# Referring to Landmark or Street Information in Route Directions: What Difference Does it Make?*

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**Abstract.** When describing routes in urban environments, speakers usually refer to both street names and visual landmarks. However, a navigational system can be designed which only refers to streets or, alternatively, only to landmarks. Does it make any difference which type of information users are provided with? The answer to this question is crucial for the design of navigational aids. We report two experiments. The first one showed that in a wayfinding task, route directions referring to streets were less effective than those referring to landmarks for guidance purposes. The second experiment showed that when people generate route directions, they tend to produce less street than landmark information. These studies provide a further illustration of the critical role of landmarks in route directions.

**Keywords.** Spatial cognition, route directions, streets, landmarks, urban navigation.

## 1. Introduction

Spatial discourse is generally considered to be a particularly good way of externalizing people's knowledge about their environment. Specifically, the interactions between space and language can profitably be investigated by studying route directions. The intent underlying route directions is twofold. First, route directions are instances of *procedural discourse*, since they are intended to guide a person – a pedestrian or a car driver – from a starting point to a distant target (Golledge, 1993; Taylor & Tversky, 1992). This procedure requires first of all that the actions to be taken and the places where they are to be executed should be identified. Landmarks in the environment are typically used to refer to these places. By this very fact, route directions also belong to the class of *descriptive discourse*, since people often describe the visual features of the environment to be traversed in addition to prescribing actions. These prescriptive and descriptive components of route directions are tightly intertwined, which makes them especially difficult to analyze, not only for psychologists, but also for the computer scientists who face the task of designing user-friendly artificial navigational aid systems (Allen, 2000; Daniel, Tom, Manghi,

* This research was supported by a doctoral research grant from the Délégation Générale pour l'Armement (DGA).

& Denis, in press; Denis, Pazzaglia, Cornoldi, & Bertolo, 1999; Streeter, Vitello, & Wonsiewicz, 1985).

Studies of route directions have shown that *landmarks* are of major importance for guiding people. The frequency with which they are mentioned is subject to individual differences. For instance, it has been clearly established that women refer to visual landmarks more frequently than men do (Bell, Fischer, & Baum, 1996; Denis, 1997; Galea & Kimura, 1993). Despite these differences, landmarks are nearly always referred to in descriptions of routes (Allen, 2000; Denis, 1997; Fontaine & Denis, 1999; Michon & Denis, 2001). Their role as navigational aids has been amply documented. Michon and Denis (2001) found that their use in urban environments is unequally distributed along the route described. They tend to be concentrated at locations where reorientations are called for, and also at any other places where reorientations *could* occur (such as crossroads). These results are congruent with the assumption that landmarks allow moving people to anticipate the critical nodes where they need to pay special care.

Another means of conveying spatial information is to focus on the *paths* along which people are moving. Surprisingly, this topic has received very little consideration. One reason is probably that the role of landmarks has mostly been documented in environments such as campuses (Cornell, Heth, & Skoczylas, 1999; Rossano & Reardon, 1999), buildings (Kirasic & Mathes, 1990; Taylor, Naylor, & Chechile, 1999), and underground environments (Fontaine & Denis, 1999). These environments are biased towards references to landmarks, and in such environments references to paths, which are unlabelled and indistinctive, are unlikely.

Nevertheless, even studies carried out in urban environments reflect some rather limited spontaneous reference to streets (Michon & Denis, 2001). Streets commonly have proper names. It is well established that proper names are more difficult to retrieve from memory than common names (e.g., Cohen & Burke, 1993; Izaute, 1999). Street names have been shown to be hard to memorize, even for expert taxi drivers, when the corresponding streets cannot be retrieved by the use of a chunking strategy (Kalakoski & Saariluoma, 2001). Even when they have been well memorized, their long-term retention is poor compared to that of landmarks (Bahrick, 1983).

The reference to street names has some limitations. Street name plates are sometimes not visible from a distance. Furthermore, as mentioned above, street names are often proper names. These names are arbitrary and do not convey any spatial or descriptive features of the streets that have to be taken. But, on the other hand, street names are a concise form of information. They also have the advantage of resolving any problem of reference since, for instance, there may be several parks in an environment, but there is definitely only one Général Leclerc Avenue. More generally, increasing the level of determinacy of the discourse is known to favor the processing of spatial discourse (Ioerger, 1994; Mani & Johnson-Laird, 1982; Schneider & Taylor, 1999).

