APPLIED COGNITIVE PSYCHOLOGY
Appl. Cognit. Psychol. **18**: 1213–1230 (2004)
Published online 15 June 2004 in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/acp.1045

Language and Spatial Cognition: Comparing the Roles of Landmarks and Street Names in Route Instructions

ARIANE TOM* and MICHEL DENIS

LIMSI-CNRS, Université de Paris-Sud, France

SUMMARY

Two experiments were conducted to investigate the processes involved when people use spatial descriptions intended to assist navigation. More specifically, we compared the effectiveness of route directions in an urban environment based on references either to landmarks or to street names. In the first experiment, the participants learned route directions that referred either to landmarks or to streets named after landmarks (e.g. a hospital vs. 'Hospital Street'). Processing times were shorter for instructions based on landmarks than for those based on street names. When the participants subsequently drew the route described, their memory was better when they had processed landmark rather than street information. The same route directions were used in the second experiment, in which the participants' memories were tested in a recognition task. The results showed that when target words referred to landmarks, the participants were more accurate and took less time to respond than when the same words were used to refer to streets. This finding indicates that the results of the previous experiment cannot be attributed to differing costs of the retrieval processes. Overall, the results of these experiments confirm the special cognitive status of landmarks in the mental representation of routes. Copyright © 2004 John Wiley & Sons, Ltd.

INTRODUCTION

People's everyday interaction with their environment constantly provides them with new items of spatial knowledge. This knowledge can be expressed in procedural forms, as when people navigate in the environment (by reproducing previous paths or inventing new ones), or in declarative forms, as when they produce oral, written or graphic descriptions of the environment (see Cornell, Heth, & Skoczylas, 1999). The re-enactment of procedures only involves the person executing them, whereas declarative spatial knowledge has the characteristic of being conveyed to other people in a context of communication in order to provide them with information likely to assist them in new navigation episodes. This is the context in which researchers have worked on the acquisition of spatial knowledge from maps (e.g. Kulhavy, Pridemore, & Stock, 1992) and, more recently, on language as a vehicle

*Correspondence to: Ariane Tom, Groupe Cognition Humaine, LIMSI-CNRS, Université de Paris-Sud, BP 133, 91403 Orsay Cedex, France. E-mail: Ariane.Tom@limsi.fr

Contract grant sponsor: Délégation Générale pour l'Armement (DGA).

of spatial knowledge (see Bloom, Peterson, Nadel, & Garrett, 1996; Landau & Jackendoff, 1993; Munnich, Landau, & Dosher, 2001). More specifically, the domain of route directions has proven to be of great theoretical value by offering a way of examining the interactions between two modules of the cognitive architecture, namely, language and spatial cognition (see Allen, 2000; Couclelis, 1996; Denis, 1997; Tversky & Lee, 1998).

In the domain of route directions, spatial discourse (or its written counterpart) has the interesting feature of combining several types of discourse in a single information package. Although route directions are typically described as belonging to the class of procedural discourse, they also include components that are not procedural in nature, but convey descriptive information about the environment traversed (by referring to visual landmarks such as buildings, shops, monuments, etc.). Route directions sometimes contain additional material that contributes to the social interaction ('It's not far', 'You can't go wrong'). To focus on the two main components, the procedural parts essentially consist of prescribing the actions that a user should perform to reach a target point in the environment ('Turn right'), whereas the other parts describe the environment in which the actions have to be executed ('There is a statue to the right of the church'). These two parts of the discourse have distinct functions and must be viewed separately. The procedural parts instruct someone which moves to make, whereas the other parts describe objects and scenes encountered during these moves. This distinction is difficult to make when the two aspects of the discourse are intertwined intimately in the same output. In particular, statements that closely articulate the prescription of actions and reference to landmarks ('Turn right just before the white building') are predominant parts of moving instructions, and the ones judged to be the most useful for assisting navigation (see Daniel & Denis, 1998, 2004; Denis, 1997; Denis, Pazzaglia, Cornoldi, & Bertolo, 1999).

How can we account for the predominant use of landmarks in direction-giving instructions? Theoretically, one could well design such instructions in purely metric terms by specifying the length of straight vectors and the angular values of reorientations at their ends. In fact, directional instructions limited entirely to enumerating movements and reorientations never occur in natural communication and would be perceived by people in the street as mostly unfriendly (see Michon & Denis, 2001). Route directions contain abundant references to landmarks, and it is tempting to postulate that they serve a cognitive function. A minimalist interpretation of such a function would be that landmarks are not introduced in route directions to convey any information about themselves, but to help in referring to coordinates within the moving space where specific actions have to be taken. For this purpose, landmarks can be thought of as 'reference points' (Sadalla, Burroughs, & Staplin, 1980) or 'anchor points' (Couclelis, Golledge, Gale, & Tobler, 1987). Referring to them simply amounts to specifying the portion of space where a key action is needed. From a cognitive point of view, introducing landmarks into route directions can also be considered as a way of helping the user of the spatial discourse to construct a visual model of the environment to be traversed in advance. Landmarks therefore permit cognitive anticipation (Denis, 1991). However, to carry out any of these functions efficiently, landmarks have to be appropriately selected from among a very large set of objects, and they must have some specific properties. In particular, they must be selected in such a way that it is easy to refer to them verbally. They must also be relevant and easily distinguished from each other. Finally, they should be introduced in the course of determinate descriptions, in order to avoid confronting the users with the typical cognitive difficulties associated with the processing of indeterminate (and also over-determinate) descriptions (Schneider & Taylor, 1999).

