Design Considerations and Evaluation Methodology for Adapted Navigational Assistants for People with Cognitive Disabilities

Javier Gomez and Germán Montoro
Department of Computer Engineering, Universidad Autónoma de Madrid, Madrid, Spain

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Abstract: Assisting pedestrians with cognitive disabilities in their movements through a city is not a simple task. Despite of the new mobile navigational software available in the market, many of these users (and their caregivers) are still resistant to use them. In some cases, due to the lack of adaptation to their needs. This issue motivated us to elaborate a set of design considerations to keep in mind when designing navigational assistants for people with cognitive disabilities. Besides, we developed a navigational prototype for smartphones that was evaluated with two users with Down syndrome. Therefore, we also propose some hints about how the evaluation should be carried out.

1 INTRODUCTION

How can I get from my position to some other place? This question can be answered thanks to our mobile phone and a navigational software. However, it could be more difficult if the user had some kind of disability. In this paper we focus on locating, giving directions and helping users with cognitive disabilities, and more specifically Down syndrome, in their walking movements through the city. By means of the smartphone as a location and information presenter device, we want to promote their independence, autonomy and self-confidence, besides giving support to caregivers.

The particular necessities of these people make even more difficult to understand the maps or directions that current navigational software provides. Not only their cognitive condition may limit them to understand complex instructions, but they usually also have some other disabilities, e.g. dyslexia, aphasia, vision problems, etc. that should also be considered when designing any assistive resource.

Current navigational software provides adaptation mechanisms, such as different palettes for day or night light, adding oral interaction or even adapting the route depending on the means of transportation (car, walking, public transport or bike) or the traffic status in real time. Nevertheless, they do not take into consideration the different cognitive load required for users with special necessities, such as Down syndrome people.

In order to address the design and evaluation processes of the assistive navigational software, we present a set of considerations based on the literature and the experimental research. These could be useful to ease the development and evaluations of future approaches. These considerations have been put into practice to design and develop an assistive navigational prototype for pedestrians with cognitive disabilities. The prototype has been evaluated with two users with Down syndrome in a real environment.

This paper is organized as follows: after reviewing the background of this topic and the current frame, we extract a set of design considerations. Then, we describe the prototype of a mobile client. Next, we present a case study, and finally we propose some design considerations and suggest a methodology for evaluating this kind of assistive software.

2 BACKGROUND

In the recent years, the interest of the research community on technologies and services specifically designed and developed to help people with special needs has grown. Not only caused by human or personal factors, but also supported by governments and institutions. Evidence of this is the ISO 9999 (ISO, 2011) that defines Assistive Technologies (AT in forward) that are "any device, equipment, instrument

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or software produced to prevent, compensate, monitor, calm or neutralize disabilities in the body structures or their functionalities, restrictions in activities or social participation". Or the Assistive Technology Act of 1998 (ATA/1998) (105th Congress of the United States, 1998) which also defines the AT as "product, device, or equipment, whether acquired commercially, modified or customized, that is used to maintain, increase, or improve the functional capabilities of individuals with disabilities".

Both definitions are very similar but they bring a common framework that can be assessed from different faces. In general, giving assistance depends on the user necessities and capabilities. Thus, the problem faced in this case study, giving navigational support, as an assistive technology artifact depends directly on the user's disability as well. For example, when calculating a route and giving directions to a person with motor disabilities (e.g. she needs a wheelchair to move), it would more interesting to suggest an accessible route, without stairs or narrow pavements, than the fastest path. On the other hand, in the case of people with cognitive disabilities it would be preferable to adapt the route in terms of cognitive load, i.e. reduce the number of decision points and their complexity. Therefore, before studying, designing and developing any assistive artifact, user necessities should be stated.

Thus, in this case study we focused on giving directions to people with cognitive disabilities. These disabilities may come from birth or acquired later, for example, brain injury after a stroke. Moreover, depending on the clinical profile, necessities may be different. Therefore, in order to provide a precise vision of the problem, we restrict this study to address the issues concerning to give directions to people with Down syndrome in their walking movements through the city.

