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Improving navigation messages for mobile urban guides: Effects of the guide's interlocutor model, spatial abilities and use of landmarks on route description

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ABSTRACT

The aim of this study was to define guidelines for designing dialogue-based pedestrian guidance applications. It was based on an investigation of human–human interactions over the phone, where one speaker took on the role of the guide and the other that of the person being guided. During these interactions, a concurrent navigation in a real large-scale environment was performed by the guided member of the dyad. The content of the route descriptions produced by the guides was analyzed in terms of the latter's representations of their interlocutors' prior knowledge of the route environment, their spatial abilities and the landmarks they mentioned. The main results show that when the guided subjects had no prior knowledge of the environment, guides with high spatial abilities provided more *NLoc* landmarks (e.g. "there is a bar") than *ExoLoc* (e.g. "there is a bar to the right of the bank") and *EgoLoc* landmarks (e.g. "there is a bar on your left"). Conversely, guides with low spatial abilities gave just as many *NLoc* landmarks as *EgoLoc* landmarks. Practical applications stemming from these results are discussed.

Relevance to industry: This paper assesses the usefulness of taking spatial abilities, prior knowledge and landmarks into account when designing a new type of guidance application, namely a dialogue-based pedestrian guidance system. It also indicates the different ways in which these factors can be taken into account during the development of such applications.

1. Introduction

Mobile phones with an assisted global positioning system (A-GPS) have been developed by several telecommunications companies. This technology is similar to that used in GPS, in that the location of a mobile phone is pinpointed in relation to signals received from satellites. Compared with a classic GPS system, however, A-GPS can locate mobile phones faster and more accurately. A-GPS can therefore serve as a foundation for new types of applications which crucially depend on the system's ability to efficiently locate a user in his/her environment. This study focused on just one of these applications: that which delivers instructions to pedestrians who are navigating in an urban context. Two different guidance modes are implemented in the guidance applications currently available on mobile phones using A-GPS technology. The first one is dedicated to drivers (like a classic auto GPS), whereas the second one is dedicated to pedestrians. In the latter, the navigation is more detailed, referring to points of interest, such as banks or restaurants. Regardless of whether the user is a driver or a pedestrian, map guidance is supplemented with written and/or spoken instructions. A-GPS allows industries to develop guidance applications dedicated to pedestrians because it can accurately locate a mobile phone within 3–5 m, as opposed to 10 m for GPS, and this position is calculated in less than 2 s as opposed to 30 or 40 s for GPS.

However, the pedestrian guidance applications that are currently available contain roughly the same information as the driver guidance applications. The present study therefore sought to identify ways of improving these applications so that they would be better suited to the particular needs of the pedestrian population. To this end, a number of findings from studies concerning human navigation tasks are described below. These highlight several factors that could well be relevant to improve pedestrian guidance applications; namely the user's prior knowledge of the environment and the

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guide's spatial abilities with regard to the landmarks that are supplied.

1.1. Theoretical and practical issues

1.1.1. Impact of prior knowledge of the environment on route description

A guide is a person who has extensive knowledge of an environment. He/she guides someone who has less knowledge about that same environment (i.e. the guided person). This is a determining factor when producing a route description during an interaction, such as over the phone. This co-construction task requires the guide to infer what the person he/she has to guide already knows about the environment. Previous studies have shown that, in asymmetric dyads (expert vs. novice), experts try to adapt their explanations to the real or supposed level of knowledge of their interlocutor. In order to communicate effectively with novices, experts (in this case, the guides) must have an idea of what the novices already know about the topic of conversation (Nickerson, 1999; Nückles et al., 2006). This adaptation primarily concerns the lexical content and syntactic structure of the discourse. For example, Isaacs and Clark (1987) showed that New Yorkers tend to indicate New York City buildings differently, depending on whom they are talking to. When talking to other New Yorkers, they tend to use building names. When talking to non-New Yorkers, they tend to describe buildings instead of naming them (see also Fussell and Krauss, 1991; Krauss and Fussel, 1990).

