as improvements can be made based on them. We have met a few times so that each team can and validate questionnaires, and also to lead and finish each PD within the limited time. We recommend in order to obtaining polished research questions, we should administer iterative design meetings, among the configured teams.

## 5 Conclusion and Future Work

This paper reflects on two sessions of conducting intensive PD with five individuals with Severe Visual Impairments (SVIs) for Near and Far Awareness Environment System (NaFEAS), which is a wearable assistive technology in wayfinding tasks. We discussed the activities and ways to engage the actual users and how we used a combination of sources to influence the needs analysis phase. We also reflect on several lessons obtained from the first and second PD. It is to make NaFEAS the result of collaboration of a designer's detailed understanding of the needs of users with SVIs and his or her in-depth understanding and thereby lends itself to contextual design. All studies will be used to develop a prototype of NaFEAS which will be reviewed and iteratively designed before being evaluated by about 24 evaluation participants with SVIs in a formative evaluation.

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