When studying route instructions, one has also to consider a related factor, namely, the *direction* of walking. Directionality is encoded in spatial mental representations (e.g., Thorndyke & Hayes-Roth, 1982). While navigating, the visibility and hence the relevance of landmarks may differ considerably depending on whether the route is traversed from A to B or from B to A (Cornell, Heth, Kneubuhler, & Sehgal, 1996; Heth, Cornell, & Alberts, 1997). We also considered this factor in our research.

Two studies are reported in this article. The first was intended to test the guiding value of streets and landmarks in a spatial discourse referring to an urban environment. For this purpose, we recorded behavioral indices reflecting the navigational performance of participants, depending on whether they were provided with instructions referring to the streets or to the visual landmarks of the environment. We used a procedure which allowed us to record the occurrence of cognitive anticipation of information. We also used a map-drawing task as a convenient mode of externalizing the mental representation of the route traversed. In the second study, we asked participants to describe the same route, while navigating either from A to B or from B to A. These verbal productions were analyzed to determine any differences in the reference to street or landmark information. Thus, the two experiments considered the same street/landmark contrast during navigation episodes, but in one case, route instructions were being used by the participants, whereas in the second experiment, the participants were generating these instructions.

## 2. Experiment 1: Using route directions in navigation

This study was designed to test the contrast between the use of landmarks and street names as components of route directions in a wayfinding task. We focused mainly on the participants' behavior during locomotion, but we also subsequently collected information about how participants would represent the newly learned route on a map.

### 2.1 Method

**Route.** The route was located in an inner suburb of Paris. It was 480 meters long. As depicted in Figure 1, it was entirely located outdoors and included six turns. Hence, six reorientations were required.

**Participants.** The participants were 40 undergraduates (20 females and 20 males; mean age: 24.40, *SD* = 3.11). They were all unfamiliar with the route to be traversed. They were randomly assigned to one of two experimental conditions, namely the Landmark-based or the Street-based condition.

**Route directions.** Route directions were constructed in two stages. First, we collected route directions from a sample of 20 people living in the study area. This corpus allowed us to identify the most frequently cited streets and landmarks. Then, two sets of instructions were constructed in parallel, so that the same portions of the route were referred to either by a street name or by a landmark. Each version of the description comprised 25 instructions, of which 15 were common to both sets and 10 were different in the two sets. These differences resulted exclusively from the use of a street name or a landmark. For instance, participants were invited either to "turn right into Jean Bouveri Street" or to "turn right toward the phone booths". Each instructional item was printed on a separate page of a booklet. The two versions of the instructions are shown in Table 1.

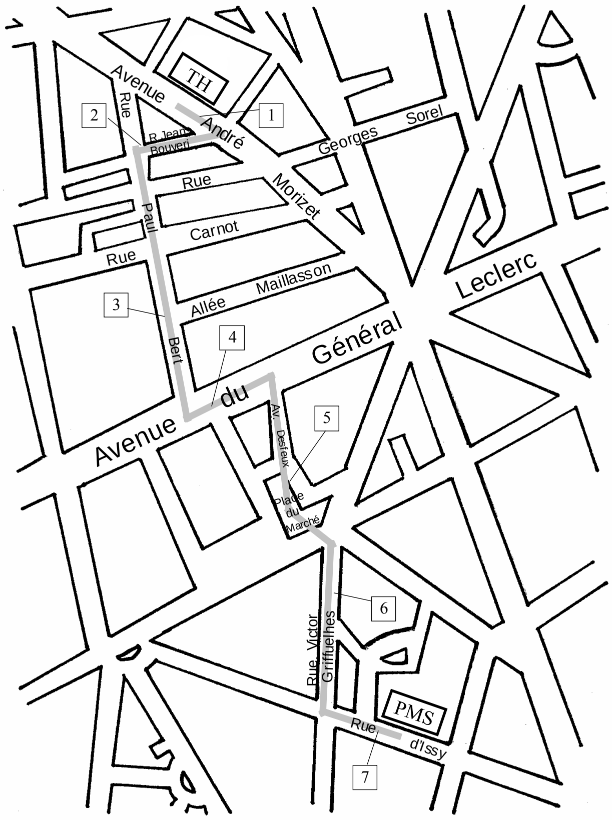


**Fig. 1.** The route used in Experiments 1 and 2 (TH = Town Hall; PMS = Park Maintenance Service; segments are numbered #1 to #7)

