NavMem Explorer: An Orientation Aid for People with Mild Cognitive Impairments

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ABSTRACT

People with cognitive impairments frequently loose orientation when navigating outdoors. Existing navigation solutions provide an overwhelming amount of information and are unable to address the users' needs and desires. In this paper, we present our current status on the development of NavMem Explorer, an orientation aid for people with mild cognitive impairments (MCI). We summarize findings from initial user studies, illustrate the design rationales, give insights into our implementation, and outline planned studies. The key design concepts of our prototype are the decomposition of complex navigation tasks into less complex navigation tasks, the personalization of content, and the use of photographs whenever possible. Thereby, we rely on and strengthen users' existing knowledge and mental capabilities. We argue that the overall design allows users with MCI to accomplish navigation tasks without loosing orientation. Thus, people will be encouraged and supported to go out alone and actively participate in social life.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Prototyping

General Terms

Design, Human Factors

Keywords

Navigation, orientation, interaction design, interaction concept, mild cognitive impairments, elderly, dementia, stroke

1. INTRODUCTION

Age related memory decline, mild cognitive impairments (MCI), and cognitive impairments that occur with diseases, such as stroke, brain injuries, or early stages of dementia, have negative effects on the ability to navigate and to orient. Affected people repeatedly experience disorientations, become scared of venturing out alone and, consequently, do not participate in social life any more. Existing navigation solutions don't allow people with MCI to maintain or recover orientation, because they provide an overwhelming amount of information and don't give targeted, clear navigation instructions.

In this paper, we design and develop an intuitive, mobile orientation aid for people with MCI. Key conceptual aspects are the decomposition of complex navigation tasks into several less complex tasks, and the use of familiar landmarks and related visual elements, such as photographs, whenever possible. We argue that this enables people with MCI to deal with navigation tasks, which are otherwise perceived as too challenging and complex. Further, the thorough personalization will allow users to rely on and strengthen their existing knowledge and mental capabilities.

We present findings from our initial user studies, where we summarize the most essential requirements for an orientation aid for people with MCI. Further, we illustrate how we iteratively proceeded to address these requirements in our design concept. Complex navigation tasks are separated in less complex tasks, guiding the user through familiar environments along well-known landmarks. Photographs reduce cognitive load and simplify orientation. We provide insights into the current implementation state and conclude the paper with plans for two planned longitudinal field trials.

2. RELATED WORK

Pedestrian navigation on a general level was investigated from various perspectives. May et al. did a requirements study to understand which information requirements pedestrians have [6]. They found that most pedestrians heavily rely on landmarks as the most important and frequently used navigation cue. Landmarks were used to support navigation decisions, but also as a mean for re-assurance, as passing an expected landmark increases a participant's confidence and trust into made decisions. It has been shown that photographs of landmarks can be used to orient oneself and navigate a route [1, 2, 8].

However, it remains questionable if and how these findings can be applied for people with cognitive impairments. Thus, there is ongoing research on how people with cognitive impairments deal with navigation tasks. Liu et al. studied various modalities, i.e., audio, images, text, and different guidance strategies for indoor navigation through a Wizard-of-Oz approach [5]. They found that all modalities can be understood by the users with cognitive impairments, but the individuals' preferences varied significantly. Consequently, they conclude that future applications should adapt to the user's individual needs as best as possible.

A reason why there are only few insights about people with cognitive impairments is that many traditional user involvement tech-

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niques fail or have limitations. It is known that people with cognitive impairments do not want to admit, are not aware of, or can not communicate their problems. Further, fixed study protocols are hard to follow, because people might have short attention spans, mood swings or depressions [7]. Lepistö and Ovaska argued that traditional observation and evaluation techniques, such as think aloud, don't work well with this user group. They concluded that several complementary evaluation methods should be applied and that individual methods should ideally be adapted to meet the specific characteristics of the user group [3]. Mayer and Zach reported that fictional characters, heavy use of pictures, and playful experiences can be valuable modifications of observation techniques [7]. Lindsay et al. supported many of these findings and presented a participatory design method tailored for people with dementia [4].

It is questionable *if* and *how* landmark-based navigation—as presented in related work—is a valuable concept for people with MCI. In this paper, we approach this question and report on initial insights from our first user studies, give insights into the design rationales of our prototype application, and outline future research objectives.