In the context of route descriptions, there are two possible scenarios: (a) the guided person is not at all familiar with the environment, or (b) the guided person is partially familiar with the environment. During an interaction, the guide constructs an initial representation of his/her interlocutor which influences the content of the route description he/she goes on to produce. For example, several researches showed an effect of prior knowledge on route content by asking students who knew their campus well to describe a route to people who also knew the campus well and to others who did not. More specifically, experimenters asked students to deliver orally a route description intended for use by another student either with or without prior knowledge, and these descriptions were audiotaped (Denis, 1997; Grall and Visser, 2001). The results obtained by Grall and Visser (2001) showed that route descriptions addressed to people without any prior knowledge of the environment contained more intermediate landmarks (i.e. landmarks along the route, between two nodes) and more detailed descriptions about landmarks (i.e. landmark features, such as color and size). Denis' (1997) study allowed landmarks to be classified as follows:

- Non-located landmarks (*NLoc*) are landmarks that are given without anchoring them in the environment;
- Ego-located landmarks (*EgoLoc*) are landmarks that are located in relation to the position of the person being guided;
- Exo-located landmarks (*ExoLoc*) are landmarks that are located in relation to each other.

The proportion of each type of landmark appeared to be determined by the extent of the guided person's knowledge. When addressing people without any prior knowledge, subjects produced more *NLoc* landmarks ("there is a church") than *EgoLoc* (e.g. "there is a church on your left") and *ExoLoc* landmarks (e.g. "there is a bar to the right of the church"). In the present study, which takes prior knowledge of the environment into account, we expected to observe differences not only in the use of landmarks but also in the way they were described. In other words, route descriptions should follow the same pattern of landmarks as that described above and more landmark descriptions should be produced when the guided had no prior knowledge of the environment.

Given that prior knowledge of the environment changes the nature of the guide's descriptions, this could be exploited in the design of guidance applications. More specifically, applications could be developed to infer the guided person's level of prior knowledge of an environment. This could be based on a simple question, such as "Have you ever been here before?" followed by a more detailed information content (i.e. more landmarks and landmark descriptions) if they responded positively.

1.1.2. Impact of spatial abilities on route description

People can be categorized according to their level of spatial abilities, ranging from people with high spatial abilities to people with low spatial abilities. This factor is known to have an effect on route content (Vanetti and Allen, 1988; Denis, 1997), as navigating through an environment and following instructions transmitted by a third person is a wayfinding task (i.e. movement towards a specific target). The person who is navigating uses his/her spatial abilities in order to reach a destination (Passini, 1994). More specifically, wayfinding tasks rely on several cognitive abilities, including spatial and working memory abilities. In terms of spatial abilities, two main abilities can be distinguished: visualisation and spatial orientation (Lohman, 1979; Hegarty and Waller, 2004). In terms of working memory abilities, both visuo-spatial working memory and verbal working memory are especially important, as they can help to update the individual's position during the navigation, and are involved in both the production of route descriptions and their comprehension. For instance, Vanetti and Allen (1988) showed that people with low spatial and verbal abilities produce fewer landmarks when they have to describe a route than people with high spatial and verbal abilities (see also Denis, 1997). Similarly, Michon (2003) showed that visual landmarks are best memorized by people who have high visuo-spatial abilities, suggesting that the imaging process is involved in the comprehension and recall of route descriptions. However, Denis (1997) showed that routes produced by guides with high spatial abilities were not rated as being of the highest quality. Thus, route description quality is not solely dependent upon the guide's spatial abilities. One way of determining whether a route description has high informative value is to measure navigating time. When Daniel et al. (2003) manipulated route quality (using good and poor descriptions), they found that it took people provided with the poor version significantly longer to reach their destination than people provided with the good version.

