Design of vibrotactile navigation displays for elderly with memory disorders

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**Abstract.** Social inclusion; the right and possibility for every person to be *a* member of a group, community, or society as a whole proves to be a significant factor for self-esteem and quality of life. Mobility is one of the major prerequisites for social inclusion and in this paper - which discusses the development of an early prototype as part of a larger project - we address the problem when mobility and hence social inclusion is limited due to a condition known as Mild Cognitive Impairment (MCI). The objective of this study is to enable social interaction by providing assistive navigation that facilitates independence through mobility for the elderly and addresses the following objectives: 1) Landmark to landmark navigation as an alternative to the more standard turn by turn navigation method and 2) Design of vibrotactile signal design for intuitive navigation support. The overall result of the study is that it is feasible to use vibrotactile displays with a sensitive range as support for navigation for the elderly and that landmark to landmark navigation shows viable potential as an alternative to tap on shoulder navigation.

Introduction and Objectives

Recent studies suggest tactile navigation displays outperform other visual displays and are effective in outdoor terrain (Elliot et al, 2010). In addition, tactile navigation systems act as responsive tactile compasses guiding the way without requiring turn-by-turn instructions or high cognitive load from the users (Pielot et al, 2010). In this paper we report on a study that addresses the most common problems for people with Mild Cognitive Impairment (MCI) that is the ability to navigate and recognize places.

The general scientific objective is to develop human-machine interaction that is grounded in an understanding of human navigation, visual and tactile perception. The challenge is to structure and utilise these capabilities into an assistive system that requires minimum cognitive load. In turn these structures may pave the way towards a solution for operational navigation support.

The specific scientific objective is to develop an operational system for navigation support of people with Mild Cognitive Impairment. By selecting this application area and addressing concrete sets of application scenarios, the paper will focus on mobile technology that facilitates social inclusion. The interaction design will address the challenge of concealed seamless and personalized navigation support.

The motivation for the above objectives lies in the understanding that mobile assistive technologies can support people with MCI to continue to act successfully and resourcefully within society leading inspired functioning lives. The paper will address one of the most significant challenges of our welfare society, namely, the increasing elderly demographic.

Seamless mobile navigation will reinforce social inclusion of people with MCI and will lower their anxiety levels when travelling as they have at hand a means to support them in cases such as where they lose their way or forget where they were going (Alapetite et al., 2009). The main results of this paper are an investigation into a new method to navigation support by Landmark to Landmark navigation and Design of vibrotactile signal patterns suitable for use by elderly citizens.

Landmark to Landmark navigation

A landmark-to-landmark based approach is proposed as an alternative to the more standardly implemented turn-by-turn systems and this approach is then made into an early prototype, which is in turn evaluated in an initial small comparative field study. We found that the landmark-to-landmark based approach aided the user in getting to the destination, but that there were differences in how the different approaches affect the users’ experience. Explicit and high frequency information (common to turn-by-turn methods) makes the user feel constricted and bossed around, while more general and low frequency information (found in a landmark-to-landmark approach) gives the user a sense of agency and freedom of movement. However, explicit high frequency makes the user feel safer and secure comparative to general low frequency information. However to date, these were early tests with a limited study that was initially tested on two young adults (23 and 25 years old) on the route shown in figure 1.

Three comparative conditions were tested:

* Turn-by-Turn (Figure 1, blue route);
* Landmark-to-Landmark with high frequency of landmarks

(Figure 1, green route);

* Landmark-to-Landmark with low frequency of landmarks

(Figure 1, red route).



Figure 1. The routes used for the primarily evaluation in the city Gistrup in Denmark. The different colors mark the different display schemes, with blue being the route for testing turn-by-turn, green the landmark-to-landmark with high frequency of landmarks and red being landmark-to-landmark with low frequency of landmarks. The crosses mark the waypoints that will be illustrated for the test participants.

For these field trials a tactile navigation belt was developed with vibrators’ placed as in figure 2. The test subjects were given a navigation task with three routes one using the tap on shoulder method and the other using land to landmark with two frequencies of landmarks. The two approaches were evaluated using a think aloud approach during the test course combined with an interview after the whole test.



Figure 2. The distribution of the vibrotactile actuators on the prototype seen from above. Five actuators are distributed evenly with 30 degrees difference on the front, two actuators covers right and left and a single actuator covers the back.

