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Landmarks' use in speech map navigation tasks

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A B S T R A C T

Tools for assisting human navigation, especially in-vehicle systems, have been extensively investigated. However, few studies have explored the design of speech-based over-the-phone guidance systems. This study examined the effect of landmarks' use and the effect of landmarks' frames of reference in route instructions on navigation efficiency during map navigation tasks and satisfaction. Twenty-seven participants performed map navigation tasks using a simulated speech navigation system in three experimental conditions: instructions containing no landmarks, instructions containing landmarks located without reference to either the traveler's body or the surrounding environment, and instructions containing landmarks located with respect to the traveler's body. Navigation performances on maps were higher and landmarks enable participants to make fewer directional errors and find their routes more efficiently. Satisfaction levels and navigation performances were lower when instructions did not contain any landmarks. Landmarks' frames of reference shifting turned out to be different between human–human situations previously used and human–computer situations used here.

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. However, A-GPS can locate mobile phones faster and more accurately than classic GPS systems. A-GPS can therefore serve as the basis for new types of applications which crucially depend on the system's ability to efficiently locate a user in his or her environment. This study focuses on the applications which deliver guiding instructions to users (pedestrians or drivers) who are navigating in an urban context.

Two different guidance modes are implemented in the guidance applications that are currently available on A-GPS enabled mobile phones. The first one is dedicated to drivers (like a classic in-car GPS), whereas the second one is dedicated to pedestrians. In the latter, the navigation needs to be more detailed, by referring to points of interest, such as banks or restaurants. Yet, most guidance applications that are currently available contain very few landmarks (Millonig & Schechtner, 2007). Though, different types of landmarks could be used during navigation tasks. The present work therefore sought to highlight which landmarks should be implemented in navigation systems in order to improve both navigation performances and users satisfaction. To this end, we administered map navigation tasks designed to elucidate the role of landmarks, according to the frame of reference they refer to, in human navigation.

1.1. Route description content

A route description contains the steps that have to be followed in order to move from an initial location to a destination, and explains the actions that must be performed at different points along the way. A route description is therefore based on the combined use of actions (e.g., turn right, turn left, go straight ahead, etc.) and landmarks (e.g., a church, a bar, etc.) (Denis, 1997) and can be studied with regard to the lexical content produced by the guide. A guide is a person with extensive knowledge of an environment, who helps another person being guided (i.e., someone with less knowledge of the same environment) to navigate in this environment. This is a determining factor for designing a route description during an interaction, say over the phone (Nickerson, 1999; Nückles, Winter, Wittwer, Herbert, & Hübner, 2006). This co-construction task requires the guide to infer what the person he or she has to guide already knows about the environment in question, in order to communicate efficiently (Nickerson, 1999; Nückles et al., 2006). In

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this type of asymmetric dyad (expert vs. novice), the expert has to try and adapt his or her explanations (i.e., the lexical content) to the real or supposed level of knowledge of the interlocutor. For example, Isaacs and Clark (1987) showed that in pictures' description tasks, New Yorkers tend to describe pictures differently depending on whom they are talking to. When talking to other New Yorkers, they tend to use building names and focused their descriptions on the location they described (e.g. "it's a big building"). Whereas when talking to non-New Yorkers, they tend to describe some pictures' characteristics (e.g. "it's a picture of a building") (see also Fussell & Krauss, 1991; Krauss & Fussell, 1990).

In the context of route descriptions, the person being guided does not know the environment at all, or has partial knowledge of the environment. During the production of a route description in the course of an interaction, the guide constructs an initial representation of his or her interlocutor. This representation will have an effect on the route description content that is subsequently produced by the guide. In most studies of route description, experimenters ask students to deliver orally a route description intended for another student who is supposed to have either some existing knowledge or no knowledge at all (e.g., Denis, 1997; Grall & Visser, 2001). For instance, Grall and Visser asked students who knew their campus well to describe a route to people who also knew the campus well and to others who did not. The results showed that route descriptions addressed to people without any initial knowledge of the environment contained more intermediate landmarks (i.e., landmarks along the route, between two nodes) and more details about these landmarks (e.g., their size and colour) than descriptions addressed to people with existing knowledge of the environment.

Studies of route description contents have also shown that they contain *descriptive* components (i.e., landmarks) as well as *prescriptive* ones (i.e., actions). The classification of landmarks proposed by Denis (1997), allows us to distinguish between three types of landmarks:

(a) Landmarks which are delivered without being located either with respect to the traveler's body or with respect to other landmarks;
(b) Landmarks which are located with respect to the traveler's body;
(c) Landmarks which are located with respect to other landmarks.