For these reasons, spatial abilities were taken into account in the study presented here. Previous studies had been based on "experimental monologue conditions" (Denis, 1997; Michon, 2003), where there was no interaction between the people being guided and those doing the guiding. More specifically, guides were asked to describe a route either by writing it down or by delivering it orally on an answering machine. We took the view, however, that it was essential to determine whether the effect of spatial abilities on route content is reiterated in an interactive context. For this reason, the present study used an experimental protocol based on real interaction between a guide and a guided person. This choice was made in order to have a more ecological experimental protocol than those used in previous studies. Insofar as spatial abilities can have an effect on both landmark memorization and production, we expected that the guide's mental representations of the environment would differ in terms of the descriptive elements they contained, varying in both richness and comprehensiveness. As the guide's productions would mostly be based on their mental representations, these, too, would differ. In particular, we expected guides with high spatial abilities to produce more descriptive elements (such as landmarks) than guides with low spatial abilities.

Three different types of spatial knowledge are said to be necessary to build a complete mental representation of an environment (Siegel and White, 1975; Thorndyke and Hayes-Roth, 1982). The first one is called "landmark knowledge". This is acquired from direct or mediated experience of an environment and allows people to recognize an object (e.g. a landmark) or a place in an environment. For instance, in Paris, this object might be the Eiffel Tower or the Champs Elysées. However, this type of knowledge does not enable people to get from one landmark to another. Thus, a second type of spatial knowledge, called "route knowledge", is also necessary. This allows people to establish connections between several landmarks to form a unique route. This knowledge is dependent upon visual memory (Darken, 2000), as it arises when someone navigates in a given environment. As a result, navigation is based on an "egocentric reference" (Satalich, 1995). At this level, the person is not able to generate shortcuts. To do so, a final type of knowledge is necessary – "configurational knowledge". This knowledge allows objects to be located in space and the distances between them to be estimated. At this level, a person can go anywhere he/she wants within the environment, thanks to his/her cognitive map of it. This last type of knowledge is dependent upon spatial abilities, especially mental rotation (Darken and Petterson, 2002). Thus, we would expect guides with high spatial abilities to have better configurational knowledge than guides with low spatial abilities. In the present study, we expected to observe differences in the average patterns of landmarks (as described by Denis, 1997) according to the guide's spatial abilities. Guides with high spatial abilities (i.e. with better configurational knowledge) would produce more *ExoLoc* landmarks, located in relation to each other, than guides with low spatial abilities. Conversely, guides with low spatial abilities (i.e. with poorer configurational knowledge) would rely more on route knowledge and, consequently, would produce more *EgoLoc* landmarks, located in relation to the position of the guided person, than guides with high spatial abilities.

1.2. Present study and hypotheses

This study had a twofold aim: the first one was to replicate and extend the effect of the guided person's prior knowledge and the second one was to enhance our understanding on how a guide's spatial abilities influence his/her production of route descriptions. In short, the purpose of this study was to replicate the effects of these factors in an interactive context and to use these results to draw up guidelines for designers of pedestrian guidance systems.

The first hypothesis, in line with previous findings, was that guides would provide more landmarks and more landmark descriptions when addressing a guided person without any prior knowledge than when addressing a person with some prior knowledge of the environment (Grall and Visser, 2001). Similarly, the second hypothesis was that guides with high spatial abilities would produce more landmarks than guides with low spatial abilities (Denis, 1997). More specifically, in line with available results, we not only expected that *NLoc* landmarks would be used more than either *EgoLoc* or *ExoLoc* landmarks (Denis, 1997), but also that there would be differences in the use of landmarks according to the guide's level of spatial abilities (Denis, 1997; Michon, 2003; Vanetti and Allen, 1988). In this interactive context, where several experimental factors were brought into play, a final exploratory hypothesis also emerged. We thus expected to observe an interaction between: (a) landmark production, (b) the guided subjects' prior knowledge of the environment, and (c) the guide's spatial abilities. Whereas the guides would develop different ways of guiding according to the guided subjects' prior knowledge of the environment, this effect would be modulated by the guide's own spatial abilities insofar as these, too, have an impact on route content. Therefore, we might well call Denis' (1997) results into question, by demonstrating that the use of landmarks in guidance applications does not follow the average pattern he described (*Nloc* > *EgoLoc* > *ExoLoc*). Denis did not investigate the extent to which prior knowledge and/or spatial abilities may affect the proportion of landmarks produced by guides. We can therefore speculate that the needs of future users in terms of landmarks may differ from those observed by Denis (1997), especially if we take into consideration the results reported by Siegel and White (1975) and Thorndyke and Hayes-Roth (1982), concerning the existence of different types of spatial knowledge which are dependent upon spatial abilities. Taking these factors into account could help designers to develop pedestrian guidance applications by building in several different user profiles. Secondary objectives are to study how best to introduce the guided person's point of view in future studies, so that it could provide relevant clues to define which information needs to be delivered by the guidance application.