The field study demonstrated that the implemented belt was capable of guiding the test subjects to the planned destination. The participants noted that they felt safest using the turn-by-turn approach, as this method explicitly told them were to go. The landmark-to-landmark approaches in comparison created a possibility of going down a dead end road or otherwise get lost. Both test persons noted that the difference in security probably could diminish over time, as long as one had a general sense of direction. Test person 2 also noted that general knowledge of the area would also help diminish the sense of insecurity. Regarding personal preference test person 2 preferred the turn-by-turn approach, as she felt she wouldn’t get lost using this. Test person 1, however, noted that she appreciated the freedom afforded by the landmark-to-landmark approach, as she was free to choose the path, which she preferred, and not being told exactly where to go. She also noted that she wasn’t forced to pay as much attention to the belt as she had a general idea of where to go, when she used the low frequency landmark-to-landmark approach.

The self-reported evaluation indicates that the different approaches possess different qualities. There seems to be a tradeoff between security and freedom, which is interesting and needs deeper investigation with a larger more diverse test group (including comparative groups of elderly and younger people) and for longer periods of time in both areas that are relatively new, new and/or familiar. Adding a prolonged time factor could mean that participants would become familiar with the system and for example, end up trusting either system once familiarity was established, or a preference depending on usual modes of navigation may be determined.

Designing vibrotactile signals

To improve on previous approaches to signal designs, we propose to think of them in the same way we think of sounds, as the experience of both vibrations and sounds are expanded over time. Loud and sudden sounds are for example not pleasant, and we expect the same to be true for amplitudes, so instead gradient changes in amplitude is expected to be more pleasant. Another concept from sounds is to encode information in a vibratory signal by modulating it over time, which allows the creation of easily perceivable signals with extra information encoded. Other methods of encoding information such as modulating the entire amplitude, modulating pause between signals or modulating the length of the signal all affect how the signal is perceived. The reason that we believe it is necessary to encode extra information because informing the user, of for example the distance to the destination, can help the user feel more secure to examine this claim and using this as a guideline, we developed vibrotactile signals that were created and applied in a laboratory setting and then qualitatively evaluated. The evaluation method showed promising results, and revealed several unanticipated results, such as a training effect, the subjects not perceiving details of complex signals, signals with fast amplitude changes are perceived as more powerful than signals with gradient changes in amplitude and as expected it was found that signals with gradient changes in amplitude were preferred by the test subjects. The evaluation method can also be easily adapted to a quantitative method, making this an easy fit further on in the development of vibrotactile signals with larger studies. The evaluation suggested that the signal developed with the guideline in mind was the preferred one, but more importantly the evaluation inspired further development of the proposed signal. The resulting proposals from these first studies need more examination before committing to large scale testing.

Summary

The project will assist in appreciating a rich and meaningful life for all and enable people with MCI (and the elderly generally) the possibility to continue to act as a resource in society. Mobility and in particular independent mobility is in this respect one of the most important prerequisite for actively participation in the society. To set a price on the value of such social inclusion is extremely difficult. For the individual, the project will facilitate the possibility to take a more active part in society lowering the risk for isolation, which easily can lead to the development of depression which increases the probability for sickness and need for care.

To break this spiral as early as possibility is important for the “compression of morbidity”, that is, the time from when you begin to need care until the time you die. Though some public costs are still associated with giving light care in the persons own home, for relatives and the surrounding society having self-maintaining independent people with MCI is a resource that benefits both social and economic factors (Bowes & McColgan, 2006, Vigsø, 2011). The two presented tactile methods for navigation support will help to ensure that mobility is not a limiting factor for participation in the society provided technologies that are easy to adapt and that can be designed to be concealed, used with little cognitive load and as unnoticed as possible.

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Bios:

**Lars Knudsen:**

Lars Knudsen is completing his master’s thesis at Aalborg University working with Wearable tactile displays and navigation. Lars' research interests include the use of interaction design, programming and electronics to expand human abilities and to inform and actuate environments.

**Ann Morrison:**

Ann Morrison is trained in Visual Arts, Humanities, Digital Media Design Science and Interaction Design. Ann’s main research contributions lie in tangible and urban computing for mobile and cultural environments focusing on play and activating participation. Ann has collaborated as a researcher-designer on a wide range of projects including locative, mundane technologies, social & mobile, urban surface display systems, mobile augmented reality applications designing pervasive games for field tests, a re-configurable iRoom, national ICT crisis response systems and educational environments. Prior to working as a researcher in Interaction Design, Ann worked as an interactive installation artist with a 20-year exhibition history, and for eight years in the multimedia industry working with design, visual arts and education.

**Hans Jørgen Andersen:**

Associated Professor Hans Jørgen Andersen research interest lies within media technology with focus on use of computer vision for support of human-computer and human-robot interaction. He is involved in development of computer vision methods supporting physical and mobile devices. These activities are supported by his experience with development of adaptive computer vision methods for use in indoor and outdoor unconstrained environments.