Supporting Cognitive Collage Creation for Pedestrian Navigation

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Abstract. How can we assist people in efficiently finding their way around a novel area? We tested a prototype navigation support system with 10 elderly pedestrians and found that adding landmark information considerably helped them in learning the structure of an unknown residential environment. We conclude that providing explicit landmark information in the learning phase seems beneficial for the creation of a rich "cognitive collage" that is fully functional in later phases when navigation support is not available.

Keywords: human spatial navigation, cognitive map, cognitive collage, path integration, landmark recognition, reorientation, navigation support systems.

1 Introduction

Present-day navigational support systems can guide you to your destination almost perfectly. These devices are so effective and easy to operate that users may become entirely dependent on them. Our goal is to develop systems that assist users in getting to know their way around a novel area. The crucial difference with existing systems is that we want to make our users independent of the device as quickly as possible.

We lean heavily on ideas developed by researchers of the psychology of human spatial navigation. The classic idea is that we somehow build up "cognitive maps" or "mental maps" of our environment. These maps have similar characteristics as the paper and electronic maps that we use today [4]; representations are enduring (fixed in memory), geo-centric (from a bird's eye perspective), and comprehensive (completely depicting the environment). Several researchers have shown that these ideas are untenable since the nature of the mental representation of the environment for navigational purposes is fundamentally different [5, 7]. The alternative view is that the human mind is lazy and opportunistic, and will only represent the necessary information for the task at hand. A more apt metaphor for mental representations for navigation is "cognitive collage" [5]; we create representations from experience, from maps, from descriptions, etcetera. The only aim is a functional representation, not a perfect one.

In order for humans to navigate from a home location to a destination (and return home safely), we appear to have access to three different mechanisms: path integration, landmark recognition, and re-orientation (see [7] for an excellent review). The first one may surprise readers since we share the method of path integration (or "dead reckoning") with insects and birds. Path integration is the dynamic updating of the

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present position and direction relative to the home or starting position. It is a simple method that requires limited memory, though it is sensitive to cumulative errors. In the method of landmark recognition, we use salient objects in the environment that are easily remembered and recognized to guide us from one location to the next. Finally, re-orientation is the method that guides us from one space to the next by recognizing the present environment by its global shape and orientation, and remembering the exits to guide us to the next space. For self-reliant navigation, humans use a combination of the methods above, depending on the structure of the environment and their personal experience.

Another matter is communicating how to get from *A* to *B* to other people. Tversky and Lee [6] asked participants to give them descriptions and depictions of a certain route. They found that there are many similarities between verbal and pictorial directions, and that they consisted of common elements: landmarks (buildings, e.g. "the Old Church"), orientations (paths, e.g. "an alley"), and actions (turn, e.g. "take a right"). May, Ross, Bayer, and Tarkiainen [2] confirmed this finding and found that landmarks are the elements in route instructions with the highest occurrence. The focus in that study was, like in Tversky and Lee [6], on generating instructions, not on actually using them. Ross, May, and Thompson [3] gave pedestrians in real navigation situations explicit information on landmarks. Their findings show a reduction of errors and an increased confidence.

Finally, we turn to the issue of the effect of age on navigational skills. Wilkniss, Jones, Korol, Gold, and Manningal [8] have found that the skill of route learning diminishes with age. For navigational aids, Goodman, Brewster, and Gray [1] found that the use of landmarks is particularly useful for elderly pedestrians. A part of the motivation for our research came from a business case developed with our project partners[1]. We wanted to find ways of assisting elderly people that are moving into eldercare and are learning their way around a new residential environment.

Our main focus is on testing the effect of landmark information on building up a functional cognitive collage of a novel environment by elderly pedestrians.

2 Prototype

We designed and developed a navigation support prototype. Our goal was to provide elderly pedestrians with a device that can guide them from *A* to *B*, and has the option of showing additional information about landmarks in the direct environment.