2. Method

2.1. Participants

Forty-eight people (11 women and 37 men) participated in the study (mean age = 22.56). Their level of education ranged from two years to seven years at university. Although it is admitted that there is a continuum in spatial abilities, in order to analyze the effect of this factor, the score of each participant was compared with the median score of the group (47) on the Minnesota Paper Form Board test (details in Section 2.2). This allowed us to categorize 26 participants as having high spatial abilities and 22 participants as having low spatial abilities.

2.2. Material, procedure and design

Guides were individually installed in an office. They were provided with a phone and a headset. In order to record conversations, the headset was connected up to a computer via a USB peripheral. The guided person was equipped with a mobile phone and earphones, so as to feel comfortable during the navigation. The phone interaction was recorded directly on a computer using Goldwave® software, which processes audio files.

In addition to this interaction situation, as previously indicated, guides had to perform a test in order to measure their spatial abilities: the Minnesota Paper Form Board (MPFB, Likert and Quasha, 1941). In this test, participants were shown a figure featuring separate geometric shapes. They were then presented with five complete figures, each assembled from smaller geometric shapes. They had to determine which one of these figures could be produced from the original set of shapes. Each participant had 20 min to solve as many problems as possible out of 64.

Guide's spatial abilities were regarded as a between-participants factor. This factor had two modalities: high spatial abilities and low spatial abilities (Spatial low vs. Spatial high). Participants were compared according to their spatial abilities: the MPFB score of each participant was compared with the median score of the whole group. The interlocutor's prior knowledge of the environment was manipulated as a between-participants factor. This variable had two modalities: with and without prior knowledge of the environment (K+ vs. K−). A confederate played the role of the guided person. Thus, regardless of the experimental condition, the guided person was the same for every guide and was introduced as being lost. Two conditions were used to simulate different levels of the guided person's prior knowledge of the environment. For half the time, the guided person introduced himself as having no prior knowledge of the environment (K−: "*I have never been in the France Telecom headquarters before. A friend of mine told me how to get out of here, but I got lost*"), whereas for the remaining time, the guided introduced himself as having some knowledge of the environment (K+: "*I have been in the France Telecom headquarters before, but this is the first time I've been in this part. A friend of mine told me how to get out of here, but I got lost*").

Participants with prior knowledge of the environment, who played the role of guides, were asked to describe a route, while the guided person was asked to follow it (neither the guide nor the person being guided was provided with geographical information). More specifically, the guides were asked to provide the guided person with items of information from memory, since they had extended knowledge of the environment in question (their workplace). The route was expected to take 10 min and was 1000 m long.

2.3. Analytical method

Every route description that was produced was transcribed. Afterwards, these transcriptions were analyzed in relation to the categorization defined by Denis (1997), which allows a precise characterization of route description contents. According to this categorization, landmarks are differentiated from prescribed actions. Landmarks consist primarily of three-dimensional physical objects. They can be either natural components of the environment (e.g. church, bus stop) or artefacts designed to indicate directions (e.g. signposts). They can also be two-dimensional entities on which movements are carried out (e.g. streets, parks, roads). Three ways of delivering landmarks have been identified: (a) landmarks given without any further indication of their location (referred to here as *NLoc*; e.g. "there is a church"); (b) landmarks introduced with an explicit reference to their spatial location with regard to an egocentric point of reference (*EgoLoc*; e.g. "there is a church on your left"); and (c) landmarks introduced by making reference to another previously introduced landmark (*ExoLoc*; e.g. "there is a bar to the right of the church").