The relevance of landmarks and their value for signalization are amply documented, but it is surprising how very little effort has so far been devoted to investigating how the *pathways* along which people navigate are referred to in spatial discourse. Pathways can be conceived as elongated surfaces along which the person moves. Route describers have to find a way of referring to them. It is worth noting that most studies of route directions have been conducted in open (campus-like) environments (see Daniel, Tom, Manghi, & Denis, 2003; Golding, Graesser, & Hauselt, 1996; Lovelace, Hegarty, & Montello, 1999). In these environments, paths often have no specific names, and this probably makes it less likely that people will refer to them in their discourse. Given this characteristic of the environments in which most empirical research has taken place so far, it is not surprising that landmarks have emerged as essential key features of route directions in most models of spatial discourse. However, what we need is to find out whether this is due to their very special cognitive status, or to bias resulting from the characteristics of the environments usually chosen by researchers investigating route directions.

An investigation carried out in an urban environment would obviously be especially helpful in attempting to answer this question. In most cities, a characteristic of the ways along which navigation occurs is that they have proper names. Furthermore, these names are displayed in a systematic, conventional fashion on street plates. This makes streets easy to distinguish from one another (apart from any other urban features). This not only contrasts with countryside or campus environments, but also with corridor-type paths in subway environments, which are unnamed, and therefore indistinct, and, as a result, rarely mentioned in descriptions (Fontaine & Denis, 1999). Referring to street names in the description of urban routes is thus likely to be useful in solving ambiguities in a straightforward manner. Street names are therefore pieces of information that people can profitably use when producing or using route directions.

Natural descriptions do contain references to street names, but to a lesser extent than to the landmarks found along these streets and at crossroads (Michon & Denis, 2001; Tom & Denis, 2003). However, the specific feature of an urban environment is that route instructions can validly refer either to landmarks or, if a describer so decides, exclusively to streets. The advantage of referring to street names is to set the user free from any ambiguity, but there are also drawbacks. The names of the streets may not always be known, and sometimes they may not be visible. Furthermore, while some streets are named after a building or an institution located on the street ('Sorbonne Street', 'Opera Avenue'), many others are named in quite an arbitrary manner, in the sense that their names refer to objects (including remote geographical ones), abstract entities, or events that are unrelated to their surroundings. Consider, for example, streets in the city of Paris with names such as 'Rome Street', 'Lilac Street', 'Providence Street', or 'Pyramids Street'. This is also illustrated by the most common situation in which streets are named after famous people ('Mozart Avenue', 'Beaumarchais Boulevard'). Such proper names do not convey any spatial information about the portion of space to which they have been allocated. Further, they cannot be retrieved from the spatial structure of the environment to which they belong. This characteristic makes street names similar to other kinds of proper names, such as the names of individuals, which are known to be more difficult to retrieve than common names (see Cohen & Burke, 1993; Izaute, 1999). Using street names in route directions can be viewed as a way of formulating more concise instructions in route giving. Being proper names, they make it unnecessary to provide definite descriptions (e.g. 'Market Street' vs. 'the paved street bordered by lamp-posts which turns left and has a bakery at the corner').

To date, only a few studies have specifically dealt with the cognitive processing of street names. Regarding the use of street names, Thorndyke and Goldin (1983) analysed the verbalizations that participants produced while learning a new route during five daily learning sessions. They found that one powerful strategy consisted of establishing links between the streets to form a survey mental representation of the route. Streeter, Vitello, and Wonsiewicz (1985) reported that participants found street names less easy to perceive and used them less often than landmarks. Regarding the ability to remember street names, Bahrick (1983) found that the long-term memory of street names was very poor, and that landmarks were less often forgotten after the same interval (10 years). In another study of long-term memory, Schmidt, Peeck, Paas, and Van Breukelen (2000) identified three factors influencing the life-span retention of street names: the degree of exposure, the quality of learning, and the extent of retroactive interference. They found that the forgetting curve of incidentally-learned material, such as street names, followed a similar time course to that of forgetting intentionally-learned material. Their results are thus consistent with the stabilization of the forgetting curve for very long-term retention intervals (decades) observed for previously well-known materials, such as a foreign language (Bahrick, 1984) or mathematics (Bahrick & Hall, 1991). This is the phenomenon for which Bahrick (1984) coined the term of ‘permastore effect’. Lastly, in their study of taxi drivers’ memory of street names, Kalakoski and Saariluoma (2001) reported that taxi drivers recalled more street names than control participants, but this was only true when streets were listed in a sequence reflecting a spatially continuous route.

The present research starts from the obvious fact that in giving route directions, it is possible to refer either to the names of the paths along which navigation is to be executed or to the objects (buildings, shops, etc.) located along these paths. In natural descriptions, these two sorts of reference are often combined, but do they serve the same cognitive function? In order to clarify this point, Tom and Denis (2003) set up an experiment intended to compare navigational behaviour guided either by landmarks or street names. The results showed that overall street-based descriptions were less effective during navigation than landmark-based descriptions in several respects. Participants following the street-based instructions stopped more frequently to check information in the environment, indicating that they experienced more hesitation when they were using instructions of this type. Furthermore, each stop or checking episode lasted longer in the street-based than in the landmark-based condition. As a result, it took longer to reach the end-point using the street-based instructions. Behavioural indicators thus reflected that participants using landmark-based instructions were more self-confident during navigation, since they stopped and checked less often and for less time, even when ambiguous landmarks were involved.

The street/landmark contrast confirms that the mental representation of a route constructed during navigation depends to a large extent on the nature of the components of instructions. However, given the methodology used by Tom and Denis (2003), the differences could only be attested by measurements of behaviour that occurred subsequent to the processing of the instructions. No information was available about any differences that may have affected the processing itself. In order to obtain such information, we designed an experiment where on-line measurements were recorded while the participants processed the instructions. In addition to chronometric measurements, we also obtained measurements of performance in two memory tasks. Another new feature of this experiment was that in order to circumvent the many practical constraints inherent in using natural environments, we used verbal material referring to a fictitious environment. This approach also helped us to construct better controlled descriptions.

EXPERIMENT 1

Experiment 1 was designed to test the differences between two sets of directional instructions in terms of their processing. Two versions of the same route directions were constructed. In the first version, instructions were based on 14 street names using nouns of typical urban buildings (for instance, 'Hospital Street'). The names of the corresponding landmarks (in this example, a hospital) were used in the other version. The two versions were thus perfectly equated as regards their semantic content, their phonological forms, and the frequency of the words used.