**Procedure.** The experimental sessions were run individually for each participant. After they had been guided to the start point of the route, the participants were given a booklet in which the instructions were printed. The participants were told that they would have to find their way with only the printed instructions to help them, and that the experimenter escorting them would be walking a few meters behind. They were instructed to stop walking and turn a page each time further information was needed to continue. These stops were used by the experimenter to note on a map of the route the exact place where the consultations took place. While they were navigating, three indices were recorded. *Directional errors* included all deviations from the intended route. *Checkings* referred to a verbally expressed intention to check some feature of a piece of information (for instance, a street name). Finally, *stops* were defined as pauses lasting more than 2 seconds. The frequency and duration of the stops and checkings were recorded. Only the occurrences of directional errors were noted, as in this case the participants were stopped and taken back to the place where the error occurred, to avoid off-route consultations. After the navigation episode, participants were asked to draw a map of the route. This map was intended to be a helpful guide to a pedestrian unfamiliar with these surroundings.

**Table 1.** Route directions used in Experiment 1

| Street-based instructions | Landmark-based instructions |
|---|---|
| 1 - Stand with your back to the Town Hall | 1 - Stand with your back to the Town Hall |
| 2 - Turn left into **Andre Morizet Avenue** | 2 - Turn left toward **the police station** |
| 3 - Cross the avenue at the first pedestrian walkway | 3 - Cross the avenue at the first pedestrian walkway |
| 4 - Turn right into **Jean Bouveri Street** | 4 - Turn right toward **the phone booths** |
| 5 - Keep going to the end of the street | 5 - Keep going to the end of the street |
| 6 - You are now in **Paul Bert Street** | 6 - You are now in front of **a bakery** |
| 7 - Turn left | 7 - Turn left |
| 8 - Go straight on | 8 - Go straight on |
| 9 - Cross **Georges Sorel Street** | 9 - Go past **the occupational medicine building** |
| 10 - Continue straight on | 10 - Continue straight on |
| 11 - Pass **Carnot Street** | 11 - Pass **the coffee shop Au Bon Accueil** |
| 12 - Go past **Maillasson Avenue** | 12 - Go past **Glycines Square** |
| 13 - Keep going to the end of the street | 13 - Keep going to the end of the street |
| 14 - This runs into **General Leclerc Avenue** | 14 - Pass in front of **a grocery** store on the corner |
| 15 - Turn left | 15 - Turn left |
| 16 - Cross at the first pedestrian walkway | 16 - Cross at the first pedestrian walkway |
| 17 - Turn left | 17 - Turn left |
| 18 - Take **Desfeux Avenue** on the right | 18 - Take the street on the right after **Pizza Hut ®** |
| 19 - You are now in the market square | 19 - You are now in the market square |
| 20 - Cross the square | 20 - Cross the square |
| 21 - Head for **Victor Griffuelhes Street** which is almost in front of you | 21 - Pass in front of **Bijou Hotel** which is almost in front of you |
| 22 - Turn right into the street | 22 - Turn right into the street |
| 23 - Go straight on | 23 - Go straight on |
| 24 - Turn left into **Issy Street** | 24 - Turn left after the entrance to **the skating rink** |
| 25 - The Park Maintenance Service is a little bit farther on, on the left | 25 - The Park Maintenance Service is a little bit farther on, on the left |

## 2.2 Results

The data were submitted to a one-way analysis of variance (ANOVA) with Instruction type as the between-participant factor.

**Behavioral indices.** The numbers and durations of the three behavioral indices considered in this study are shown in Table 2. While directional errors were not found to differ in the two conditions [$F(1,38) = 1.12$, $p > 0.05$], checkings and stops were significantly less frequent in the Landmark-based than in the Street-based condition [$F(1,38) = 19.99$, $p < .0001$, and $F(1,38) = 24.50$, $p < .0001$, respectively]. Furthermore, the durations of these last two behavioral indices were significantly shorter in the Landmark-based than in the Street-based condition [$F(1,38) = 19.64$, $p < .0001$, and $F(1,38) = 24.93$, $p < .0001$, respectively].