We used a HTL Advantage PDA with 624 MHz CPU and 128 Mb memory with a 640 x 480 pixel touch screen display of size 12.5 cm. The PDA had a built-in GPS receiver. In addition, we used an external electronic compass of type Wintec WBT100 with its own GPS receiver that communicated with the PDA through Bluetooth. The PDA and compass were encased in a wooden frame as shown in Figure 1.

The operating system of the PDA was Windows Mobile 6.0, and the application was written in C# 2.0 under the .NET compact framework. The 3D graphics protocol was DirectX, with the 3D objects stored as .obj files and the texture images as .jpg files. For the log and configuration files we used simple .txt files. During navigation,

[1] Delft University of Technology, TNO Human Factors, and Logica Management Consulting collaborated within the MultimediaN project on developing innovations for multimodal interactive applications.

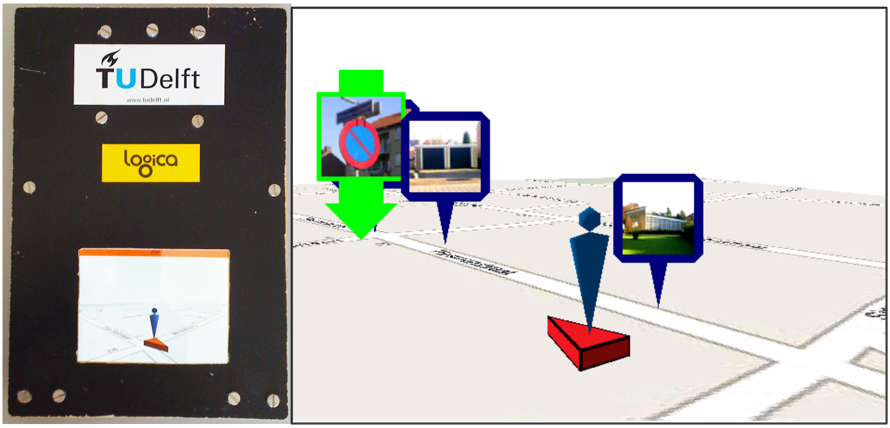

Fig. 1. Prototype of our navigation support device (left), and an example screenshot of the display during navigation in the experimental area in Soesterberg, the Netherlands (right)

the location data was measured and stored in the PDA, as well as in the memory of electronic compass.

The user could hold the device in his or her hands and walk normally while occasionally consulting the information provided on the display. Figure 1 shows a screenshot of the prototype in action. The display showed a map in perspective projection that was always oriented in the forward-up direction. The location of the user was indicated on the map by an abstract blue figure, and the heading direction was depicted by a red arrow. In addition to the red arrow that conveyed in which direction to walk, a waypoint was added to make it even clearer where the user would have to go next.

Objects in the environment were indicated by small photographs on vertical “billboards” that were always facing the user. The billboards had a slender arrow coming out of the bottom that was touching the map with its sharp end, indicating the location of the object. We distinguished two kinds of objects: waypoints and landmarks. Waypoints are easily recognizable objects (for example fire hydrants or traffic signs) that were on the path of the pedestrian and their photographs were shown on the billboards with a green edge. The waypoints functioned as indicators of intermediate locations on the path to the destination. Landmarks were (large) objects that were easily identifiable structures that could be seen from the pedestrian’s vantage point (for example houses or bridges) shown on billboards with a blue edge. Depending on the condition in the experiment, landmarks where either present on the screen or not, as will be explained in detail in the next section.

3 Experiment

We tested our navigation support prototype in an experiment with 10 elderly pedestrians that were asked to walk around a residential area in Soesterberg, the Netherlands. The goal of the experiment was to find out if they could learn the environment with the help of the prototype to the extent that they could subsequently navigate efficiently without its assistance.