3 LITERATURE REVIEW

The state of the art offers a considerable number of studies, developments and open questions regarding different disabilities. However, when focusing on users with cognitive disabilities they reduce drastically. The complexity of the brain and the differences between subjects make this research area difficult but challenging at the same time. Braddock et al. evidenced this issue in (Braddock et al., 2004): ATs have been traditionally designed for people with different disabilities, such as motor control (robotic prostheses) or communication (augmented and alternative communication devices). But they rarely studied or developed to assist people with cognitive disabilities. Despite of this hurdle, literature reviews still provide interesting projects and studies. In particular, many of them are focused on assisting people with cognitive disabilities in their daily lives, such as GUIDE (O'Neill and Gillespie, 2008), COACH (Mihailidis et al., 2000), Autonomamente (Barbieri et al., 2010), ePAD (Mihailidis et al., 2010), ATHENA (Hidalgo et al., 2011), or 2D-Tasks (Caballero-Hernández et al., 2012).

Particularly, we focus on navigational assistants, which are rarely prepared for people with cognitive disabilities. In this sense, mobile application markets offer a significant number of navigational systems, supported by big technological companies e.g. Google, Apple, Microsoft or some other specialized in navigation and maps, e.g. Tom Tom, Garmin, etc. Besides, almost all of them provide some adaptation mechanisms. Regarding the interface they usually offer different languages, daylight/night mode, 2D or 3D maps, etc. But also the route calculation is usually adapted to the means of transportation or the traffic. However, in most cases the cognitive load is not considered when adapting both the interface and the interaction. A map with an icon to represent the user and a highlighted route is the most common view. Around this map a lot of extra information is included, such as speed, the next instruction, GPS signal quality, time to destination, etc. These screens, full of information, continuously updated and, in many cases, not so easy to understand make these applications not suitable for guiding people with special needs. Besides, according to Boisvert et al. (Boisvert et al., 2009), when designing mobile aids for people with cognitive disabilities, the cognitive load should be reduced, by means of offering customized experience, multimodal information, giving regular feedback and preventing errors. Related to interface design, some important notes are given in (Cole, 2011). In the paper the author introduces the Patient Centered Design approach that integrates User-Centered Design and Participatory Design to develop assistive systems adapted to patients necessities (in this case users with cognitive disabilities).

Anyway, there are some interesting research papers in this topic such as MAPS, by S. Carmien (Carmien, 2006) (Carmien, 2003), which is a prompting PDA software to assist people with special needs. Moreover, if it's combined with a GPS coordinates server, it can be programmed to guide the user in outdoors movements. Another interesting research is the one done by Richter (Richter et al., 2010), that employed user models to improve the user experience and (Richter and Duckham, 2008), a discussion on how instructions should be given. Finally, Liu et al. presented in (Liu et al., 2009) the design process and the evaluation of a guiding system, exploring the suitability of visual widgets and directions for users with cognitive disabilities. On the other hand, authors such as Beeharee and Steed (Beeharee and Steed, 2006), Fickas et al. (Fickas et al., 2008), Liu et al. (Liu et al., 2009), Lemoncello et al. (Lemoncello et al., 2010) explored different mechanisms to give directions to people with cognitive impairments, namely using arrows, audio prompts, maps and landmarks. In general, all authors agreed that the use of landmarks is the best way to orient and guide these particular users. Additionally, Garcia et al. (García de Marina et al., 2012) explain some other issues, such as the difficult to distinguish between left and right (when using textual instructions) and the confusion that produced the difference between the actual view and the picture shown, i.e. elements that appear or do not appear.

Therefore this is a challenging topic, moreover if we consider that, according to (Carmien, 2010) people with cognitive disabilities usually present limitations on spatial navigation skills that makes more difficult to guide them.