**Table 2.** Average number and duration of directional errors, checkings and stops for each condition (*SD*s are in parentheses)

| | Number | | Duration (seconds) | |
|---|---|---|---|---|
| | Street-based condition | Landmark-based condition | Street-based condition | Landmark-based condition |
| Directional errors | 0.70 (0.80) | 0.45 (0.69) | _ | _ |
| Checkings | 1.25 (0.97) | 0.20 (0.41) | 29.73 (19.70) | 5.90 (13.78) |
| Stops | 1.70 (1.13) | 0.30 (0.58) | 15.01 (8.86) | 3.18 (5.81) |

**Consultations.** The locations where each new piece of information was consulted were compared in the two conditions. For each instruction, we subtracted the distance from the start point to the point of consultation with the Street-based instructions from the same measurement for the Landmark-based instructions. Figure 2 shows an example of how such differences were calculated. This computation was made for each instruction, which resulted in a total of 25 differences. A negative value indicated that the corresponding instruction was consulted earlier in the Landmark-based than in the Street-based condition. A positive value indicated the reverse.

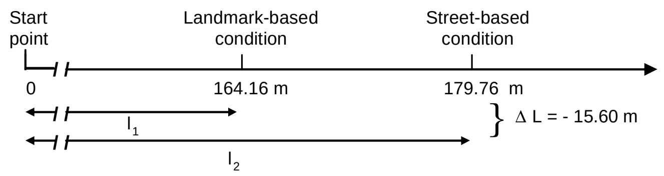


**Fig. 2.** Example of a calculated difference (Instruction #13)

The results are shown in Figure 3. The first two differences were null, indicating that the corresponding instructions were consulted at exactly the same locations (in this case, the starting point). Twenty differences were negative, and 8 of these were significant differences. Three values were positive, only one being significantly different. Because the consultation of a new instruction means that the preceding one is no longer relevant, we had to consider the content of every instruction that preceded those which induced significant differences. We found that of the 9 significant differences, 3 referred to instructions common to both descriptions, and 6 to instructions that differed in the two descriptions. This last finding indicates that the corresponding landmarks cited in the description made it possible to consult the next instruction sooner. As landmarks are bigger than street name plates, they are identified earlier, and consequently the next instruction is consulted earlier in this condition. This, however, does not suffice to account for all the differences. For instance, the skating rink was not identifiable from a distance as its entrance and name plate faced away from the direction of navigation. Nevertheless, the participants still consulted the next instruction earlier in the Landmark-based condition.

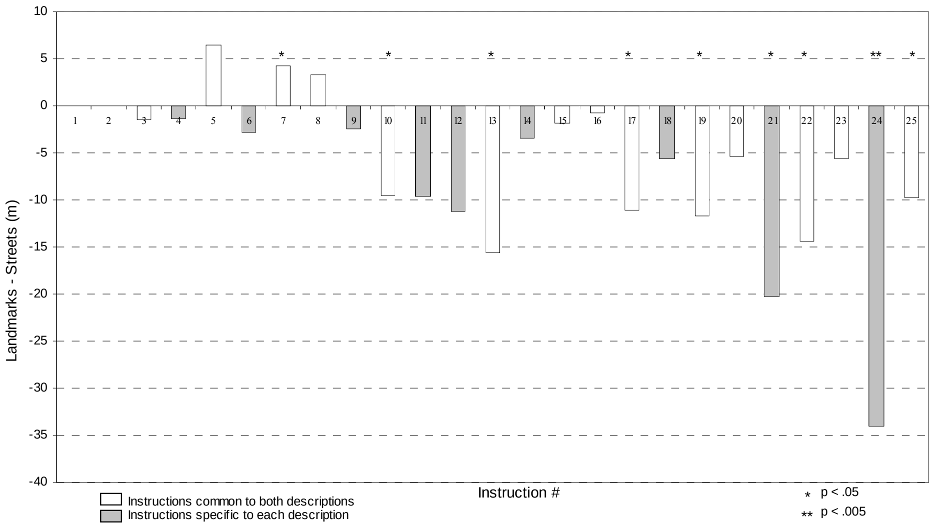


**Fig. 3.** Differences in consultation locations for both conditions

**Map drawing.** The maps that participants drew were analyzed according to several criteria. As shown in Table 3, we focused here on the number of items recalled. Further, we considered only the 10 streets or 10 landmarks that had been mentioned in the descriptions. Actually, the participants reported very few other pieces of information in their drawings. These were only landmarks, and they were given only by the participants of the Landmark-based condition. In the Street-based condition, participants drew more streets than landmarks [$F(1,38) = 31.53$, $p < .0001$], and the reverse pattern emerged in the Landmark-based condition [$F(1,38) = 212.42$, $p < .0001$]. Interestingly, in the Street-based condition, the participants drew fewer streets than their counterparts drew landmarks in the Landmark-based condition [$F(1,38) = 60.48$, $p < .0001$].