Denis (1997), as well as Roger, Bonnardel, and Le Bigot (2009), showed that the proportion of each type of landmark is dependent on their types. When addressing to people without previous knowledge, more landmarks with no explicit specification on their position (e.g., "*there is a church*") are produced than landmarks located with respect to the traveler's body (e.g., "*to your left there is a church*") and landmarks located with respect to other landmarks (e.g., "*to the right of the church there is a bar*"). This is true in real navigation (Roger et al., 2009) as well as in imagined navigation (Denis, 1997).

Such studies show that a great many landmarks and different types of landmarks are naturally produced to guide people who have no initial knowledge of an environment. Landmarks very certainly have an effect on guiding systems users' efficiency and satisfaction. However, the use of landmarks in these systems must lean on frames of reference's studies insofar as they are focused on objects' localization either according to other objects' position or according to people's position in the environment.

1.2. Spatial perspectives and landmarks' frames of reference use

Spatial frames of reference are coordination systems that enable to localize objects and spatial relations between these objects (Shelton & McNamara, 2001). Landmarks that have been studied in route description context reflect different strategies that a speaker can use to talk about space. Indeed, when someone describes large scale environments (i.e. environments too large to be seen in one glance) he or she mainly uses two spatial perspectives (Taylor & Tversky, 1992, 1996). In the first one, route perspective, the environment is described from the changing viewpoint of a traveler in the environment, typically called "you". Objects are described relative to the traveler's position in terms of "your" left, right, front, and back (Perrig & Kintsch, 1985; Taylor & Tversky, 1992, 1996). A relative spatial frame of reference is thus used in this perspective. According to Levinson (1996), a route perspective uses an addressee-centered frame of reference in which the traveler is the referent. In the second one, called survey perspective, the speaker takes a fixed viewpoint above the environment and describes objects relative to other objects using environmental directions, north, south, east, and west (e. g., Perrig & Kintsch, 1985; Taylor & Tversky, 1992, 1996; Tversky, Lee, & Mainwaring, 1999). The survey perspective uses an allocentric frame of reference, called "absolute" (Levinson, 1996) or "environment-centered" (Taylor & Tversky, 1996). Moreover, the way people learn about space can affect spatial strategies they use. Maps usually enhance survey perspective insofar as it can be seen from one viewpoint and it gives a representation of the environment from above. On the opposite, real navigation usually enhances route perspective insofar as it implies an imaginary tour of the environment from different viewpoints (Tversky, 1996).

Spatial descriptions can be either egocentric (also called deictic) or intrinsic (Levinson, 1996). Egocentric spatial descriptions use term depending on the speaker viewpoint and also depending on when and where he or she is talking (e.g. mine, here, left, right, etc.). Intrinsic spatial descriptions use another viewpoint than the speaker, usually the addressee's or objects' viewpoint. In route description, Denis (1997) asked students to write a route description dedicated to people with no initial knowledge of the environment. He then studied route descriptions' content, allowing him to identify two different kinds of intrinsic landmarks (corresponding to 51, 6% of guiding instructions produced). In both cases speaker explicitly uses a specific frame of reference. More precisely, 35, 6% instructions (out of 51, 6%), contained landmarks located with respect to the traveler's body (e.g. "*you will see a church on your right*") and 16% of instructions (out of 51, 6%) contained landmarks located with respect to other landmarks (e.g. "*to the right of this church, you will see a bar*"). On the opposite, 48, 6% of landmarks produced in Denis' corpus did not refer to any frame of reference, they were located without being located with respect to the traveler's position or with respect to any other landmarks (e.g.: "*you will see a bar*"). This last type of landmark questions the type of frame of reference they refer to. Indeed, instructions such as "*there is a bar nearby*" can be true no matter what the speakers' frames of reference are. Such descriptions have been called "*local references without a coordinate system*" (Levelt, 1989) or "*neutral with respect to frame of reference*" (Schober, 1995). The opposition between egocentric and intrinsic descriptions is therefore not precise enough to cover the whole possibilities people have to describe space. Schober (1995) thus identified six different spatial perspectives in human–human situations: 1) speaker-centered (also called egocentric or deictic), 2) addressee-centered (intrinsic), 3) object-centered (intrinsic), 4) both-centered (ambiguous with respect to addressee's or speaker's frame of reference, 5) environment-centered (extrinsic), and 6) neutral (no frame of reference can be chosen). Thereby, landmarks in Denis' corpus that refer to the traveler's body can be considered as addressee-centered; landmarks that refer to other objects can be considered as object-centered and landmarks that did not refer to any frame of reference can be considered as neutral.