3. USER REQUIREMENTS STUDY

The project started with a thorough requirements gathering. Besides literature review we recruited a total sum of 45 stakeholders. The group consisted of 21 potential end-users from our target group, i.e., elderly, people with (mild) dementia, people who had a stroke, and 28 experts, i.e., caregivers or therapists with different backgrounds. The participants were mostly recruited through end-user organisations within the consortium, such as the Swedish STROKE-Riksförbundet (engl. Swedish Stroke Association), or through end-user organisations which are affiliated to a consortium partner. We conducted a series of six user studies, including surveys, focus groups, interviews and field trials. The goal was to understand the users' everyday problems and to identify limitations of existing solutions. Further, we collected information about how participants imagine a perfect product for the intended purpose.

The observations indicate that basic usability aspects are particular important for our target audience: a solution should be simple, reliable, safe and easy to use. It should follow a clear navigation structure, infer required information automatically, and avoid lengthy or moving texts in unusually small font sizes or with low contrast. Instead, texts should be precise, contrasty and clear. Icons and images should only be used to accompany text if relevant and helpful.

Regarding the navigation and orientation, we identified that users desire a device which provides orientation information on demand or in case the user is lost, whereby the latter should be automatically identified by the device. It is important that the system supports an existing active lifestyle and works well with various, daily outdoor activities of the target audience, e.g., going for a walk or visiting a relative. In addition, users requested a lifeline functionality, which allows the user to contact a relative, caregiver or service centre if needed. This would allow to get personalized assistance and instructions from a trusted and reliable source. Users with dementia would appreciate if additional information, such as the user's location, can also be shared with relatives. This would allow a callee to get targeted recommendations and support straight away.

We further identified requirements regarding the physical appearance and ergonomics of the device: it should be robust, reliable, small, light, and should come with a bright, clear, and large screen and without buttons on the side or back of the device. It should be compatible with existing devices, such as hearing aids or wheelchairs, and allow a one handed use.

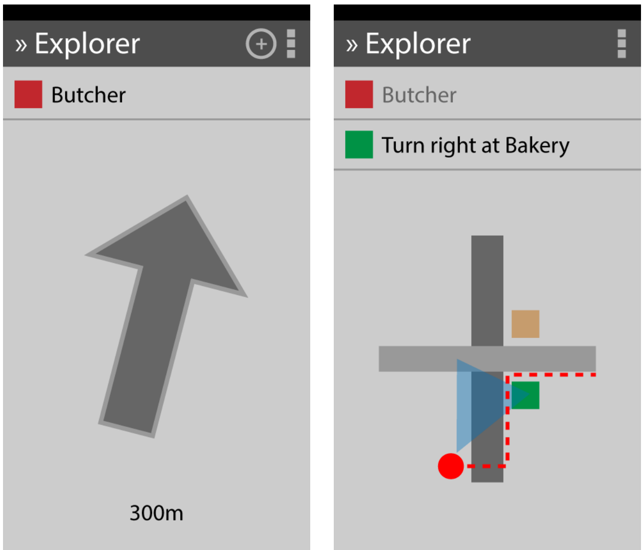

Figure 1: The first of a total of six design iterations focused on the most essential aspects. For example, the left sketch shows that the *butcher* is located slightly to the right in 300 m. The right sketch illustrates how the navigation instruction "turn right at bakery" could be visualized on an abstract map.

4. DESIGN: NAVMEM EXPLORER

These requirements served as a starting point for our iterative design process, where we followed many suggestions given by Lindsay et al. [4]. We focused on interactive user interface elements and mostly omitted hardware requirements, as we plan to consider these during the final product development. Based on the study insights we created initial sketches on how a potential user interface could look like. We started with rough, quickly created sketches, each showing an essential functionality, e.g., a screen with orientation information (see Figure 1). The relations and transitions between the individual functions were illustrated through lines, which were labelled with the action the user would do. These sketches were repeatedly discussed and elaborated in consortium-wide phone conferences and physical meetings. Further, we regularly confronted users of our target group with our sketches and gathered feedback for the next iteration. We ended at our sixth iteration, because only details were still subject to discussion.

In summary, our design consists of three key aspects, which we describe in the following paragraphs.

1. Separate a complex navigation task into several less complex navigation tasks.
2. Rely on existing, environmental knowledge of users, and incorporate this knowledge into the navigation instructions.
3. Make use of user-created photographs whenever possible.