3.1 Participants

Ten elderly people, 60 to 72 years old (2 women and 8 men), were selected from a pool of volunteers for their age and the fact that they had never been in the residential area where the experiment took place. This area was close to the TNO Human Factors institute in Soesterberg that manages this pool of experimental participants and graciously allowed us the use of their facilities. The participants were paid for their services.

3.2 Procedure

On arrival we informed the participants about the goal of the experiment and had them fill out a survey about their navigational aptitude. We asked them about their experience in using maps and electronic navigation systems, and asked them to self-assess their navigational abilities.

We subsequently familiarized them with the prototype and escorted them out of the building to the starting point *A* that was about 300 meters from the TNO building. The experimenter explained to the participant that their task was to follow the guidance of the navigation device to walk to the destination point *B*.

At the destination point *B* we asked them to hand in the device and gave them the second task. They now had to walk back to the starting point *A* without help of either the device or the experimenter. It is important to emphasize that they did not know this in advance; they could not have foreseen that they would be asked to find the starting point without any assistance. The experimenter had set a maximum duration of 30 minutes for the return walk; this limit was actually never reached.

After arriving back at the starting point, the experimenter and the participant went back into the TNO building. During the debriefing session, the participants were asked to draw a map of the area that they had just navigated through. Finally, they filled out a survey about their navigation experience during the experiment, and were asked about the usability of the prototype. There was also space on the survey papers for suggestions and remarks.

3.3 Conditions

The experimental route in the Soesterberg residential area (Figure 3) was about 1 kilometer long and had 10 turns. We photographed 12 waypoints and 20 landmarks that could be shown on the display of the device. Examples of landmarks are a church, a bank, and a children's play-field (see also Figure 2).

The most important independent variable in the experiment was the presence or absence of landmark information on the display during the walk from *A* to *B*. The reader should keep in mind that this information was not necessary for finding the destination *B* since there was already a rich set of information about which route to follow. The crucial question is whether this additional information, showing landmarks along the route they were presently walking, made it easier for them to walk back to the starting point without assistance.

Fig. 2. Examples of typical landmarks (top row) and waypoints (bottom row)

Fig. 3. Satellite image of the experimental route (red line) in a residential area in Soesterberg, the Netherlands, with the TNO building on the bottom right

4 Results

First of all, each participant managed to find destination *B* with the guidance of our navigation support prototype. On average it took them about 17 minutes, ranging from 14 to 22 minutes. Interestingly, all participants were also successful in finding the starting point *A*. It took them on average 13 minutes, within a range of 8 to 17 minutes. We found no significant difference in walking time between the two conditions "landmarks present" or "no landmarks", either for the route from *A* to *B*, or the route back from *B* to *A*.

There was however a difference in the route that participants had taken back to the starting point *A*. Figure 4 shows the results of Participant 1 who could see the landmark information on the display ("landmarks present"). The green line indicates the route from *A* to *B*, and the red line shows the route back from *B* to *A*. As one can see, this person took a very similar route back to the starting point.

Figure 5 shows the results for Participant 4 in the "no landmark" condition. It is clear that the route back (red line) is quite different. The participant takes a detour but succeeds in getting back on track, eventually finding the "home" position.