The aim of this experiment was to find out whether the contrast between streets and landmarks still occurred when reading times were determined from on-line measurements of text processing. Should this be the case, reading times would be expected to be longer in the Street-based condition. This expectation is based on the assumption that the ingredients that differentiate a street-based from a landmark-based description are likely to be processed as arbitrary names (rather than names referring to individual spatial entities).

Subsequent measurements of memory were recorded. After reading one version of the route directions, the participants had to draw the route from memory. In a further memory task, they were given cues for retrieval. Specifically, they were asked to connect the elements that composed the route, as displayed on a pre-drawn map. The cues were expected to be particularly useful in the condition where participants had processed a street-based description, and so possibly reduce the differences previously found between the two conditions.

Method

Participants and design

Forty undergraduates, 20 females and 20 males, with a mean age of 23.90 years ($SD = 3.30$) took part in the experiment. They were randomly allocated one of the two experimental descriptions. The experimental design involved the description (Street- or Landmark-based) as the only two-level, between-participant factor.

Materials

Several precautions were taken in constructing the route directions to be used in this experiment. To balance the difficulty of processing and memorization in the two descriptions, only street names referring to landmarks were included in the Street-based description. The same landmarks appeared in the Landmark-based description in the corresponding instruction. All streets were referred to as 'streets' (there were no 'avenues', 'boulevards', and so forth), again to equalize the processing difficulty in the two sets of directions. The directions of turns were the same within the two descriptions, with six reorientations to the right and five to the left. To construct contextually valid route directions, we chose street names which do actually exist in the city of Paris, France, and which correspond to landmarks that are likely to be encountered in a town. In French, each landmark was designated by a single word. Furthermore, the nature and the proportions of the components typically found in route directions were respected. Denis' work (1997) has provided a classification of these ingredients. Five classes of items were distinguished: action prescriptions, action prescriptions with reference to landmarks, landmark introductions, landmark descriptions, and commentaries. Across several corpora, the frequencies of

Table 1. Route directions used in Experiment 1

Street-based description	Landmark-based description
1. This is quite a long route	1. This is quite a long route
2. First, stand with your back to Town Hall Street	2. First, stand with your back to the town hall
3. Three hundred metres away on your left, you will see Hospital Street	3. Three hundred metres away on your left, you will see a hospital
4. Cross Park Street	4. Cross a park
5. It is always crowded	5. It is always crowded
6. Turn right after Fountain Street	6. Turn right after the fountain
7. On your right is Church Street	7. On your right is a church
8. Turn left here	8. Turn left here
9. Building Site Street is in front of you	9. There is a building site in front of you
10. Keep going as far as Post Office Street	10. Keep going as far as the post office
11. It is very small	11. It is very small
12. Then, turn right after Hotel Street	12. Then, turn right after the hotel
13. Go as far as School Street	13. Go as far as the school
14. On the left, you will see Station Street	14. On the left, you will see the station
15. Turn left before Market Street	15. Turn left before the market
16. On the right, you will see Fish Shop Street	16. On the right, you will see a fish shop
17. On your left, there is Nursery Street	17. On your left, there is a nursery
18. Turn right	18. Turn right
19. Go straight on	19. Go straight on
20. On your left, you will see Theatre Street	20. On your left, you will see the theatre

occurrence of those classes were found to be quite consistent (Daniel & Denis, 1998). These frequencies were therefore used to construct our material, with the stipulation that each class was to be represented at least once. As a result, each set of route directions comprised a total of 20 instructions. Full descriptions are given in Table 1.

Procedure

The participants read either the Street-based or the Landmark-based description. Both descriptions were presented instruction by instruction in a self-paced presentation procedure on a laptop screen (Twinhead 5100T). The Experimental Run Time System (ERTS) software was used in this experiment (Beringer, 1994). Sentences were centred on the screen and written in a yellow, size-18 font on a blue background. The space bar allowed the participants to display the next sentence, and this caused the previous one to disappear. It was not possible to refer back in the description. The time allowed for reading an instruction was limited to 32 s, but no participant ever reached this limit.

The first memory task consisted of drawing the memorized route on a blank A3 (297×420 mm) sheet of paper using a blue pen. Once it was finished, the sketch was removed. Participants were then invited to read the same description twice more. The drawings were completed and/or modified after each reading, first with a red pen, then with a green one. A pilot study showed that three readings were necessary for participants to retain information. If necessary, participants were free to start a new sketch. Only three participants did so after the second reading, and four after the third one. Participants were also invited to write down any landmarks or street names that they remembered, but the location of which they had forgotten.

Lastly, the participants completed a second memory task, which consisted of a route reconstruction task. For this purpose, the participants were given a map that contained the elements which had to be connected to reconstruct the itinerary previously described. The map displayed either the 14 street names or the 14 landmarks previously cited in the corresponding route directions, plus 20 distractors of the same type (i.e. 20 street names or landmarks, respectively). Participants were asked to highlight the itinerary they had learned on this map using a coloured pen. The response times and the number of directional errors were recorded. The stopwatch was stopped while the participants were straying from the route.

Results

Reading task

The sentences composing the two descriptions differed in length, and so reading times were calculated in milliseconds per character, blanks included. It should be noted that the results to be reported here were confirmed when raw values for reading times were used as the dependent variable.

Figure 1 shows the mean reading times for each item class in each description. The data were submitted to an analysis of variance (ANOVA) with a $2 \times 5 \times 3$ mixed design, with two descriptions (Street- and Landmark-based descriptions), five classes of items (action prescriptions, action prescriptions with reference to streets/landmarks, street/landmark introductions, street/landmark descriptions, and commentaries), and three readings. Following Wright's (2003) recommendation, we report the values of confidence intervals (CI) for every dependent measurement along with the corresponding F values.