The way people navigate in an environment is based on wayfinding. Wayfinding is "*the process of determining and following a path or route between an origin and a destination*" (Golledge, 1999). People can learn about and understand a new environment either (a) through empirical navigation within that environment or (b) through symbolic navigation using environmental representations, such as maps, pictures, etc. Wayfinding relies on a mental representation of the environment (Wickens & Carswell, 1987), and three kinds of spatial knowledge appear to be necessary to construct this representation: landmark, route and survey knowledge (for further details, see Passini, 1992; Satalich, 1995; Thorndyke & Hayes-Roth, 1982). These three kinds of knowledge can be acquired from direct navigation but also from map exploration (Gale, 1990; Golledge, 1999; Waller, Hunt, & Knapp, 1998). Route knowledge (i.e. knowledge based on landmarks) is the one that is especially developed, when people do not have initial knowledge of the environment to travel (Münzer, Zimmer, Schwalm, Baus, & Alsan; 2006). Therefore, in this case, landmarks should play an important part during map tracing tasks especially when tasks are performed by people with no initial knowledge.

Previous studies showed that, in route description tasks (during imagined or real navigation) dedicated to people with no initial of the environment, the descriptions contained more neutral landmarks followed by addressee-centered landmarks (Denis, 1997; Roger et al., 2009). It is then expected that neutral and addressee-centered landmarks should be the most relevant landmarks in map navigation tasks performed by people with no initial knowledge of the environment. However, would it still be true in map navigation tasks? The fact of associating a paper map, which entails an allocentric viewpoint of the environment, to landmarks that can refer to a different viewpoint could have an effect on navigation performances. Indeed, map and guiding instructions need to be aligned (i.e. use the same frame of reference) in order to enable satisfying navigation performances. Then, the fact of using neutral landmarks in guiding instructions should increase both navigation performances and satisfaction insofar as they enable to align the map with the guiding instructions. Indeed, neutral landmarks, by not referring to any explicit frame of reference, do not require people to match the allocentric paper map's view to what is heard (i.e. they should be directly accessible). According to Schober (1995) the advantage of neutral frame of reference stems from the fact that they do not imply any shifting of frame of reference to be understood. Likewise, insofar as Miller and Johnson-Laird (1976) showed that addressee find it easier to understand a description from their own point of view, addressee-centered landmarks should thus be relevant in route description assistance systems. However, although addressee-landmarks should more efficient, to understand during real navigation (since real navigation entails a route perspective of the environment), it should not be the case during map navigation tasks assisted by a speech navigation system. In these situations, participants have to align landmarks' frames of reference (i.e. an intrinsic viewpoint of the environment) to the allocentric map's viewpoint. In short, a) paper maps usually help individual to develop survey views of the environment to travel, since they inherently represent an allocentric view of the environment (e.g., Denis & Zimmer, 1992; Thorndyke & Hayes-Roth, 1982). On the opposite, b) addressee-centered landmarks imply an intrinsic view of the environment. So, addressee-centered landmarks should result in a decrease of navigation performances, by requiring shifting of frame of reference between landmarks' frame of reference and paper maps' frame of reference.

1.3. Present study

By manipulating the types of landmarks indicated to participants, the aim of our study was to investigate the effects of landmarks' frames of reference shifting during map navigation tasks, when using a simulated speech-based over-the-phone guidance system. We used a Wizard-of-Oz (WOZ) setting in order to simulate the system. With this technique, a human confederate simulates the functionalities of a real system (Fraser & Gilbert, 1991). The participant does not know that the system is simulated. The confederate thus handles the participant's request and sends, him or her, the appropriate answer. To test the system, a series of map navigation tasks were designed and analyzed. To this ends, we set out (a) to determine whether landmarks play a decisive role in human navigation, by observing their effect on navigation efficiency and satisfaction during map navigation tasks, and (b) to determine which frames of reference should be use to introduce landmarks in speech-based over-the-phone guidance systems. Our working assumptions were (a) that landmarks would improve navigation efficiency and satisfaction and (b) that landmarks' frames of reference would have an effect on navigation efficiency and satisfaction. In other words, assuming that landmarks do indeed improve navigation efficiency and satisfaction, it was expected that the indicators usually used to measure navigation performances in route description studies, such as the time taken to complete the task or the number of directional errors and hesitations (see Denis, Pazzaglia, Cornoldi, & Bertolo, 1999; Tom & Denis, 2003), would decrease when the system delivered landmarks. In the same way, assuming that the fact of shifting frames of reference can affect navigation, it was expected that addressee-centered landmarks should decrease navigation performances whereas neutral landmarks should increase them (Schober, 1995). Drawing actions were also analyzed, to determine whether performances were improved by the inclusion of landmarks. In line with studies conducted by Tversky and Lee (1998, 1999), each pen movement was classified as right, left, straight ahead or backward (i.e., a correction, when participants went back along a line they had previously drawn). Then, the total number of drawing actions (including corrections) and the number of efficient drawing actions (excluding corrections) were calculated. Finally, it was also expected that user satisfaction (i.e., general satisfaction, instruction formulation preferences) would increase when landmarks were included (see, for instance, Alm, Nilsson, Järmark, Savelid, & Hennings, 1992; Bengler, Haller, & Zimmer, 1994; May, Ross, & Osman, 2005).