4 DESIGN RECOMMENDATIONS

As it was stated in the previous section, current navigational applications do not present adaptation mechanisms for cognitive impaired people. However, some previous studies offered interesting ideas, such as the use of landmark-based instructions, which produced better results in the experiments. On the other hand, simple and clean interfaces are usually valuable guidelines when designing applications for people with cognitive disabilities. Additionally, studies like (Krüger et al., 2004) or (Ishikawa et al., 2008) stated that, in some cases, the assistive device could act as a distractor. Therefore, the design of the interface is a key task.

Besides, it is very important to take into consideration the necessities of the caregivers. Providing assistance with an adapted system should decrease the effort necessary to do it by traditional methods. Adaptation of the system to the environment and the users should facilitate this task.

Considering these previous works and relevant ideas extracted from the researched literature, and with the assistance of experts and caregivers, we propose a set of considerations that may help when developing assistive navigational software for people with cognitive disabilities:

- The less possible information on the screen, the better. Interfaces should be clean and simple. Users should only receive relevant information for their goal. For instance, for an advanced user it would be interesting to know the subsequent decision points. For cognitive disabled people, this information could be confusing or distract them of their goal.
- Destination points should be selected from a previously created list. Regular uses, in many occasions, employ their navigation systems to go to new and unknown places. Nevertheless, people with cognitive disabilities, and more specifically Down syndrome, do not usually move alone to new places. The places they are usually allowed to go by themselves are restricted to a certain number. This way, the destinations should be constrained to a previously set up list. Additionally, this also relieves the user to look for places (using searching boxes) or remembering additional information about the destination (e.g. exact address).
- Real images of the landmarks should be combined with atomic instructions. Studies like (Richter and Duckham, 2008) demonstrated that the performance is related to the way that directions are given. In this sense, atomic instructions i.e. “continue straight” or “turn left” in combination with landmark identification fit better with the user necessities and help them in the learning process. This way, showing an image of the landmark and telling the user to “continue straight until you see this” may lead to a better user experience and an improvement in the learning process. Additionally, the cognitive load is reduced since these instructions are easier to understand than combined instructions, such as “turn the second on the left and then right”.
- A navigation system should promote their autonomy. The most immediate task of these systems is to guide users to the destination but, additionally, they should promote their independence. To employ such systems should not only provide the knowledge for a concrete route, but also to help users to learn new routes and landmarks identification. Since users have to pay attention to real environment landmarks that makes them familiar with their surroundings and what they find in their routes.
- The system should provide additional information to assist users in the process to identify the landmarks. This can be done by notifying them about the distance to the next decision point or land-

mark. This information can be presented in different ways, but it should consider how to reduce the cognitive load. Therefore, instead of showing measures like meters or a scale, the system may be provided of a coloured filling bar. This is an easy-to-understand and friendly interface. Besides, using colors provides another source of feedback, since variations in color attract user attention effectively (Brown, 1999). Additionally, as García–Herranz et al. demonstrated in (García-Herranz et al., 2012), people with cognitive disabilities usually relate colors to states in the same way as users without disabilities. Green means good, red bad and amber in the middle. This way, a green bar that fills as the user walks or turns in the correct point provides useful and simple information.

- The system should have mechanisms to prevent and solve errors. People with cognitive disabilities present lower error acceptance so prevention should be dealt by means of awareness. The system should be aware of users' position and distance, and notify them when they are reaching a decision point or if they are taking a wrong direction. On the other hand, getting or feeling lost may produce a stressful situation. Keep-calm messages or communication channels with the caregiver should be considered for these situations.
- Caregivers and relatives should be kept in mind. Therefore, communication and supervision tools should be provided. Particularly, it would be interesting for the caregiver to be able to locate the user at any time, or study the routes followed to analyze her performance.

5 MOBILE NAVIGATION ASSISTANT PROTOTYPE

Before developing a new system focused on a specific group of users it is very important to be sure of how you should face their problems and design the interface they are going to use. This is how, with the design considerations presented in the previous section, we designed a first prototype to validate the functionality of such a system. The employed architecture is irrelevant for this study and only a general description of it is presented.