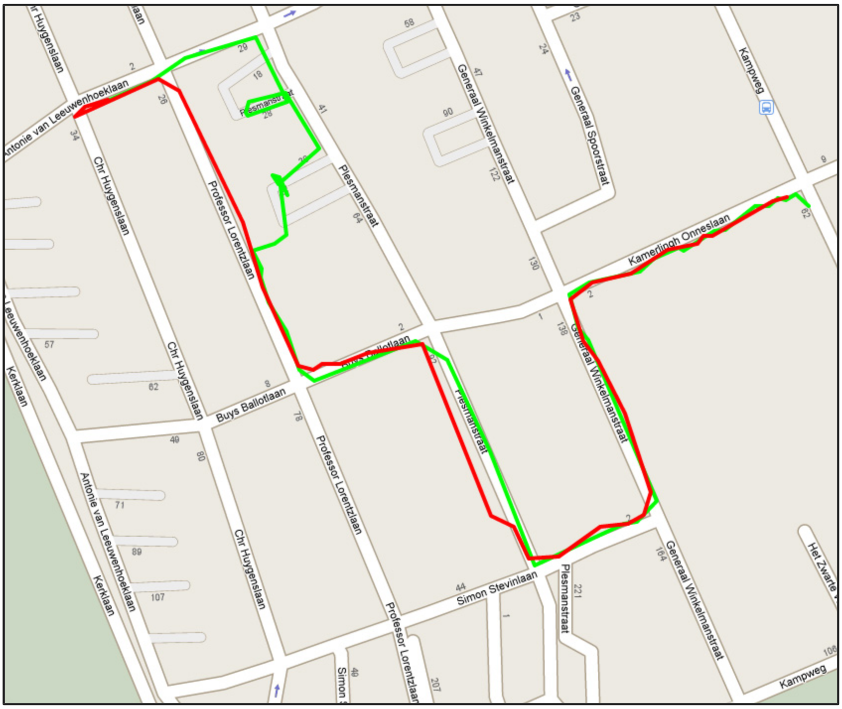

Fig. 4. Results of Participant 1 in the "landmarks present" condition. The green line indicates the route from A to B, and the red line the route back from B to A. The routes are very similar.

We analyzed the routes of all 10 participants in detail and counted the number of waypoints and landmarks that the participants have seen on their way back to the starting point. Our criterion for similarity was that they should have encountered at least 66% of waypoints and 66% of landmarks. If both percentages were under 66% we called them "different". Table 1 shows an overview that shows that 4 out of 5 participants that were shown landmarks on the device took a similar route back, and 4 out of 5 participant that were not shown landmarks took a different route back.

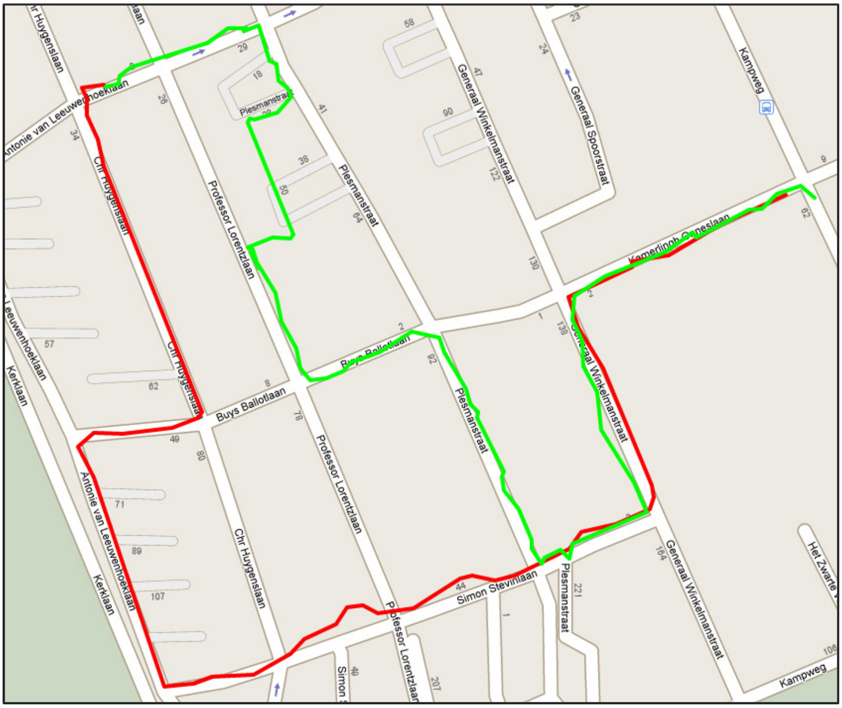

Fig. 5. Results of Participant 4 in the "no landmarks" condition. The green line indicates the route from A to B, and the red line the route back from B to A. Return route is very different.