Firstly, the analysis showed that the description type had an overall effect on processing times. Participants processed instructions faster in the Landmark-based condition ($M = 166.35$, $SD = 40.89$) than in the Street-based one ($M = 200.37$, $SD = 50.04$). The difference (−34.02) was significant (95% CI from −62.34 to −5.70, $F(1, 38) = 5.54$,

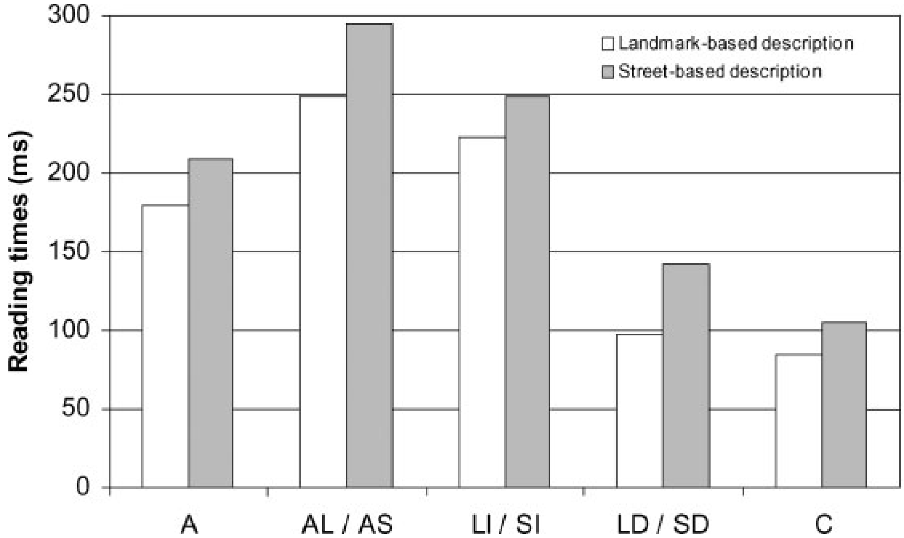

Figure 1. Reading times per character for each item class in each description (Experiment 1). Abbreviations: A: action prescriptions; AL/AS: action prescriptions with reference to landmarks/streets; LI/SI: landmark/street introductions; LD/SD: landmark/street descriptions; C: commentaries

$p < 0.02$). Tukey *post hoc* analyses showed that the difference between the descriptions was significant only for the second and third readings.

Processing times were different for the five components of route directions, $F(4, 152) = 74.43$, $p < 0.0001$. Commentaries and descriptions of landmarks or streets required the shortest processing times ($M = 94.76$, $SD = 36.81$, and $M = 120.48$, $SD = 69.75$, respectively), followed by actions ($M = 194.12$, $SD = 88.33$), introductions of landmarks or streets ($M = 235.50$, $SD = 63.95$), and actions with reference to a landmark or a street ($M = 271.95$, $SD = 74.03$). Tukey *post hoc* analyses showed that all differences between the classes compared pairwise were significant, except that between commentaries and descriptions of landmarks or streets. Interestingly, the Description × Class interaction was not significant, $F(4, 152) < 1$, indicating that the same order of classes was found for both descriptions. The hierarchy observed in the processing times allocated to the different classes of items thus seems to be a robust phenomenon.

Reading times differed for the three readings, $F(2, 76) = 9.55$, $p < 0.0005$. Tukey *post hoc* analyses showed that this was because reading times were shorter for the third reading. The Description × Reading interaction was significant, $F(2, 76) = 8.30$, $p < 0.001$. Tukey *post hoc* analyses showed that reading times were stable across readings for the Street-based description (all *p*s > 0.05). This was because two classes (namely, actions with reference to streets and introductions of streets) took as long to process at the third reading as in the two previous ones. In contrast, in the Landmark-based condition, reading times were shorter during the third reading.

Map drawing task

To analyse the maps, we focused on three different aspects. Table 2 shows the mean values of the selected drawing responses: the number of recalled items, the conditional frequencies of correctly located items, and drawing times per recalled item (in seconds). The data were submitted to an ANOVA with a 2 × 3 (Description × Reading) mixed design.

We first analysed the number of items recalled, either streets or landmarks. The participants who read the Landmark-based description recalled an overall average of 10.28 items ($SD = 1.34$), whereas the recall of those who read the Street-based description was only 6.47 ($SD = 2.17$) (out of a total of 14 items in both cases). The difference (+3.81) was significant (95% CI from 2.69 to 4.93, $F(1, 38) = 44.67$, $p < 0.0001$). The number of items recalled increased as the readings progressed, $F(2, 76) = 157.87$, $p < 0.0001$. The Description × Reading interaction was not significant. The same results were obtained when items of which the location had been forgotten were included in the analysis.

The second finding of interest was closely linked to the preceding one. The participants using the Landmark-based description did recall more items, but the locations of these items also had to be considered. Correctly located items were those that were correctly located relative to the previous item cited in the description, that is to the right, to the left or in front of this item. Because more items were recalled from the Landmark-based description (which means that correctly located items were more likely to be included in this description), we computed conditional relative frequencies using the following equation:

$$\text{Conditional frequency} = \text{Frequency of correctly located items}/\text{Frequency of recalled items}$$

The results showed that correctly located items were overall more frequent for the Landmark-based ($M = 0.76$, $SD = 0.18$) than for the Street-based description ($M = 0.53$, $SD = 0.28$). The difference (+0.23) was significant (95% CI from 0.08 to 0.38,

Table 2. Means and *SD* values (in brackets) of the drawing responses after the three readings of the Street- and Landmark-based descriptions (Experiment 1)

	Reading 1		Reading 2		Reading 3	
	Street	Landmark	Street	Landmark	Street	Landmark
Number of recalled items	3.20 *(1.70)*	6.85 *(2.06)*	6.25 *(2.57)*	10.95 *(1.79)*	9.95 *(3.46)*	13.05 *(1.15)*
Conditional frequencies of correctly located items	0.45 *(0.41)*	0.75 *(0.25)*	0.56 *(0.33)*	0.73 *(0.21)*	0.58 *(0.28)*	0.81 *(0.21)*
Drawing times per recalled item (s)	57.88 *(29.95)*	21.54 *(10.88)*	33.39 *(32.41)*	13.19 *(4.42)*	24.63 *(22.52)*	9.45 *(5.20)*

$F(1, 38) = 9.28$, $p < 0.005$). The effect of Reading and the Description × Reading interaction were not significant.