**Table 3.** Average number of streets and landmarks drawn on the map for both conditions

| | Street-based condition | Landmark-based condition |
|---|---|---|
| Streets | 2.24 (1.78) | 0.00 (0.00) |
| Landmarks | 0.30 (0.80) | 6.60 (1.76) |

### 2.3 Discussion

Experiment 1 clearly showed that street-based instructions were much less efficient than landmark-based ones for guiding someone unfamiliar through an urban environment. This was first demonstrated by the analysis of behavioral indices collected during navigation. The frequency of errors was not affected by the use of landmark or street information. Since the participants were allowed to consult the instructions while they were walking, the probability that they would stray from the intended route was almost zero. However, we found that stops and checkings were both more frequent and longer when participants were being guided by street-based information. Further, the Street-based description tended to be followed step by step, since no anticipation in consultation was seen. Finally, map drawings showed that the memory of the route was also impaired when participants had been guided by street-based information. Overall, our findings support the contrast between streets and landmarks in the use and memory of spatial information, and the critical role of landmarks in processing route directions.

## 3. Experiment 2: Generating route directions during navigation

Results from Experiment 1 showed that landmarks are more efficient than street names for guiding people along a novel route in an urban environment and helping them memorize information about it. However, one can wonder whether this differential effect in processing the two sets of information is confirmed when people are *describing* urban routes. In particular, would their descriptions refer less frequently to streets than to landmarks?

### 3.1 Method

**Route.** The route was the same as the one used in Experiment 1.

**Participants.** The participants were 24 undergraduates (12 females, 12 males; mean age: 23.33, *SD* = 5.06). None of them had participated in the previous experiment.

**Procedure.** The experimental sessions were run individually for each participant. The participants were first accompanied by the experimenter to the starting point (the Town Hall, for one half of the participants, and the Park Maintenance Service for the other half). Those who started from the Town Hall were informed that the target was the Park Maintenance Service (Direction A), and those who started from the Park Maintenance Service were informed that the target was the Town Hall (Direction B). The participants were then invited to follow the experimenter along the route, and to describe it aloud in such a way that these instructions would allow other people unfamiliar with the surroundings to find their way. The participants were equipped with a Dictaphone and a microphone. When they reached the end point, the participants were brought back to the starting point (by a different route). Once they were back at the starting point, the participants were asked to navigate along the same route a second time, and to describe it again. This time, the participants were followed by the experimenter.

### 3.2 Results

**Coding the verbal productions.** First, all 48 descriptions were transcribed. They were analyzed according to the procedure designed by Denis (1997). All statements were formatted into a set of minimal units of information. These standardized propositions were then divided into 12 classes:

- Class 1: Action ("Go straight on")
- Classes 2 / 3: Action with reference to a landmark / a street ("Pass a laundry", "Take Victor Griffuelhes Street on the left")
- Classes 4 / 5: Introduction of a landmark / a street ("Face a bar", "There's another street")
- Classes 6 / 7: Description of a landmark / a street ("The bar is named Black and White", "It's a narrow street")
- Classes 8 / 9: Location of a landmark relative to another landmark / a street ("The pedestrian walkway is on the left of the Town Hall", "Pizza Hut is at the corner of the street")
- Classes 10 / 11: Location of a street relative to a landmark / another street ("Victor Griffuelhes Street is just after the Bijou Hotel", "The street is perpendicular to Victor Griffuelhes Street")
- Class 12: Commentaries ("You can't miss it")

**Quantitative analyses.** Data were submitted to an ANOVA with Directions (A or B) as the between-participant factor and Descriptions (first or second) as the within-participant factor.
We first considered the number of propositions that the participants generated during navigation (cf. Table 4). The number of propositions was similar in both descriptive episodes: $F(1,22) = 1.67$, $p > .05$. However, *post hoc* analyses showed that in the second description, fewer propositions were used for Direction B than for Direction A ($p = .01$).

**Table 4.** Average number of propositions for both descriptions and both directions

| | Description 1 | Description 2 |
|---|---|---|
| Direction A | 66.50 (31.40) | 67.00 (27.89) |
| Direction B | 59.17 (24.75) | 48.42 (15.80) |

We wondered whether this difference was true for the whole route, or whether it only emerged for specific portions of it. We therefore divided the route into 7 segments delimited by the 6 reorientation points. However, because the first segment of the route was very short, data from segments 1 and 2 were merged. We therefore analyzed 6 segments, considered as repeated measures. As shown in Figure 4, the differences between descriptions were mainly located in specific parts of the route, and even appeared as early as the first description for a specific portion of the route.