Table 1. Overview of the number of participants taking a similar or a different return route given the conditions "landmarks present" or "no landmarks"

Condition / Return route	landmarks present	no landmarks
Similar	4	1
Different	1	4

Fisher's exact statistical test reveals that the probability of this distribution of results is 0.099, rather low but not enough to be considered significant with $p < 0.05$.

The participants in our experiment were also asked to sketch the route they had just taken. We found a wide variability in the quality of these maps (see Figure 6): from just a few lines, to a complete and accurate drawing with an indication of the location of waypoints and landmarks, and an indication of the return route. There is however no correlation between the similarity of the return route and the quality of the sketches.

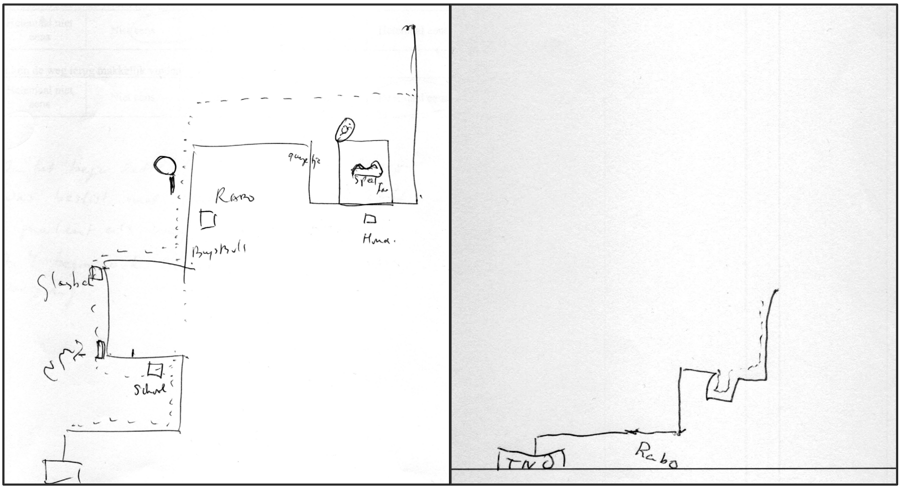

Fig. 6. Sketches of Participant 1 (left) and Participant 3 (right)

The surveys revealed quite a large variability in self-assessed navigational skills, but that does not that correlate with performance. The usability of the device was generally rated quite high although it was commented that the photos of the landmarks could have been clearer. We are planning to use more iconic images instead of photographs in the future.

Occasionally the weather conditions were of influence on the experiment. One time it rained during the initial phase of the experiment and that mainly affected the quality of the GPS signal resulting in temporary low accuracy of the localization. It took some time before the first waypoint emerged but that was the only problem. Another time, the sun was shining brightly at low angle and this affected the visibility because of glare on the screen. Especially the visibility of the photographs of the waypoints and landmarks was negatively affected.

5 Conclusion

We tested whether providing explicit landmark information during the exploration of a novel environment would accommodate elderly pedestrians in becoming independent of navigation support systems. We found strong indications that this may be the case but we are reluctant to draw very strong conclusions given our small sample size (N = 10).

For example, we can not exclude the possibility that our experimental participants have used the method of path integration to navigate back to the starting point; all participants managed to return within a reasonable time, even though some used an entirely different route. In future experiments we plan to probe their representation of their location relative to "home" by having them set a dial in the direction of the home location at multiple points along the route. If they are capable of giving accurate estimations of the direction of the home position from a location where the home is not visible, then the path integration system is fully functional.

Furthermore, the residential area in Soesterberg that we used had clearly visible boundaries, so it was very hard to get lost in this area. Participants may have used their knowledge about the structure and size of Dutch residential neighborhoods in making decisions about their route. That can be considered a part of the cognitive collage of our participants that we had no control over.

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