Lastly, we analysed the time taken to complete the drawings. Drawing times (in seconds) were divided by the number of items (streets or landmarks) recalled after each reading. We found that drawing times per item were overall shorter for the participants who had read the Landmark-based description ($M = 14.73$, $SD = 5.83$) than for those who had read the Street-based description ($M = 38.63$, $SD = 23.20$). The overall difference (−23.90) was significant (95% CI from 13.42 to 34.38, $F(1, 38) = 43.62$, $p < 0.0001$). The results of this analysis were confirmed when raw values for drawing times were taken into account.

Reconstruction task

We measured the time taken by the participants to highlight the correct route on the map. The participants who had read the Street-based description took longer to reconstruct the route on the map ($M = 155.30$, $SD = 51.36$) than those who had learned the Landmark-based description ($M = 78.80$, $SD = 36.67$). The difference (+76.50) was significant (95% CI from 48.84 to 104.16, $F(1, 38) = 29.39$, $p < 0.0001$).

The analysis of the number of directional errors made by the participants during the reconstruction of the itinerary showed that the participants using the Street-based instructions made more mistakes ($M = 0.98$, $SD = 1.22$) than those using the Landmark-based instructions ($M = 0.10$, $SD = 0.45$). Once again, the difference (+0.88) was significant (95% CI from 0.31 to 1.45, $F(1, 38) = 9.28$, $p < 0.005$).

Discussion

Our results showed that reading times were not significantly different for the first, second and third readings of the Street-based instructions, but that the time taken was shorter for the third reading of the Landmark-based instructions. The difference between the descriptions was attributable to two classes of items: actions with reference to streets and introductions of streets. The results therefore tend to suggest that street names call for more costly processing operations. Although landmarks took less time to process than streets, they were better recalled and better located relative to each other than streets were, and they were more easily accessed in memory (as indicated by the drawing times). These results are consistent with the assumption that a network of streets is more difficult to draw than a sequence of landmarks. Since this possibility had been anticipated, we took into account the number of streets that were named, but not located. More landmarks were recalled than street names. Finally, even when cues were provided to remind the participants of the route in the reconstruction task, the Landmark-based description was still confirmed to induce better performance than the Street-based one.

Our findings strongly suggest that street names are not processed as referring to buildings, but more like arbitrary proper names. The reading times reflect the difficulty of processing these items and of integrating them into a mental spatial representation of the route. In contrast, participants using the Landmark-based description may have constructed a good representation of the route much earlier, possibly by using visualization as an encoding strategy, as shown by their drawings. The visualization hypothesis was proposed by McWeeny, Young, Hay, and Ellis (1987) in a distinct, although related context, namely the retrieval of people's names. In the experiment of McWeeny et al. (1987), participants had to memorize faces together with the name and occupation of these individuals. The names used were either unambiguous (e.g. Hyde) or ambiguous, in that they also referred to occupations (e.g. Baker). The authors found that names were less well recalled than occupations, even in the case of the ambiguous ones. Presumably, street names are not as arbitrary as people's names. The likelihood of Mr Baker being a baker is almost zero, whereas it is quite likely that there is (or used to be) a hospital in Hospital Street. Nevertheless, street names, even ambiguous ones, seem to be handled here as proper names. Cohen and Burke (1993) explained the low recall of proper names by their relative meaninglessness, since they cannot be retrieved from a dense semantic network, whereas common names can. Moreover, clinical observations are congruent with a dissociation regarding the processing and the retrieval of common and proper names. Cases of selective impairment for proper names have been reported for people's names (Lucchelli & De Renzi, 1992) and for country and city names (Semenza & Zettin, 1988). The arbitrariness of proper names was also invoked by Schmidt et al. (2000) to explain the long-term forgetting of street names.

We can then assume that even when they indirectly refer to landmarks, street names tend to be processed and retrieved as proper names. They do not provide any implicit description of the designated locations. A visualization strategy is therefore unlikely to be implemented and, as a result, processing and retrieval are impaired. Note also that while landmark-based and street-based descriptions may use the same terms (as in this study), they are not necessarily equivalent in terms of real-world applicability. The landmarks would apply to items currently in the environment. Street names that refer to a landmark may refer to a landmark that historically was located on the street, but is no longer there. People are aware of this difference, and so may be more likely to treat landmark-based street names as arbitrary.

We also found that providing cues helped people to remember the route they had learned. In the reconstruction task, participants were confronted with maps where the streets previously learned were all displayed and acted as cues for retrieval. Errors were low for both the Street-based and the Landmark-based conditions. However, participants using the Street-based description took longer to reconstruct the route than did those using the Landmark-based description. This finding may have been due to the fact that street names simply require more time to be recognized than the corresponding landmark names, and the next experiment was designed to test whether this was actually the case.

EXPERIMENT 2

The second experiment was designed to explore further the contrast between the memory of streets or landmarks. The differences between Street-based and Landmark-based descriptions found in Experiment 1 may be ascribable to the greater difficulty in retrieving information from memory during recall for the Street-based condition. Experiment 2 was designed to test memory without any explicit retrieval effort. The same two descriptions were used as in Experiment 1. Memory for streets or landmarks was tested in a recognition task in which participants simply had to decide whether a word displayed had been included in the previously learned description. The same words—which once again could refer either to a street or to a landmark—served as targets after both descriptions. If no differences were found between the two conditions in the recognition task, this would indicate that the differences found in Experiment 1 were due to differing retrieval processes. Conversely, if the differences were still maintained, they would denote deep differences in the encoding of street and landmark information.