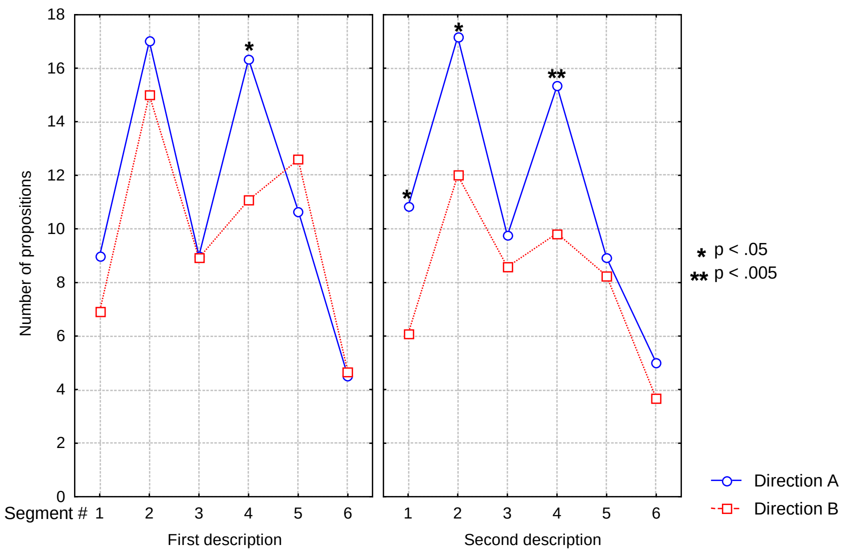


**Fig. 4.** Average number of propositions per segment for both directions and both descriptions

The correlation between the number of propositions for Descriptions 1 and 2 was significant: $r\ (22) = 0.72$, $p < .005$. Table 5 shows that this correlation was confirmed for almost all parts of the route. Thus, although the protocols were quite different in length, the differences between participants appeared to reflect reliable individual characteristics.

**Table 5.** Correlations between numbers of propositions for each segment of the route

| | | Description 1 | | | | | | Description 2 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Segment # | 1 | 2 | 3 | 4 | 5 | 6 | 1 | 2 | 3 | 4 | 5 | 6 |
| Description 1 | 1 | 1 | | | | | | | | | | | |
| | 2 | .66** | 1 | | | | | | | | | | |
| | 3 | .66** | .87** | 1 | | | | | | | | | |
| | 4 | .70** | .70** | .63** | 1 | | | | | | | | |
| | 5 | .48* | .85** | .78** | .62** | 1 | | | | | | | |
| | 6 | .52** | .60** | .63** | .43* | .60** | 1 | | | | | | |
| Description 2 | 1 | .67** | .46* | .43* | .72** | .24 | .28 | 1 | | | | | |
| | 2 | .38 | .55** | .31 | .65** | .43* | .20 | .48* | 1 | | | | |
| | 3 | .39 | .59** | .49* | .63** | .47* | .24 | .42* | .77** | 1 | | | |
| | 4 | .60** | .58** | .46* | .80** | .43* | .22 | .64** | .72** | .59** | 1 | | |
| | 5 | .27 | .53** | .47* | .52** | .49* | .37 | .34 | .50** | .64** | .32 | 1 | |
| | 6 | .48* | .63** | .64** | .61** | .54** | .36 | .59** | .52** | .51** | .52** | .49* | 1 |

* $p < .05$ ** $p < .005$

**Content analyses.** The further point of interest was the distribution of propositions across the 12 classes defined earlier. Table 6 shows this distribution. It was found to be consistent for both descriptions, for both directions of the route, and for all 6 segments of the route, since the main effects of these factors were not found to be significant (all *p*s > .05). *Post hoc* analyses were performed on these data. In particular, we considered the presence of clusters. A cluster was defined as a group of classes of which the frequency of occurrence did not significantly differ from each other, but did differ significantly with respect to the other classes. Three clusters emerged (see Table 6). The first one comprised actions alone or actions associated with a landmark or a street, together with introductions of landmarks. Interestingly, streets were used as frequently as landmarks when they were associated with an action. The second cluster included descriptions of landmarks and introductions of streets. Streets were therefore introduced less frequently than landmarks ($p < .0001$). The third cluster included all the remaining classes. This cluster notably showed that the participants again felt it less necessary to describe a street than a landmark ($p < .005$). Finally, when considering the five classes that included references to landmarks, their summed frequencies amounted to 53.33%, whereas the corresponding number was only 27.21% for the classes that focused on streets.