A basic user interface concept is to separate complex tasks, e.g., to navigate to a destination in a far neighbour town, into several

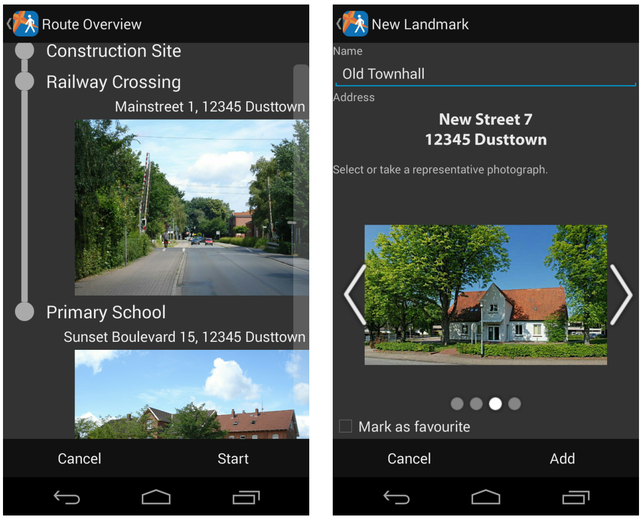

Figure 2: A navigation task is separated into several, less complex sub-tasks. The route overview shows all landmarks along the route (left). Users can add new landmarks at any time (right). The design makes strong use of photographs as visual cues to remember the individual landmarks. We argue that these concepts allow the users to rely on and strengthen their mental capabilities.

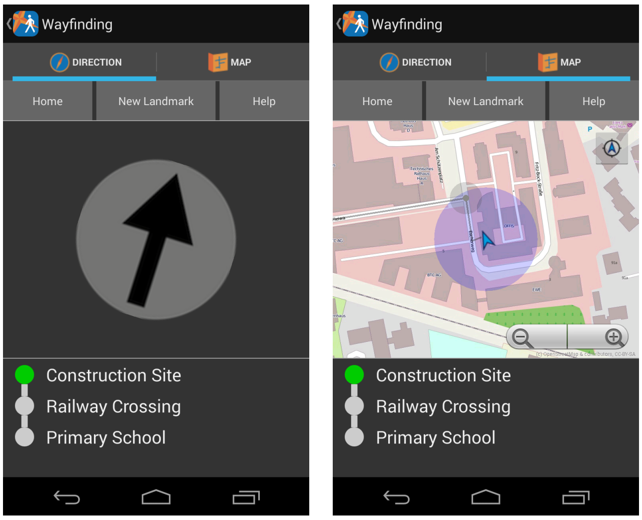

Figure 3: The actual wayfinding screen is separated into two different views, fulfilling the varying information need of the users (left serves orientation needs, right serves navigation needs). Particular design elements, such as the route outline, are re-used across the whole application. Note the significant refinement in comparison to the initial sketches of the same views, as shown in Figure 1.

consecutive, smaller tasks, e.g., to go to a familiar railway crossing and then proceed to a known primary school etc. (see Figure 2, left). Consequently, the user faces a sequence of small, solvable problems instead of a monolithic, complex problem. This approach comes with two major advantages. First, the whole route can be trained in advance, because the sub-destinations, i.e., landmarks along the route, are known. Second, the regular landmarks along the route reassure the users in their task and serve as confirmation for what they are doing [6]. This decomposition is a key aspect of our design and we argue that this would enable users with MCI to deal with situations, which are otherwise perceived as too complex.

To separate a navigation task into several small navigation tasks, the applications needs knowledge about the environment. Most importantly, the application needs to know which landmarks are known to the user. Although there is research on what makes a universally acknowledged and recognized landmark, we decided to exclusively rely on user-defined landmarks (see Figure 2, right) or landmarks, which are provided by relatives. Thereby, we don't require the user to learn and identify new landmarks. Instead, we make personalization a key aspect and, thus, allow users to rely on and strengthen their existing knowledge and mental capabilities.

To strengthen the personal relation to landmarks and to have prominent visual cues, each landmark comes with at least one self-made photograph [1, 2, 8]. These photographs are available whenever a landmark's name is not sufficient for the user to identify a landmark. Although we encourage users to take their own photographs, there is an option to select photographs from prominent web sources, such as Google Street View. These can serve as placeholder until the user is able to capture his/her own image.

The requirements showed that users have different information needs, depending on whether they are well-oriented or not. Thus, the actual wayfinding is separated into two different views (see Figure 3). The *direction* view serves basic orientation needs and provides a rough idea of the direction to the next waypoint. The *map* view serves more complex navigation needs, uses a detailed map and, thus, provides more information to the user. A route overview, showing the recent progress and next intermediate landmark, is present in both views. The idea is that the application is continuously monitoring the disorientation level of a user and then adapts the view automatically. This adaptation is essentially done by permanently comparing the current user location against a continuously adapting, on-device database of frequently visited places. Thus, infrequently visited places are considered as being unfamiliar. For a more detailed prediction we also plan to consider other aspects, e.g., excessively frequent changes in user orientation or a significant decrease in average walking speed. However, the user is always able to override any of these automatic decisions.