2. Method

2.1. Participants

Twenty-seven participants (14 men and 13 women) took part in the experiment. Participants were adults recruited through a volunteers' database. Their average age was 29.37 years ($SD = 10.13$). The participants received a shopping voucher to thank them for taking part in this study.

2.2. Material

2.2.1. Maps and drawing equipment

Ten special event maps were selected (e.g., university fair, car show, etc.). One of these maps was used for the familiarization phase, while the nine remaining maps used for the test were modified by adding several icons representing landmarks (e.g., first-aid station, WiFi hotspot, cloakroom, etc. see an example, Fig. 1). These included experimental landmarks (i.e., manipulated landmarks mentioned in the instructions) and extra landmarks (i.e., landmarks that did not aid navigation as they were not included in the instructions). The latter were used to make sure that the experimental landmarks were not too visually salient in the maps.

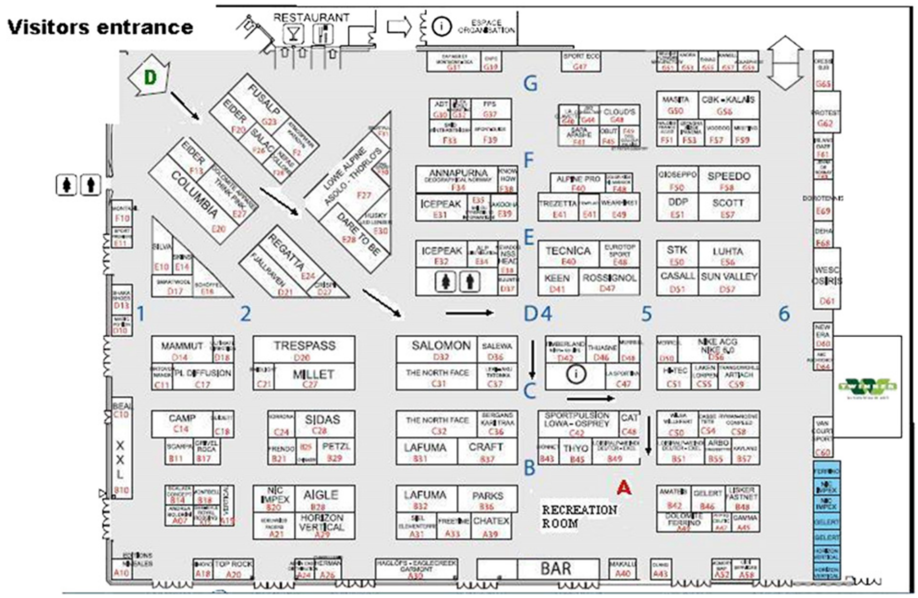

Fig. 1. Map sample with the example of route to be followed corresponding to the one presented in Table 1. On the map, on the left corner, the green "D" represents the departure point. On the right bottom, the red "A" represents the arrival point. Finally, the black arrows represent the route to be followed. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

Maps measured 90 × 120 cm and were colored. They were placed on the test table in front of the participant, together with a whiteboard pen for drawing the routes. Maps were plastic-coated, so that all the routes could be drawn on the same original maps (i.e., the whiteboard pen marks could be erased after each task).

2.2.2. Routes and simulated guidance system

Three routes were created for each map. Each route nominally needed five pen movements to be completed, corresponding to five instructions. Only the second, third and fifth instructions contained a manipulated landmark (see an example in Table 1). Each manipulated landmarks' formulation is detailed in the section below.

The simulated guidance system could be divided into two parts: (a) the recordings of the oral instructions and (b) the vocal commands used by participants to obtain the information.