Method

Participants and design

Forty participants, 20 females and 20 males, participated in the experiment. The participants were all undergraduates and the mean age was 23.10 years ($SD = 3.40$). None of them had taken part in the previous experiment. They were randomly allocated one of the two experimental descriptions. The experimental design involved the description (Street- or Landmark-based) as a two-level, between-participant factor.

Materials

The descriptions used in Experiment 1 were used again here.

Procedure

The descriptions were presented instruction by instruction in a self-paced presentation procedure on a laptop screen (Twinhead 5100T). The ERTS software was also used in this experiment. Instructions were centred on the screen and written in a yellow, size-18 font on a blue background. The participants read the description only once. A pilot study had shown that a single reading was sufficient for the successful completion of the recognition task. After reading the description, the participants were shown a series of 28 words, one at a time. Fourteen of the words were targets (i.e. the names of the 14 landmarks or streets previously learned) and 14 were fillers. Fillers were names that could be either landmarks or street names, and which could plausibly be encountered in a town. Word order was counter-balanced across participants. The targets and fillers are shown in Table 3.

Four 28-word lists were compiled. In List 1, the words were randomly chosen with the constraint that no more than three fillers or targets were to appear in immediate succession. The words in List 1 were numbered from 1 to 28. List 2 consisted of the words listed from 28 to 1. List 3 consisted of words 15 to 28 and 1 to 14 and List 4 of words 14 to 1 and 28 to 15. Each word to be recognized was centred on the screen and written in a yellow, size-18 font on a blue background, and written in uppercase. Participants first saw a '+' signal lasting 1000 ms, indicating that the word was about to be displayed on the screen. The signal then disappeared for 100 ms and the word appeared. The inter-stimulus interval was

Table 3. Target words and fillers used in Experiment 2

Target words	Fillers
Town hall	Bakery
Hospital	Skate rink
Park	Consulate
Fountain	Court
Church	Bank
Building site	Gymnasium
Post office	Grocery
Hotel	Cinema
School	Police station
Station	Library
Market	Opera
Fish shop	Stadium
Nursery	Museum
Theatre	University

fixed at 3100 ms. The participants had to decide in each case whether the word displayed had been included in the description they had read. They had to respond as accurately and quickly as possible by pressing the shift right key for 'yes' or the shift left key for 'no'. These response keys were labelled 'yes' and 'no', respectively. The participants were all right-handed. The word remained on the screen until the participants had responded.

Results

Reading task

Reading times were calculated in milliseconds per character, including blanks. The data were submitted to an ANOVA with a 2×5 (Description $\times$ Class) mixed design. The participants processed the Landmark-based instructions faster ($M = 169.08$, $SD = 47.08$) than the Street-based ones ($M = 202.51$, $SD = 57.88$). This difference (-33.43) was only marginally significant (95% CI from -66.13 to -0.73, $F(1, 38) = 4.02, p = 0.055$). These times were very similar to those found in Experiment 1 for the first reading ($M = 178.51$, $SD = 58.56$, in the Landmark-based condition, and $M = 219.03$, $SD = 81.65$, in the Street-based condition, which did not differ significantly from each other, $p = 0.22$ with a Tukey test).

Processing times were different for the five components of route directions, $F(4, 152) = 52.55$, $p < 0.0001$. Commentaries and descriptions of landmarks or streets both required the shortest processing time ($M = 113.01$, $SD = 59.90$, and $M = 106.47$, $SD = 62.96$, respectively), followed by actions ($M = 167.18$, $SD = 89.25$), introductions of landmarks or streets ($M = 220.41$, $SD = 57.92$), and actions with reference to a landmark or a street ($M = 221.89$, $SD = 57.72$). Tukey *post hoc* analyses showed that all differences found between classes by pairwise comparisons were significant, except for those between the commentaries and descriptions of landmarks or streets and those between the introductions of landmarks or streets and actions with reference to a landmark or a street. The Description $\times$ Class interaction was significant, $F(4, 152) = 5.13$, $p < 0.0001$. Tukey *post hoc* analyses revealed that this was due to the fact that two classes, namely the introductions of landmarks and the actions with reference to a landmark, were processed faster than their street-based counterparts.

Recognition task

Four categories of response were distinguished: hits, correct rejections, false alarms, and omissions. The ANOVA did not reveal any impact of presentation order on either the frequency of responses for each category, or response times, and so data obtained using the four lists were pooled.

Figure 2 shows the data. An ANOVA was performed on the data with description as the single between-participant factor. In the Landmark-based and the Street-based conditions, the average numbers of hits were 12.91 ($SD = 1.37$) and 11.65 ($SD = 1.53$), respectively; the numbers of correct rejections were 13.23 ($SD = 1.17$) and 12.03 ($SD = 1.03$), respectively; those of false alarms were 0.70 ($SD = 0.98$) and 1.97 ($SD = 1.07$), respectively; and those of omissions were 1.09 ($SD = 1.33$) and 2.35 ($SD = 1.53$), respectively. Significant differences were found between the two conditions for all four indicators. Participants produced significantly more hits (+1.26) and correct rejections (+1.20) in the Landmark-based than in the Street-based condition (95% CI from 0.36 to 2.16, $F(1, 38) = 7.39$, $p < 0.01$, and 95% CI from 0.52 to 1.88, $F(1, 38) = 11.82$, $p < 0.001$, respectively). The reverse pattern was found for false alarms (-1.27) and omissions