In a nutshell, thanks to the current on-line services (such as Google Maps) that provides tools to model environments, calculate routes and counts with huge street level pictures databases, we were able to decrease the time caregivers have to spend to model new environments and take photographs of the landmarks. In order to process and adapt all this available information to our mobile client, a middle server was developed.

Once the user chooses the destination point (from a previously loaded list, stored in the server), the server requests the map service for the route between the two points, split it, and asks for the images associated to each landmark. Finally, all this is information is sent to the user's phone in a proper format.

5.1 Mobile Client

The mobile application is the most important element of this study. From the user's point of view it is the module that she has to deal with. So, considering the user's special needs, the graphical interface and means of interaction have to be carefully designed. Therefore, following the previously stated ideas we decided to develop the interface shown in Figure 1. As can be seen, the interface is divided into different sections (from top to bottom):

Figure 1: Interface screenshot.

The application name is in white font over dark grey background. These colors were intentionally selected to make it clear that this is not an active part of the interface. Under it, the instruction is displayed in black font over light green background. Apart from the text, the instruction is read aloud as the interface loads. Then, we find a red button with the text "Help". Again, colors are intentionally selected, meaning "something is wrong". This button provides the prevention and error correction mechanisms. This is, if the user feels lost or in panic, she can press the button and the caregiver would be automatically notified about the stress situation and the location of the user. After that, in the middle of the interface, as the most important element, the system presents the real picture of the landmark that the user has to find. In this case it is a street-level view extracted from Google Street View Service. Right under the image, the distance bar is showed. It is slightly filled of green, which means that the user is still "far" from the decision point and, therefore, from that image. This feedback mechanism helps the user to be aware of her performance. Additionally, once the bar gets almost full, the phone rings and vibrates to notify the user that the decision point is close. Finally, two navigation buttons are placed at the bottom part of the interface. Regarding the design we did not change any color or shape, and placed them as regular buttons. The one on the left, with the text "Previous" is used in case the user wants to go back and repeat from the last decision point to make sure of the route. The other one, "Next", is pressed when the user reaches a decision point and wants to receive the next instruction and its associated landmark picture.

As it was said in previous sections, instructions have to be simple and easy to understand. This is why these systems should split the route into atomic steps. For this case study prototype every decision point is divided in two parts: first, the user is asked to continue straight until she finds the picture shown in the interface. Once she is at that decision point, she is asked to turn left or right and, then, a new street-level picture of the next landmark is shown. Finally, she is asked again to continue straight until she reaches the decision point showed in the picture.

In order to illustrate it, in Figure 2 we sketched an example route. In this case the user has to go from the post station (blue circle with a white envelope) to the bank (green circle with a white dollar symbol inside). The proposed route follows the red numbered dots (from 1, starting point, to 5, destination point). As it can be seen, the other red dots correspond to decision points. Besides, for every decision point we present two pictures: the first one to provide the user with a view of the landmark and, the second one, to help her in the turns. Pictures are adapted to the turning direction. This is, they are showed according to the point of view of the user.

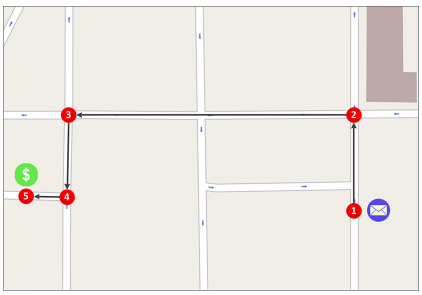

Figure 2: Route sketch to go from the post station to the bank. The decision points has been highlighted with numbered red dots.

6 CASE STUDY

In order to evaluate our navigation assistance concept and the proposed design considerations, we ran a first case study experiment with two participants. They both were Down syndrome young men. As they stated in the interviews, they were not used to going alone to near places, although their relatives wanted them to do it. This prototype tried to fit their needs.