Prescribed actions are intended to convey the idea of movement. More specifically, they define the directions to follow. Two main categories of propositions for prescribing actions have been identified: (a) without any reference to a landmark, expressing the idea of progression (e.g. "go straight on") or reorientation (e.g. "turn right") and (b) with reference to a landmark (e.g. "go to X", "cross X", where X is a landmark). Two further categories were defined. The first one contained descriptions of the visual characteristics of landmarks that had previously been introduced, such as their color or size (e.g. "there is a blue bar called Espariat") and the last one contained a few propositions, which were essentially commentaries about distances and durations (e.g. "you should be there in a few meters/minutes").

2.4. Dependent measures

We recorded the number of occurrences of each descriptive category (using Denis' (1997) categorization). These included *NLoc landmarks* ("*there is a bar*"), *EgoLoc* landmarks ("there is a bar on your left") and *ExoLoc* landmarks ("*there is a bar close to the church*"). Two additional descriptive categories were recorded: commentaries ("*it will take almost 15 min*" or "*walk on for a further 50 m*") and landmark descriptions ("*it is a large, pink-colored building*"). Finally, time-on-task (s) was recorded.

3. Results

3.1. Landmark categories

The data were analyzed with an ANOVA, with prior knowledge and visuo-spatial ability as between-participants factors and landmarks as a within-participants factor. Results are set out in Fig. 1.

The analysis revealed a main effect of the interlocutor's prior knowledge on the use of landmarks ($F(1,44) = 9.05$, MSE = 5.68, $p < .01$, partial $\eta^2 = .171$) and a main effect of the landmarks ($F(2,88) = 22.47$, MSE = 4.06, $p < .001$, partial $\eta^2 = .338$). Guides produced more landmarks when they interacted under condition K− than under condition K+. *NLoc* landmarks were used more than *EgoLoc* landmarks and *ExoLoc* landmarks. Moreover, the landmarks × prior knowledge × spatial abilities interaction was significant ($F(2,88) = 3.27$, MSE = 4.06, $p < .05$, partial $\eta^2 = .069$). Planned comparisons revealed that, under condition K+, regardless of the guide's spatial abilities, *NLoc* landmarks were used more than *EgoLoc* and *ExoLoc* landmarks ($F(1,44) = 7.07$, MSE = 5.45, $p = .01$