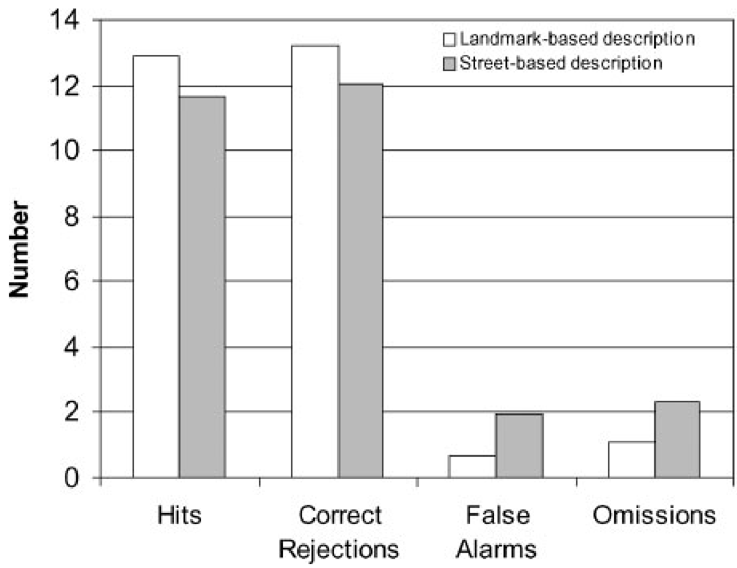

Figure 2. Number of hits, correct rejections, false alarms, and omissions after using the Street- or Landmark-based description (Experiment 2)

(−1.26) (95% CI from −1.91 to −0.63, $F(1, 38) = 15.56$, $p < 0.0005$, and 95% CI from −2.15 to −0.37, $F(1, 38) = 7.77$, $p < 0.01$).

We also computed d' values in order to obtain a single measure of response accuracy. For this purpose, we computed conditional frequencies for hits and false alarms, and then converted them into d' values using Elliott's (1964) tables. The analysis showed that d' was substantially higher in the Landmark-based ($M = 3.52$, $SD = 1.08$) than in the Street-based condition ($M = 2.23$, $SD = 0.66$). The difference (+1.29) was found to be significant (95% CI from 0.74 to 1.84, $F(1, 38) = 20.41$, $p < 0.0001$).

Figure 3 shows the response times (in milliseconds). A significant difference was found between the two conditions for hits ($M = 1217.06$, $SD = 310.87$, in the Landmark-based condition, and $M = 2920.27$, $SD = 1187.44$, in the Street-based condition). Participants performed faster (−1703.21) in the Landmark-based than in the Street-based condition (95% CI from −2254.01 to −1145.21, $F(1, 38) = 38.52$, $p < 0.0001$). The same pattern was found for correct rejections ($M = 1237.49$, $SD = 281.82$, in the Landmark-based condition, and $M = 2937.10$, $SD = 1233.19$, in the Street-based condition). Participants performed faster (−1699.61) in the Landmark-based than in the Street-based condition (95% CI from −2241.17 to −1165.50, $F(1, 38) = 36.10$, $p < 0.0001$).

Discussion

Results for reading times in this experiment accurately replicated those obtained in Experiment 1 for the first reading. Once again, reading times for the Landmark-based and the Street-based conditions were equivalent. In the recognition task, there was a significant difference between the two experimental descriptions as to the number of correct responses. Recognition scores, however, were high in both cases, indicating that the participants found it easy to recognize these items. However, the items were recognized more quickly by participants who had read the Landmark-based description. The contrast

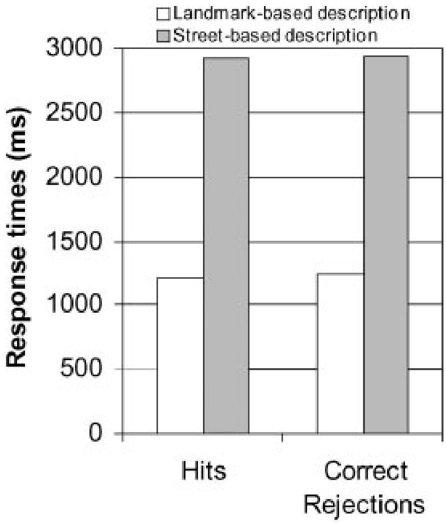

Figure 3. Response times for hits and correct rejections after using the Street- or Landmark-based description (Experiment 2)

between streets and landmarks was thus confirmed, even though the same words were used to designate them, and the participants did not have to make any effort of retrieval in the memory task. This finding strongly suggests that the locus of the difference between streets and landmarks is not located during the retrieval phase, but as early as the encoding phase. This finding should also be related to the literature concerned with contextual effects on word-level processing and, in particular, reports that concrete words are identified more quickly than abstract words (e.g., Balota, 1994; Balota, Ferraro, & Connor, 1991).

GENERAL DISCUSSION

The purpose of this research was to establish whether route directions based on objects situated along paths are equivalent to route directions based on the paths themselves. The experiments reported here were intended to investigate the contrast between using street names or landmarks to process spatial instructions. Only one experiment, to our knowledge, has specifically investigated this topic (Tom & Denis, 2003), whereas a large number of studies have focused on the importance of landmarks in the production of route directions (e.g. Denis, 1997; Galea & Kimura, 1993; Klein, 1982). These studies agree about the specific value of landmarks for indicating where any important action—mainly, progression or reorientation—has to be executed. However, the paths along which the actions are executed can also be used for orientation purposes. This is especially true in urban settings, where paths are explicitly labelled by name plates. Our studies were intended to test the relevance of the contrast between the use of streets and landmarks to guiding people along an unfamiliar route and allowing them to retrieve the information conveyed by the instructions efficiently.