It is very important that the user can't get completely lost. Thus, in case the provided navigation information aren't sufficient, there is a *lifeline* functionality. This lifeline allows a user to get in touch with a relative or caregiver through a regular phone call. In the background and with the user's consent, additional information about the location, the recently passed landmark, and the destination of the trip is shared. We envision that this information can be accessed by the callee through a web interface to provide targeted recommendations and instructions.

Many of the presented concepts rely on the presence of certain information, such as user-provided landmarks. However, it could be the case that the application is used in completely unfamiliar environments, e.g., when the user is travelling during holidays, and crucial information are missing. Our design concepts adapt to this missing information as far as possible to always provide the user with a maximum possible orientation support and experience.

5. IMPLEMENTATION

The prototype was developed as an Android application, which allows an easy development, deployment and distribution for testing purposes or studies. A big plus of newer Android versions is the support of so called fragments, modular and re-usable user interface elements. Each fragment contains a certain part of the user interface, such as the route overview in Figure 2 (left), which then can be re-used across the app, like we did in the actual wayfinding view (see Figure 3, bottom). With extensive use of fragments we saved a lot of implementation effort and were able to create a familiar user experience among different views, which we argue is helpful to avoid unnecessary cognitive load.

However, we were also facing the problem that an application is unable to run in kiosk mode, which means that the application can accidentally be left by the user, possibly leading to confusion and disorientation. We found a workaround by defining the NavMem Explorer application as a *launcher*, i.e., the Android default application which provides the user with the home screen and an overview of installed applications. Thereby, several complicated interactions are required to enable the user quitting the application.

It is planned to release the NavMem Explorer as a product in the future. We plan to release the application in two ways. First, we plan to deploy a custom phone with NavMem Explorer pre-installed. This will also allow us to realise the requirements regarding physical shape and ergonomics of the device, e.g., no buttons on the side of the phone. Further, we will be able to do low-level modifications to the Android operating system, making tricky workarounds obsolete. Overall, this allows us to provide the best possible user experience. Second, we plan to release the application through the Google Play store. This distribution channel aims at more tech-savvy users, which are regular smart phone users and consider the NavMem Explorer as a nice add-on.

6. PLANNED STUDIES

The added value and impact of NavMem Explorer will be investigated in two longitudinal studies. Both studies will run over a period of at least one month and the application will be made available to at least 30 persons from our target users, i.e., people with MCI, dementia, stroke, and elderly. The first study will focus on the investigation of different means to present the navigation instructions, such as different navigation instruction visualizations or multimodal feedback. We will likely study which information presentation concepts can be understood easily, which allow the user to reach the destination quickly and safely, and which induce the least cognitive load. In a following design and development cycle these findings will be used to create the final interaction concept.

We will conclude the project with a second longitudinal field trial, which will study details of the final interaction concept. In this study we will identify final, market-relevant tweaks and optimizations, which we will incorporate into the demonstrator before release. Further we will collect quantitative information how NavMem Explorer compares to traditional navigation solutions or other navigation solutions targeting at people with MCI.

7. CONCLUSIONS

People with cognitive impairments frequently loose orientation when navigating outdoors. Existing navigation solutions provide an overwhelming amount of information and are unable to address the users' needs and desires. In this paper, we presented NavMem Explorer, an orientation aid for people with mild cognitive impairments. We summarized the most essential insights from our conducted requirements studies. Further, we illustrated the application's design concept and the three key conceptual aspects: the decomposition of complex navigation tasks into less complex tasks, the use of personal landmarks and the accompany of those by photographs whenever possible. We gave insights into the challenges we were facing during the ongoing implementation and sketched how we will evaluate the application in future studies.

We argue that the NavMem Explorer will allow people with mild cognitive impairments to accomplish complex navigation tasks without loosing orientation or becoming scared to do so. With NavMem Explorer people will be encouraged and supported to go out alone and actively participate in social life.

Although the application was designed for people with mild cognitive impairments we are interested to investigate the underlying concepts for other target users, such as people without cognitive impairments or people with more severe cognitive impairments. We agree that particularly the latter case will be challenging to study and to design for, but a working solution certainly will have a huge impact on the society. Further, we are interested to extend our scope and, beside pedestrians, also address car navigation or multimodal transportation.

8. ACKNOWLEDGEMENTS

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