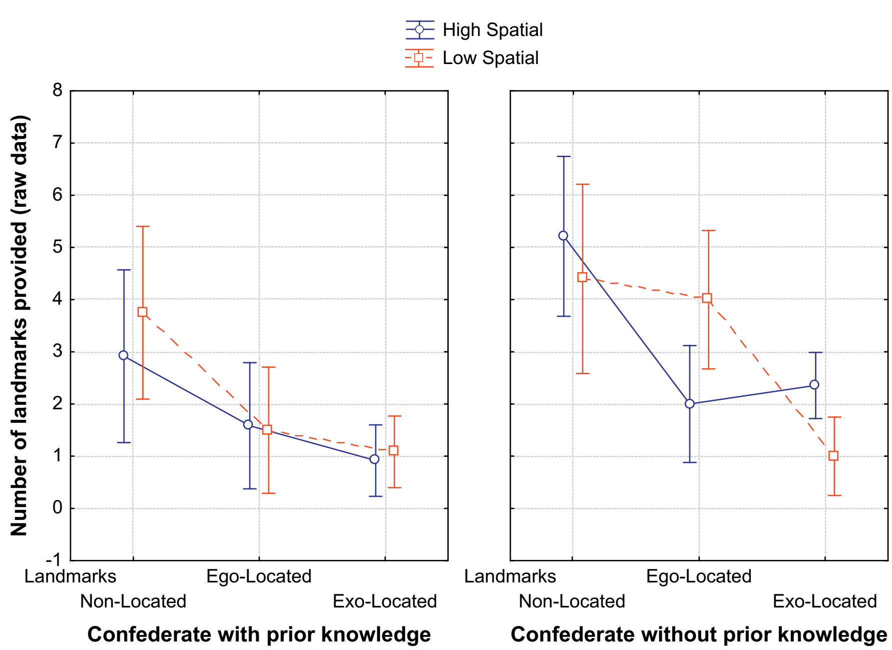

Fig. 1. Means (standard deviations) for content categories according to the degree of prior knowledge of the environment assigned to the guided user and the spatial abilities of the guides.

and $F(1,44) = 45.78$, MSE = 4.92, $p < .001$ respectively). Conversely, under condition K−, guides with low spatial abilities produced more *EgoLoc* landmarks and fewer *ExoLoc* landmarks than guides with high spatial abilities ($F(1,44) = 5.41$, MSE = 4.31, $p < .05$ and $F(1,44) = 7.74$, $p < .01$ respectively), whereas guides with high spatial abilities produced more *ExoLoc* landmarks than guides with low spatial abilities ($F(1,44) = 7.74$, MSE = 7.74, $p < .01$).

3.2. Time-on-task, commentaries, landmark descriptions

The data were analyzed with an ANOVA, with prior knowledge and visuo-spatial ability as between-participants factors (see Table 1).

The analysis failed to reveal any significant difference in time-on-task ($F_s(1,44) < 1$). However, one main effect was observed: the interlocutor's prior knowledge influenced both the use of commentaries ($F(1,44) = 6.94$, MSE = 1.31, $p < .05$, partial $\eta^2 = .136$) and landmark descriptions ($F(1,44) = 4.74$, MSE = 6.90, $p < .05$, partial $\eta^2 = .097$). Guides produced more commentaries and fewer landmark descriptions when they interacted with K+ guided subjects ($M = 1.79$, S.D. = 1.38 and $M = 3.21$, S.D. = 2.15 for commentaries and landmark descriptions respectively) than when they interacted with K− guided subjects ($M = .92$, S.D. = .78 and $M = 4.92$, S.D. = 2.95). No other comparison reached statistical significance. In other words, guides described more landmark features (“it is a large, pink building”) when they interacted with K− subjects. Conversely, guides provided more time and distance estimates when interacting with K+ subjects (“it's not far from here”, “walk for 50 m”).

4. Discussion

This study was designed to analyze route description content in order to define guidelines for the design of phone-based pedestrian guidance applications. Analysis of the interactive context studied here produced two important findings.

First, the results showed that the interlocutor model (K+/K−) does indeed have an effect on route description content, in line with previous findings (Grall and Visser, 2001). More specifically, route descriptions contained more landmarks and more detailed descriptions of these landmarks when the interlocutor had no prior knowledge of the environment. Several different patterns of landmarks used in route descriptions were also identified: *NLoc* landmarks were most frequently used followed by *EgoLoc* and then *ExoLoc* landmarks. Thus, the importance of landmarks in route descriptions has been demonstrated not only in monologues situations (Denis, 1997) but also, as in our study, in an interactive context. Since *NLoc* landmarks were the ones most frequently used, it might be useful to include this type of landmark in pedestrian guidance systems. However, landmark occurrences differed according to the guide's spatial abilities (this point is discussed in the following paragraphs). The results suggest that, when interacting with a user who has some prior knowledge, the system should give him/her an estimate of time and distance. The reason for this is that people without any knowledge of the environment do not know it well enough to exploit this type of information efficiently, in contrast to people who do have some prior knowledge of the environment.