The experiments took place in their home town and users were required to walk a route of 600 meters between two main landmarks: the train station and the City Hall. To reach the destination, they had to perform two 90 degrees turns to the left. As they did not live in the city center, the route was completely new for them.

6.1 Methodology Proposal

To evaluate the system it is important to define a precise methodology. For this study, and following the literature, we decided to divide the experiment in different sessions and tests. In first place, both users were asked to complete two questionnaires. The first one about personal information, technology and internet habits. The second one to evaluate their self-report about navigational tasks.

This way, with the first test, we were able to get an initial idea of their capabilities, needs and relation with technology. Besides, they also had a first training session with the prototype, so that they could get familiar with the system.

Then, they were asked to answer the Santa Barbara Sense Of Direction Scale (SBSODS) test by Hegarty et al. (Hegarty et al., 2002), in order to get their self-report on how they considered themselves about giving and understanding directions or maps. This test consists of 15 questions to be answered in a 1 to 7 Likert scale (1 strongly agree, 7 strongly disagree). Nevertheless, in order to provide a reliable and neutral test, we proposed 8 questions written in a positive way (e.g. "I am very good at giving directions") and another 7 questions in a more negative sense (e.g. "I have trouble understanding directions"). Therefore, positive answers scores should be inverted so that higher values can correspond to better results.

After that, in a new session, participants were asked to walk through the proposed route, using a phone equipped with the navigation assistant prototype. In order to gather first-person thoughts, the "think aloud" procedure (Lewis, 1982) was carried out to get extra subjective information about user's feelings and opinions. Besides, according to (Lepistö and Ovaska, 2004) these techniques provide more information than usability tests or questionnaires. To do that, each participant was asked to wear a head-mounted camera and a voice recorder.

Finally, after the walk, participants were asked to take two additional tests and a short interview. The first test consisted of a sequence of real images of the decision points. With them, they were asked about the direction they had taken. This is a widespread mechanism to measure the spatial knowledge (Siegel and White, 1975). After that, the USE Questionnaire (Lund, 2001) was given to the users to evaluate the usability of the system and ask them their opinion. This test provides user's opinion of four topics, namely "Usefulness", "Ease of use", "Ease of Learning" and "Satisfaction". Finally, a short oral interview was carried out to ask them about the things they liked most and least.

6.2 Results

The experiments yielded interesting results to define and complete the previously presented design considerations and methodology for evaluation:

- First of all, we checked that the guidance approach worked: splitting a complex direction in atomic instructions and presenting street level images to identify landmarks made users to find the route easily and arrive at their destination.
- Moreover, thanks to the progress bar they were able to estimate the remaining distance to the next decision point without effort. In fact, according to the subsequent interviews, the progress bar was the most valuable part of the application, followed by the real images.
- Regarding to user's performance we can highlight that both users reached the destination in an acceptable time (less than tree times the calculated time) without any external assistance besides the navigational software.
- According to the later study of the recordings, their performance was slightly different, but they shared some common attitudes. For example, both participants paid more attention to the phone, looking for the landmark, as they got closer to it. This is important since it demonstrates the importance of the use of alarms to help them to identify the landmarks.
- In contrast, the required time to identify landmarks and directions at the decision points was different. Participant 1 needed less time on average. When asked about landmarks identification, none of the users answered right to all the questions, but again their responses were different. This shows how important it is that the system adapts to each specific user as well as how they need to repeat the same route multiple times in order to get confident with its steps.
- On the other hand, according to the interviews, the users and their caregivers, found the prototype very interesting. They were eager to use them again in future routes as a way to find their way without the need of external help.