For each route, instructions were designed and synthesized using SPOweb software and then recorded as .wav files. Three versions of these instructions were recorded (underlined text below), corresponding to the three experimental conditions: (a) instructions with addressee-centered landmarks (e.g., "turn into the second hallway, <u>the cloakroom will be on your left</u>") and (b) instructions with neutral landmarks (e.g., "turn into the second hallway, <u>there will be a cloakroom close by</u>"); (c) instructions without landmarks (e.g., "turn right into the second hallway that bears off the left"). In order to increase variability between instructions, each version was recorded in three different verbal forms: infinitive, imperative and mixed (i.e., a route containing three infinitive instructions and two imperative ones, or vice-versa). In addition, instructions that were not manipulated (see Table 1) had the same content and number of words across all the conditions, and there was the same number of words in each manipulated instruction and in each version.

Five vocal commands were available to participants. "Repeat" enabled them to listen again to the instruction they had just heard, "Next" enabled them to listen to the next instruction, "Previous" enabled them to go back to the previous instruction, "Summary" enabled them to hear the list of commands, and "Restart" enabled them to start all over again from the beginning.

Table 1
Example of route delivered by the simulated system (see Fig. 1 to get the corresponding map).

Position	Instruction	Type of instruction
1	Go straight ahead	Not manipulated
2	Turn left into the second hallway, you will see the rest room	Experimental
3	Turn right into the first hallway	Not manipulated
4	Take an immediate left, you will see an information centre close by	Experimental
5	Turn right into the first hallway	Not manipulated
6	You have now arrived at the recreation room	Not manipulated

2.2.3. Questionnaires

General satisfaction questionnaire. Four statements were extracted from a questionnaire developed by Le Bigot, Rouet, and Jamet (2007). This questionnaire was designed to examine the participants' degree of satisfaction with the usability of the simulated guidance system. Three statements were used to assess participants' general satisfaction ("The service was easy to navigate"; "In general, I was satisfied with the service"; "I obtained the expected instructions"), while the fourth one, insofar as instruction contents were manipulated, concerned the subjective quantity of information that was delivered ("I found that the system gave me a lot of information"). The participants gave their answers on a 5-point Likert scale ranging from 1 (I don't agree at all) to 5 (I agree completely).

Formulation preference questionnaire. This questionnaire was designed to gauge participants' preferences for the different instruction contents (see examples in Table 2). It contained four questions, each featuring four versions of the instructions (corresponding to Denis' classification of landmarks, i.e., including object-centered landmarks even though they were not manipulated here). For each question, participants were asked to select their favorite version. In order to increase variability between versions, each question could be formulated in either the infinitive or the imperative. However, instruction length was the same across all

Table 2
Example of a formulation preference question.

Type of landmarks	Instruction formulation
No landmarks	Turn immediately right into the second hallway that bears off to the left
Neutral landmark	Turn immediately right into the second hallway, there will be a cloakroom nearby
Addressee-centered landmark	Turn right into the second hallway, the cloakroom will be on your left
Object-centered landmark	Turn right into the second hallway, the cloakroom is close to the Exit

four content conditions. The instruction versions and the order of the questions were counterbalanced across the questionnaires.

2.2.4. Recording equipment

Each participant was equipped with a land phone and a headset, so as to feel comfortable during the test. A camera recorded each participant during the test. The experimenter playing the "Wizard" was also equipped with a land phone and headset. In order to record the interaction between the simulated system and the participants, the headsets were connected to a computer (via a USB peripheral). The phone interaction was recorded directly using GoldWave® software, which processes audio files.

2.2.5. Procedure

Participants were tested individually in a quiet room, which was partitioned into a control room, where the experimenter monitored the simulated system, and a test room for participants. The task consisted in drawing routes on several maps, assisted by spoken instructions delivered over a phone using a WOZ technique. The simulated guidance system was presented as an over-the-phone guidance system prototype, which was able to process natural language (i.e., with no limit on vocabulary when formulating a request).

Participants were told to use the system to find their way on maps. A map was put on the table in front of each participant. The participants familiarized themselves with the system and the task by drawing two routes on the same map. Next, they drew 27 routes on nine different maps (i.e., three routes per map). For each new map, the experimenter showed the departure and arrival points of the three routes that had to be drawn. Departure points were highlighted on each map by a green flag and numbered one to three (i.e., from (1) for the first route to (3) for the last one). Arrival points were not indicated on the map, but given one at a time so that the participants did not try to locate them in advance. Instead, participants were asked to turn over a piece of paper at the beginning of each route to discover their destination. Once participants had been given this information, the experimenter returned to the control room, and started the video recording of the route drawing task and the audio recording of the telephone interaction. Participants were not allowed to rotate maps during the tasks. At the end of each route, participants answered the general satisfaction questionnaire. Finally, when all the sets of routes had been drawn, participants answered the preference questionnaire. Participants received three sets of instructions (one per route) for each map. The order of routes and maps was counterbalanced. During navigation tasks, the experimenter could hear (through his headsets) the vocal commands pronounced by the participants. Once he heard it he was supposed to quickly and accurately deliver the information requested.