**Table 6.** Ranked frequency of occurrence of each class

| | Class | Frequency (%) |
|---|---|---|
| Action with reference to a landmark | 2 | 20.57 |
| Action | 1 | 17.54 |
| Introduction of a landmark | 4 | 16.62 |
| Action with reference to a street | 3 | 15.73 |
| Description of a landmark | 6 | 9.65 |
| Introduction of a street | 5 | 6.30 |
| Description of a street | 7 | 3.62 |
| Location of a landmark relative to a street | 9 | 3.44 |
| Location of a landmark relative to another landmark | 8 | 3.25 |
| Commentary | 12 | 1.73 |
| Location of a street relative to a landmark | 10 | 1.11 |
| Location of a street relative to another street | 11 | 0.45 |

Note: Limits of clusters are shown by double lines

**Analysis of directional errors.** Though the experiment was not designed to examine the behavior of participants during navigation, we nonetheless recorded the number of directional errors committed by the participants during the second walk. If they strayed from the intended route, the participants were immediately stopped and taken back to the place were the error occurred. As shown in Table 7, there were few errors, but an interesting result emerged, in that all errors were committed by the participants navigating in Direction B. The difference between Directions A and B was thus significant: $F(1,22) = 7.32$, $p < .01$. Furthermore, the errors always occurred at the same place (in segment 2).

**Table 7.** Number of directional errors

| | Direction of walking | |
|---|---|---|
| | A | B |
| Directional errors | 0.00 (0.00) | 0.47 (0.60) |

### 3.3 Discussion

The analysis of descriptions first showed that the direction of walking along the same route resulted in differences in the length of the descriptions. These differences appeared from the first walk for a portion of the route, and may be explained by an environmental asymmetry in the frequency of salient landmarks. This asymmetry was also responsible for the more frequent directional errors for Direction B. As a matter of fact, it is much easier to walk straight on in the direction of a big avenue (Direction A) than to come from this avenue and then take the fourth perpendicular street on the left (Direction B). Interestingly, in the second walk, differences in the length of the descriptions also emerged for two other parts of the route. This time, these differences could be attributed to a change in the content of the instructions. For instance, instead of enumerating a series of landmarks, participants could refer to a single avenue and so could be more concise. Furthermore, the variability observed in the length of descriptions was consistent for all parts of the route. This result probably reflects a cognitive style.

The second point of interest was the content of the directions, and particularly the reference to either landmarks or streets. Streets were less often introduced and described than landmarks, and they were associated with actions to be executed less frequently (although non-significantly) than landmarks were. The articulation between actions and places is known to be the core prescriptive component of route directions. Further, the frequency of occurrence of this class of items accounts for the efficiency of instructions (e.g., Daniel et al., in press; Denis, 1997). The most striking result is that directions contained twice as many references to landmarks as to streets.

## 4. Conclusions

Overall, our studies have confirmed the existence of a marked contrast between street and landmark information in route directions. Although street names offer an ideal solution to many referential problems, they appear to be poor guides, at least for a person totally unfamiliar with an environment. Furthermore, the spatial knowledge they provide is not as helpful as that provided by landmarks (Allen, 2000; Denis, 1997; Fontaine & Denis, 1999; Michon & Denis, 2001). Street names are nonetheless used in route directions, although less often than landmarks. In addition, our data show that the direction of walking does not affect this phenomenon.

Any effort to enhance the quality of urban route directions must consider these findings. Behavioral data of the kind reported here can be used as a basis for developing a formal model of landmark saliency. For instance, Raubal and Winter (2002) have considered cognitive and perceptual concepts to define attractive landmarks that allow newcomers to a city to successfully reach their destination. Recent work has also shown that the selection of salient features can be computed automatically (Nothegger, 2003). Our findings can therefore contribute to the improvement of route planning services by including appropriate features for the cognitive expectations of the human users.

## References


[1] Allen, G. L. (2000). Principles and practices for communicating route knowledge. *Applied Cognitive Psychology, 14*, 333-359.

[2] Bahrick, H. P. (1983). The cognitive map of a city: Fifty years of learning and memory. In G. H. Bower (Ed.), *The psychology of learning and motivation: Advances in research and theory* (pp. 125-163). New York: Academic Press.

[3] Bell, A. B., Greene, T. C., Fischer, J. D., & Baum, A. (1996). *Environmental psychology*. Fort Worth: Harcourt Brace College Publishers.