7 DISCUSSION

7.1 Design Considerations

From the carried out evaluation, we confirmed and extended the design considerations that should be followed in the process of developing mobile assistive navigational software for people with cognitive disabilities. The following are the characteristics that a navigation assistant should satisfy in order to fit these users needs:

Regarding the interface design:

- Users and caregivers should be included in the design process. This way we ensure that we design a prototype to solve problems without creating new ones. By including experts (i.e. therapists, educators, tutors, etc.) in the design process we may avoid future errors and develop the appropriate adapted software.
- It should be simple and clean, avoiding distracting information. To do that, the design should be friendly, iconographic and minimalist in order to catch user's attention.
- Multimodality should be supported (texts, images and voice) in order to overcome reading or vision problems. Many users present some other disabilities, such as low vision, which should be considered while designing the interface. In order to overcome some of these other disabilities, providing the information in different ways could allow the application to be used by a wider range of users.
- Colors usually have the same meaning for users with special necessities that for users without disabilities. Nevertheless, and related to the previous point, color blindness should be taken into consideration to chose a proper palette.
- Feedback should be provided, but not acting as a distractor. Users need to know whether they are doing right or not, but in a non-intrusive way that

does not require full attention.Besides, the system should be aware of user's progression and be proactive, notifying whenever it is needed.

- Due to the lower error acceptance of these users, prevention mechanisms should be included.

Regarding the route calculation and guidance:

- In order to save human and time resources, space modeling, route calculation and landmark images should be as automatically processed as possible.
- The use of images to identify landmarks is accepted as an accurate way for guiding. The more realistic and updated the images are, the easier will be to identify landmarks.
- Atomic instructions (continue straight or turn left/right) seem to work properly. Therefore, to divide routes into these instructions is a good technique.
- To provide continue and accurate feedback contributes directly to the user's performance.

7.2 Methodology for Evaluation

In section 6.1, we proposed a methodology for evaluating these systems. After the case study, we noticed some aspects that we could highlight:

- Participants should not be overwhelmed. Putting the user in unpleasant or uncomfortable situations without a reason may affect her opinion or performance. Asking and listening to caregivers and even given them the opportunity to participate may become the environment more familiar. This will facilitate that the user can interact and participate actively.
- Performance relies on users' capabilities. Therefore, the more we know about them, the better. In other words, personal data or habits are valuable information that may provide a first idea of the possible user performance. However, large tests or interviews may make users get tired, affecting their mood, answers or performance.
- In general, Likert scale tests do not work well with these users. Their answers are usually biased to the extremes so they should be avoided. Instead of them, more open questions, which let users explain their thoughts will be better. Furthermore, the "think aloud" method has demonstrated to be particularly useful when evaluating systems with cognitive disabled people.
- Although SBSODS is widely known as a good measurement of users' self-opinion about navigational tasks, they should be adapted for cognitive disabled people.
- Recording users' point of view provides valuable information, both qualitative and quantitative. Head mounted cameras or camera-equipped glasses are affordable choices.
- Time and location registries are another source of analysis of user's performance. The more precise is the gathered information, the deeper the studies will be able to be.

8 CONCLUSIONS

In this paper we have presented a set of design recommendations to take into consideration for the development of new adapted navigational assistants for people with cognitive disabilities. Besides we propose a methodology as long as recommendations for evaluating these systems. In order to validate these ideas, we developed a navigational prototype to assist pedestrians with cognitive disabilities in their walking movements through the city.

This prototype was tested with two users with Down syndrome in an open environment. Since the number of tests is not big enough to validate the system it becomes a first case study that can support the initial ideas presented in this paper as long as offer new considerations to take into account.

The design guidelines were based, at the beginning, in literature review. But, thanks to the field trial and the experience gathered with these first users, we have been able to have an initial confirmation and extension of our proposals. The same happened with the evaluation methodology.

Since this is a first case study we consider that it can already provide some useful considerations about the design and evaluation processes in the development of adapted navigational assistants for people with cognitive disabilities, as stated in previous sections. Therefore, for future work the prototype should be tested with more users, re–adapting the interface, design guidelines and evaluation methodologies to the results obtained with a wider variety of users and situations.

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