2.2.6. Dependent measures

Navigation performances. Performance measures were similar to those used in real-life navigation tasks (Denis et al., 1999; Tom & Denis, 2003). The numbers of directional errors and hesitations (short stops lasting less than 5 s and long stops lasting more than 5 s) were counted and the navigation time per route was measured in seconds. Lastly, the total number of drawing actions was recorded as an indicator of drawing efficiency.

Satisfaction measures. The participants' satisfaction with instruction contents was measured through questionnaires. The participants' general satisfaction was evaluated by adding up their ratings of the three statements in the satisfaction questionnaire (score from 0 to 15). The statement concerning the amount of information delivered was isolated in order to determine whether participants perceived variations in instruction content (score from 0 to 5). Moreover, participants' preferences for particular instruction contents were analyzed. Each participant had to indicate his or her order of preference for the instruction formulations provided in four consecutive questions. The formulation in first position scored 4, the one in second position scored 3, and so on. Then, the mean preference score for each type of landmark was calculated.

3. Results

3.1. Navigation performance

ANOVAs were performed on the navigation performance measures. Instructions' formulation (addressee-centered landmarks, neutral landmarks and no landmarks) was treated as a within-groups factor. Mean and Standard-Deviation are reported in Table 3.

The analyses showed an effect of instructions' formulation on the number of directional errors, $F(2, 52) = 14.21$, $p < .001$, $\eta^2_p = .353$. Planned comparisons showed that instructions without landmarks generated more errors than instructions containing addressee-centered or neutral landmarks, $Fs(1, 26) > 20.19$, $p < .001$. The difference between addressee-centered and neutral landmarks was not significant, $F(1, 26) < 1$. The analyses also showed a marginal effect of instructions' formulation on completion times, $F(2, 52) = 2.85$, $p = .067$, $\eta^2_p = .099$. Planned comparisons showed that when instructions did not contain landmarks, completion times were slightly longer than when they contained neutral landmarks, $F(1, 26) = 4.05$, $p = .05$. The analyses showed a marginally significant effect of instructions' formulation on the number of hesitations, $F(2, 52) = 3.08$, $p = .058$, $\eta^2_p = .104$. However, while planned comparisons showed that instructions without landmarks generated more hesitations than instructions containing neutral landmarks, $F(1, 26) = 4.86$, $p < .05$, the difference between addressee-centered and neutral landmarks was not significant, $F(1, 26) < 1$.

Lastly, the analyses showed an effect of instructions' formulation on the number of drawing actions, $F(2, 52) = 3.36$, $p < .05$, $\eta^2_p = .115$. Planned comparisons showed that more drawing actions were made without landmarks than with addressee-centered landmarks, $F(1, 26) = 6.560$, $p < .05$. The difference between addressee-centered and neutral landmarks was not significant, $F(1, 26) < 1$.

Table 3
Means (and Standard Deviations) for navigation performances according to instruction formulation (type of landmarks).

	Addressee-centered landmarks	No landmarks	Neutral landmarks
Directional errors	1.06 (.93)	1.84 (1.09)	1.05 (.90)
Completion time	83.40 (21.65)	92.73 (30.88)	79.6 (20.55)
Hesitations	1.39 (.70)	1.65 (.93)	1.24 (.66)
Drawing actions	9.12 (1.43)	10.06 (2.32)	9.29 (2.09)

In summary, navigation performances improved when landmarks (addressee-centered or neutral) were used in instructions compared with when no landmarks were used. Furthermore, drawing performances improved when landmarks (especially addressee-centered landmarks) were used in instructions, compared with when no landmarks were used.

3.2. Satisfaction

Friedman ANOVAs were performed on the satisfaction measures (ordinal data), with instructions' formulation as a within-participants factor, followed by nonparametric pairwise comparisons (Wilcoxon signed-rank test). Mean and Standard-Deviation are reported in Table 4.

First, the analyses showed that general satisfaction was affected by instructions' formulation, Chi^2 ANOVA(2) $= 17.37$, $p < .001$. When instructions contained addressee-centered or neutral landmarks, general satisfaction was higher than in the no landmarks condition, all $z > 2.88$, $p < .01$. The difference between addressee-centered and neutral landmarks was not significant, $z = .216$, $p > .10$. The perception of information quantity was marginally affected by instruction formulation, Chi^2 ANOVA(2) $= 5.95$, $p = .051$. Formulations with addressee-centered and neutral landmarks were judged to deliver too much information compared with the no landmarks condition, all $z > 2.00$, $p < .05$. The difference between addressee-centered and neutral landmarks was not significant, $z = .521$, $p > .10$.