[4] Cohen, G., & Burke, D. M. (1993). Memory for proper names: A review. *Memory, 1*, 249-263.

[5] Cornell, E. H., Heth, C. D., Kneubuhler, Y., & Sehgal, S. (1996). Serial position effects in children's route reversal errors: Implications for police search operations. *Applied Cognitive Psychology, 10*, 301-326.

[6] Cornell, E. H., Heth, C. D., & Skoczylas, M. J. (1999). The nature and use of route expectancies following incidental learning. *Journal of Environmental Psychology, 19*, 209-229.

[7] Daniel, M.-P., Tom, A., Manghi, E., & Denis, M. (in press). Testing the value of route directions through navigational performance. *Spatial Cognition and Computation*.

[8] Denis, M. (1997). The description of routes: A cognitive approach to the production of spatial discourse. *Current Psychology of Cognition, 16*, 409-458.

[9] Denis, M., Pazzaglia, F., Cornoldi, C., & Bertolo, L. (1999). Spatial discourse and navigation: An analysis of route directions in the city of Venice. *Applied Cognitive Psychology, 13*, 145-174.

[10] Fontaine, S., & Denis, M. (1999). The production of route instructions in underground and urban environments. In C. Freksa & D. M. Mark (Eds.), *Spatial information theory: Cognitive and computational foundations of geographic information science* (pp. 83-94). Berlin: Springer.

[11] Galea, L. A. M., & Kimura, D. (1993). Sex differences in route learning. *Personality and Individual Differences, 14*, 53-65.

[12] Golledge, R. G. (1993). Geographical perspectives on spatial cognition. In T. Gärling & R. G. Golledge (Eds.), *Behavior and environment: Psychological and geographical approaches* (pp. 16-46). Amsterdam: North Holland.

[13] Heth, C. D., Cornell, E. H., & Alberts, D. M. (1997). Differential use of landmarks by 8- and 12-year-old children during route reversal navigation. *Journal of Environmental Psychology, 17*, 199-213.

[14] Ioerger, T. R. (1994). The manipulation of images to handle indeterminacy in spatial reasoning. *Cognitive Science, 18*, 551-593.

[15] Izaute, M. (1999). De la dénomination: la spécificité des noms propres. *L'Année Psychologique, 99*, 731-751.

[16] Kalakoski, V., & Saariluoma, P. (2001). Taxi drivers' exceptional memory of streets names. *Memory and Cognition, 29*, 634-638.

[17] Kirasic, K. C., & Mathes, E. A. (1990). Effects of different means for conveying environmental information on elderly adults' spatial cognition and behavior. *Environment and Behavior, 22*, 591-607.

[18] Mani, K., & Johnson-Laird, P. N. (1982). The mental representation of spatial descriptions. *Memory & Cognition, 10*, 181-187.
[19] Michon, P.-E., & Denis, M. (2001). When and why referring to visual landmarks in direction giving? In C. Freksa & D. M. Mark (Eds.), *Spatial information theory: Cognitive and computational foundations of geographic information science* (pp. 292-305). Berlin: Springer.
[20] Nothegger, C. (2003). Automatic selection of landmarks. Unpublished master's thesis (Diplomarbeit), Vienna Technical University, Vienna, Austria.
[21] Raubal, M., & Winter, S. (2002). Enriching wayfinding instructions with local landmarks. In M. J. Egenhofer & D. M. Mark (Eds.), *Geographic information science* (pp. 243-259). Berlin: Springer.
[22] Rossano, M. J., & Reardon, W. P. (1999). Goal specificity and the acquisition of survey knowledge. *Environment and Behavior, 31*, 395-412.
[23] Schneider, L. F., & Taylor, H. A. (1999). How do you get there from here? Mental representations of route descriptions. *Applied Cognitive Psychology, 13*, 415-441.
[24] Streeter, L. A., Vitello, D., & Wonsiewicz, S. A. (1985). How to tell people where to go: Comparing navigational aids. *International Journal of Man-Machine Studies, 22*, 549-562.
[25] Taylor, H. A., Naylor, S. J., & Chechile, N. A. (1999). Goal-specific influences on the representation of spatial perspective. *Memory and Cognition, 27*, 309-319.
[26] Taylor, H. A., & Tversky, B. (1992). Spatial mental models derived from survey and route descriptions. *Journal of Memory and Language, 31*, 261-292.
[27] Thorndyke, P. W., & Hayes-Roth, B. (1982). Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology, 14*, 560-589.