The pedestrian guidance applications that are currently available mostly signal points of interest in which typical errands can be carried out (e.g. restaurants, banks or monuments that can be visited). The results of the present study suggest that landmarks considered relevant for pedestrian guidance systems should include any store or business that is encountered by the guided person along his/her route (bar, bakery, etc.), as well as visible monuments (merry-go-round, fountain, etc.). Thus, this study highlights the fact that pedestrian guidance systems should be critically based on “microscopic” information, which is not necessarily the case for driver guidance systems. This microscopic information, featuring the type of landmarks identified in this study, would help to reduce the uncertainties and ambiguities that are an integral part of wayfinding tasks in dynamically changing situations. Similarly, it might be useful to offer pedestrians an opportunity to obtain descriptive information about the environment through which they are navigating, especially about the landmarks they are likely to meet along the way. These items of information would reassure them about the route they had chosen, by helping them to compare and match the environment in front of their eyes with the environment being described by the guide. It would help them to feel more confident in their interaction with the guidance application and also avoid difficulties in calculating distances. The pedestrian guidance systems that are currently available are mostly based on distance estimates (e.g. “after 50 m, turn right”), but this type of information does not appear to suit every person's needs, since the guides, in the present study, only supplied this sort of information to the people being guided who had a degree of prior knowledge (using the “commentaries” category). Previous studies have already showed that this type of content is very rarely included in route descriptions produced by humans (Denis, 1997). One way of reducing this discrepancy between users' needs (between K+ vs. K−) would be to give landmark descriptions to people with no prior knowledge of the environment (i.e. describing the features of landmarks they will encounter along their route). This would match the behavior we observed in the guides.

These results can also be interpreted as highlighting the way that the expert (here, the guide) adapts to the characteristics of his/her interlocutor (Bonnardel, 1993; Isaacs and Clark, 1987). This type of human behavior should be taken into account in order to develop guidance applications for pedestrians that are both easy to use and satisfying for users.

Second, no significant difference was found in the quality of route descriptions in terms of navigation time. However, the types of landmarks that were produced differed according to the manipulated factors. More specifically, our study calls previous results into question concerning the effect of spatial abilities on route description content. Unlike previous studies (Denis, 1997; Michon, 2003), the obtained results did not indicate that guides with low spatial abilities provided significantly fewer landmarks than guides with high spatial abilities. Nevertheless, under condition K−, we did observe an interaction between (a) spatial abilities, (b) knowledge of the environment and (c) use of landmarks. More specifically, guides with low spatial abilities produced more *EgoLoc* landmarks, whereas guides with high spatial abilities produced more *ExoLoc* landmarks. Thus, depending on their spatial abilities, guides describe the environment differently according to their interlocutor's prior knowledge of it. The fact that guides with high spatial abilities gave more *ExoLoc* landmarks to interlocutors without any prior knowledge suggests that they used their configurational knowledge to supply a more elaborated description

Table 1
Means (standard deviations) for content categories and navigation times according to the degree of prior knowledge of the environment assigned to the guided user and the spatial abilities of the guides.

Prior knowledge	With		Without	
Spatial abilities	Spatial +	Spatial −	Spatial +	Spatial −
Commentaries	1.83 (.33)	1.75 (.33)	.92 (.30)	.90 (.36)
Landmark descriptions	3.33 (.75)	3.08 (.75)	5.14 (.70)	4.60 (.83)
Navigation times	404.33 (49.40)	438.16 (38.34)	439.14 (38.10)	429.90 (35.44)

of the environment by describing its layout (Siegel and White, 1975; Thorndyke and Hayes-Roth, 1982). Guides with high spatial abilities may give more *ExoLoc* landmarks (situating landmarks in relation to each other) in order to ensure that the person in situ will easily find the location being described. This type of description could be a mark of good configurational knowledge of the environment and, thus, of a good cognitive map. In contrast, the fact that guides with low spatial abilities processed requests differently, giving more *EgoLoc* landmarks under condition K−, may be a sign that they had to make an effort to describe the environment and that their route description was based not on their configurational knowledge but rather on their route knowledge.