More importantly, the analyses showed that formulation preferences were affected by instructions' formulation, Chi^2 ANOVA(3) $= 47.94$, $p < .001$. Pairwise comparisons showed that formulations with addressee-centered landmarks were preferred to all other formulations, all $z > 3.63$, $p < .001$. Preferences for formulations with object-centered and addressee-centered landmarks did not differ significantly, $z = 1.40$, $p > .10$, but both were preferred to formulations without landmarks $z > 3.62$, $p < .001$.

In summary, satisfaction was improved when landmarks (addressee-centered or neutral) were used in instructions, even if these formulations were judged to contain a lot of information, compared with instructions containing no landmarks. The participants also clearly preferred formulations with landmarks, especially addressee-centered landmarks.

4. Discussion

The aims of the present study were to confirm that landmarks can be useful in guidance systems and to study the effects of landmarks' frames of reference shifting during map navigation tasks, when using a simulated speech-based over-the-phone guidance system. The results confirm the benefit of landmarks' use in map navigation tasks by showing that, during an interaction with a simulated speech-based guidance system, landmarks improve both participants' performances and their level of satisfaction.

Concerning the benefit of landmarks during map navigation tasks, the first relevant result is that task completion times were slightly longer when there were no landmarks in the instructions. Similarly, we showed that more directional errors and hesitations were performed when instructions did not contain any landmarks. Navigation performances can therefore be improved by including landmarks in instructions. Landmarks help people insofar as they hesitate less when landmarks are used and they navigate quickly. It seems that landmarks prevent participants from going in the wrong direction, as fewer directional errors were observed when landmarks were used. In the same way, the analyses showed that more tracing actions were performed without landmarks than with addressee-centered landmarks. This result suggests that when instructions do not contain landmarks, the participants find it harder to implement them. On the other hand, when addressee-centered landmarks were used, the participants performed fewer erroneous actions as if it entailed the information they needed to go directly in the right direction. Addressee-centered landmarks may thus help participants to figure out where they are heading more accurately. In this sense, this particular type of landmark seems a promising factor for the design of speech-based guidance systems, insofar as they seem to be useful in helping people to understand route's content. This point is particularly crucial, given that efficient navigation stems from route instructions comprehension. Altogether these results reinforce the idea that navigation efficiency stems from action formulation but also from landmarks use (Denis, 1997) and that landmarks should constitute key information that needs to be included in speech-based guidance systems. The present study thus extends previous results obtained in studies looking at ways of improving assistance to drivers (for instance, Alm et al., 1992; Bengler et al., 1994; Burnett, 2000; May et al., 2005). In short, instructions without landmarks corresponded to the least efficient instruction formulation, that is, they led to poorer performances and less satisfaction. This result is interesting because it shows that, just as the *production* of route descriptions is based on the conjoint use of actions and landmarks (Denis, 1997; Roger et al., 2009), so, it seems, is the *comprehension* of route descriptions.

The present study also questioned the type of landmarks that should be used to improve navigation assistance. Concerning both frames of reference used here, complement results from the ones obtained in previous human–human situations (Schober, 1995) were observed. Indeed, both instructions containing neutral and addressee-centered landmarks, enabled participants to obtain satisfying navigation performances. Contrary to our expectations, in map navigation tasks assisted by simulated speech guiding systems, the shifting in frames of reference between the map and addressee-centered landmarks was not significantly more difficult than the fact of using neutral landmarks (i.e. landmarks that did not imply any shifting in frame of reference). Thereby, the egocentric–non egocentric model used by Schober (1995) in human–human situations cannot be directly applied since the present study is based on human–computer situations in which a system with no cognitive limitations replaces the human guide. More precisely, in human–human situations, the interaction relies on both the guide (i.e. the speaker who produces the guiding instructions) and the guided person (i.e. the addressee who has to follow the guiding instructions). In these situations, the guide is trying to reach a compromise between a) the comprehension's cost of the guided person by producing addressee-centered instructions that are easier to understand by the guided and b) his or her own production's cost by favoring egocentered instructions over addressee-centered ones

Table 4
Means (and Standard-Deviations) for satisfaction measures according to instructions' formulation (type of landmark).

	Addressee-centered landmarks	No landmarks	Neutral landmarks	Object-centered landmarks
General satisfaction (max 15)	12.72 (1.16)	11.78 (1.45)	12.74 (.99)	–
Amount of information (max 5)	4.03 (1.03)	3.76 (1.12)	3.96 (1.15)	–
Formulation preferences (mean position)	3.34 (.50)	1.59 (.48)	2.41 (.54)	2.64 (.46)

since these latter are more difficult to produce insofar as they imply to adopt someone else's point of view. According to Schober (1995) this compromise in human–human situations is reached by using neutral instructions which are both easier to produce (from the guide's point of view) and easier to understand (from the addressee's point of view). From a practical point of view, the fact that egocentric–non egocentric model cannot be directly used in human–computer situations is an interesting result. Indeed, while addressee-centered landmarks can be difficult to produce in human–human navigation tasks (since the speaker has to adopt the addressee's viewpoint), this difficulty can be exceeded when using a guiding system that do not get any limitation in producing addressee-centered landmarks. Moreover, insofar as people find it easier to understand a description from their own point of view, guiding systems should really profit from using addressee-centered landmarks.

Finally, the results also showed that participants' satisfaction depends on instructions' formulation. When instructions contained addressee-centered or neutral landmarks, general satisfaction was higher than when they contained no landmarks. Analyses confirmed the advantage of addressee-centered landmarks since participants found these formulations to be the most satisfying, followed by object-centered and neutral landmarks. Conversely, instructions containing no landmarks were the least satisfying. Altogether, these results once again show that addressee-centered landmarks could be extremely useful in the design of speech-based guidance systems. Indeed, insofar as satisfaction is known as a decisive factor in interface acceptance (ISO 9241, part 11, 1997), it can be assumed that addressee-centered landmarks are the most suitable landmarks in the case of navigation assisted by a simulated speech system.

This result needs however to be moderated since results also showed that addressee-centered landmarks led to a feeling of discomfort concerning the amount of information perceived by the participants. This result highlights the fact that speech is evanescent (Chafe, 1982), that is, once an instruction had been played, individuals did not have any tangible reminder of the content they had just heard (unlike information displayed on graphical interfaces). Therefore, designers must be careful when defining the length of system prompts (in the case of system speech output) so that the information is fully understood and does not overload the user's working memory (see Le Bigot, Jamet, Rouet, & Amiel, 2006). This point is very important, as instructions' comprehension is crucial to navigation tasks performance.

From a human–computer interaction perspective, researches on the design of in-vehicle navigation systems have shown that two different types of instructions were used: only distance estimates (e.g., "in 200 miles, turn right") or actions associated with landmarks (e.g., "at the church, turn right") (see Millonig & Schechtner, 2007). Besides, several studies have shown that landmarks can improve in-vehicle guidance system usability (Bengler et al., 1994; Burns, 1997; ISO standard 9241-11, 1997). As in-vehicle studies, our study in speech-based over-the-phone guidance systems confirms that when instructions did not contain landmarks, participants performed less efficiently and were less satisfied than when instructions contain neutral and addressee-centered landmarks. Insofar as usability is a pregnant concern when designing a new system, the present study thus reinforces the idea that, to be efficient, a guidance system must contain landmarks. More precisely, the present results concerning landmarks' frame of reference could lead us to question the ways in which they are used in route descriptions. More specifically, we can consider that neutral landmarks (e.g., "turn right, you are arriving at the Champs Elysees, you will see the Arc de Triomphe") should mostly be used to define a wide navigation area. As for addressee-centered landmarks (e.g., "turn right onto the Champs Elysees; you will then be facing the Arc de Triomphe"), which provide more precise indications, they could be used at key points along the route. To resume, by specifying the role of each type of landmark in route description, we should be able to improve the actual knowledge about landmarks.

To conclude, this study brings new information about landmarks' frames of reference, several shortcomings can be identified. The first refers to the fact that neutral landmarks did not enable participants to navigate more efficiently (even though they should have since they do not imply any shifting in frame of reference with the maps). This surprising result may be due to the task used here. Indeed, during map tracing tasks, participants drew their routes on the maps. These routes could be considered as visual cues that prevent the participants from having to remember their current position on the map and thus free mental resources that could be then used to shift frame of reference more easily. This explanation makes sense insofar as, within the egocentric–non egocentric model, the fact of shifting frame of reference is costly (Schober, 1995) and whatever may save cognitive resources could then enable participants to shift their frames of reference more efficiently. Moreover, even though the present results enable to conclude that the use of addressee-centered landmarks could be a key component to assist people during map navigation, it was unfortunately not the case for neutral landmarks. Consequently, the results obtained in the present study should be regarded as opening up avenues for future research on the way landmarks, and more especially landmarks' frames of reference, can improve navigation. Lastly, this study should be enlarged by manipulating the whole set of spatial frames of reference identified by Schober (1995) in different kind of navigation tasks (real vs. imagined vs. virtual navigation).

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