In the present study, under condition K−, whereas guides with high spatial abilities described the surroundings of a given landmark, guides with low spatial abilities did not describe the environment's layout, but instead made an effort to describe the environment from the guided person's point of view. This supports the results obtained in Isaacs and Clark's (1987) study, in which New Yorkers used longer descriptions to identify buildings for non-New Yorkers, whereas for New Yorkers, they simply used the names of buildings. It is as if guides with high spatial abilities tried to make K− users picture the whole environment and tried to help them to build a rich mental representation of it. In contrast, guides with low spatial abilities concentrated on making them move forward along the route, describing landmarks according to the guided person's actual body position. A parallel can be drawn with the two processes which, according to Sholl (1996), are activated during human navigation and make it easier to develop the spatial knowledge described above. The first process, which may be preferred by guides with low spatial abilities, is based on self-object relationships, which are dynamically modified when a movement occurs (i.e. via an egocentric reference). The second process, which may be preferred by guides with high spatial abilities, is based on object–object relationships, which are more stable and anchored in their cognitive map.

These differences in description modes could prove useful to designers of pedestrian guidance applications, in that they could help them to define how a system should deliver landmarks to users. Three presentation formats could be used in such applications:

- landmarks without references,
- landmarks in relation to other landmarks,
- landmarks in relation to the actual position of the guided person.

These presentation formats would then have to be tested in order to determine their effect on the navigational performance of guided individuals. Thus, our results and those of future studies will enhance wayfinding effectiveness and increase the satisfaction of future users of guidance applications.

5. Conclusion

The study presented in this paper was based on an interactive context, which allowed route descriptions to be analyzed in a more ecological situation than in previous studies in this area. It also went one step further, by identifying the ways in which route descriptions vary according to the guided person's prior knowledge of the environment. This study helped to clarify the fact that a route description is composed of guidance instructions which have to be modulated according to the guided person's prior knowledge of the environment.

Our study highlighted the crucial importance of taking landmarks into account in navigation. Its originality lay in its emphasis on the fact that landmarks do not have to be restricted to banks or restaurants, and can also take the form of more contextual cues (e.g. a bar, a bakery or a fountain). By delivering contextual landmarks along the route, a pedestrian guidance application could reassure the user by confirming that he/she is heading in the right direction. Concerning the use of landmarks in pedestrian guidance applications, our results underline the importance of how a landmark is anchored in space. Furthermore, we demonstrated an effect of the interaction between spatial abilities and prior knowledge on landmark production.

These factors need to be considered together and could lead to the definition of several different user profiles. This finding could boost the development of guidance applications whose content is adapted according to the characteristics of the person being guided. More specifically, this study highlights the fact that visuo-spatial abilities, being a differential factor, can explain why there are several different ways of describing the environment in order to guide someone. Accordingly, additional research centered on users' visuo-spatial abilities could prove relevant to the design of pedestrian navigation assistance systems. Guidance applications should be adaptive systems, which dynamically adapt their content to their users' characteristics. More specifically, if the system can infer the user's level of prior knowledge and his/her spatial abilities, the number of landmarks and the way they are anchored (without an anchor vs. in relation to the user's body vs. in relation to other landmarks) can be varied in order to meet the needs of each individual user. If the design of a guidance system is based on someone elaborating a representation of an environment, a number of guidelines could be drawn up, according to the results obtained here. First, adding landmarks to guidance information would appear to be crucial. Moreover, it seems that *EgoLoc* landmarks should be the landmarks most frequently used in a guidance application. Another way of delivering descriptive information would be to add descriptions of landmarks, such as their size and color. All this information could be regarded as confirmatory feedback, helping users to feel more confident about the direction they have to follow. To confirm our results, these results now need to be replicated in other experimental conditions. This particular study focused on route production, but we believe that route comprehension also needs to be studied, together with the way it can be affected by users' spatial abilities. This aim could be achieved by studying interactions between a guide and a guided person according to their respective spatial abilities. This would help us to understand the extent to which the interlocutor's spatial abilities can (positively and/or negatively) affect route production and comprehension. Future research will make it possible to study relationships between the production and comprehension of route descriptions, as well as the effect of spatial abilities on both these aspects.

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