Tom and Denis (2003) showed that for a pedestrian, being guided by street names was less efficient than being guided by landmarks. The question, however, was whether this contrast was already present while people were acquainting themselves with the instructions. To answer this question, in Experiment 1, we relied on reading times as indicators of the processing of the route directions. Our findings indicated that from the second reading of the description, reading times were shorter when the instructions were based on landmarks rather than streets. The results obtained for the first reading were confirmed in the second study (in which the participants read the instructions only once). Nevertheless, in the drawing phase, landmarks were better recalled than streets. Furthermore, highlighting the memorized route on a map took less time when the description previously read had been based on landmarks. Experiment 2 was also designed to find out whether the differences between street-based and landmark-based descriptions were to be interpreted in terms of differing retrieval processes. Recognition accuracy was higher in the Landmark-based condition, and the same words were recognized more quickly when they had previously been included in a description based on landmarks. As recognition tasks typically avoid the need for any retrieval effort, the persistence of this contrast strongly supported the hypothesis that streets and landmarks are encoded differently.

To sum up, our results suggest that the cognitive cost involved in processing landmarks is lower than that associated with streets. They confirm that memory of streets is poorer than memory of landmarks. To explain these results, both conceptual and geometric differences between streets and landmarks should be considered. Conceptual differences were discussed by Landau and Jackendoff (1993), who claimed that any account of spatial mental representations must call upon two distinct sets of elements, namely, places and paths. Whereas places typically contain landmarks or reference objects, paths are the routes linking these places. Geometric differences pertain to the fact that whilst landmarks can be represented as zero-dimension spatial entities (dots), streets may be seen as one-dimension entities (lines) (see Gale, Golledge, Pellegrino, & Doherty, 1990). Thus, landmarks may be more effective than streets when representing a previously unknown route, as it is easier to construct a mental representation of a route based on interconnected dots than one based on interconnected extended lines.

A further contrast between streets and landmarks may result from the fact that street names are processed, encoded, and retrieved as proper names. The explanation, here, is that proper names are arbitrary, meaningless labels (Cohen & Burke, 1993; Lucchelli & De Renzi, 1992; Schmidt et al., 2000). Street names only designate locations, without reflecting any further spatial or descriptive properties of the places described. They are therefore 'pure referring expressions' (Semenza & Zettin, 1988). This is not the case for landmarks, the properties of which can easily be inferred, and may possibly contribute to the formation of visual images. For instance, a French town hall can readily be imagined as being a large building with a flag fluttering on the front. Furthermore, like all common names, landmarks involve dense semantic networks. A town hall can be linked to a building, a mayor, or even a wedding. The encoding of landmarks thus markedly differs from the encoding of street names. The most striking result to emerge from our experiments is that the arbitrary character of street names remains valid even though we had deliberately introduced some ambiguity into our materials, where the street names were created from landmark names. This core property definitely confirms the contrasting cognitive status of streets and landmarks in the mental representation of navigational space.

ACKNOWLEDGEMENTS

The research reported in this article was supported by a doctoral research grant from the Délégation Générale pour l'Armement (DGA). The authors are grateful to Daniel Wright and two anonymous reviewers for their helpful comments on a previous version of the manuscript.

REFERENCES

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

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.

Bahrick, H. P. (1984). Semantic memory content in the permastore: fifty years of memory for Spanish learned in school. *Journal of Experimental Psychology: General, 113*, 1–29.

Bahrick, H. P., & Hall, L. K. (1991). Lifetime maintenance of high school mathematics content. *Journal of Experimental Psychology: General, 120*, 20–33.

Balota, D. A. (1994). Visual word recognition: the journey from features to meaning. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 303–356). San Diego, CA: Academic Press.

Balota, D. A., Ferraro, F. R., & Connor, L. T. (1991). On the early influence of meaning in word recognition: a review of the literature. In P. J. Schwanenflugel (Ed.), *The psychology of word meanings* (pp. 187–222). Hillsdale, NJ: Erlbaum.

Beringer, J. (1994). ERTS: a flexible software tool for developing and running psychological reaction time experiments on IBM PCs. *Behavior Research Methods, Instruments, and Computers, 26*, 368–372.

Bloom, P., Peterson, M. A., Nadel, L., & Garrett, M. F. (1996). *Language and space*. Cambridge, MA: MIT Press.

Cohen, G., & Burke, D. M. (1993). Memory for proper names: a review. *Memory, 1*, 249–263.

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

Couclelis, H. (1996). Verbal directions for way-finding: space, cognition, and language. In J. Portugali (Ed.), *The construction of cognitive maps* (pp. 133–153). Dordrecht, The Netherlands: Kluwer.

Couclelis, H., Golledge, R. G., Gale, N., & Tobler, W. (1987). Exploring the anchor-point hypothesis of spatial cognition. *Journal of Environmental Psychology, 7*, 99–122.

Daniel, M.-P., & Denis, M. (1998). Spatial descriptions as navigational aids: a cognitive analysis of route descriptions. *Kognitionswissenschaft, 7*, 45–52.

Daniel, M.-P., & Denis, M. (2004). The production of route directions: investigating conditions that favour conciseness in spatial discourse. *Applied Cognitive Psychology, 18*, 57–75.

Daniel, M.-P., Tom, A., Manghi, E., & Denis, M. (2003). Testing the value of route directions through navigational performance. *Spatial Cognition and Computation, 3*, 269–289.

Denis, M. (1991). *Image and cognition*. New York: Harvester Wheatsheaf.

Denis, M. (1997). The description of routes: a cognitive approach to the production of spatial discourse. *Current Psychology of Cognition, 16*, 409–458.

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.

Elliott, P. B. (1964). Tables of d'. In J. A. Swets (Ed.), *Signal detection and recognition by human observers* (pp. 651–684). New York: Wiley.

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.

Gale, N., Golledge, R. G., Pellegrino, J. W., & Doherty, S. (1990). The acquisition and integration of route knowledge in an unfamiliar neighborhood. *Journal of Environmental Psychology, 10*, 3–25.

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

Golding, M. J., Graesser, A. C., & Hauselt, J. (1996). The process of answering direction-giving questions when someone is lost on an university campus: the role of pragmatics. *Applied Cognitive Psychology, 10*, 23–39.
Izaute, M. (1999). De la dénomination: La spécificité des noms propres. *L'Année Psychologique, 99*, 731–751.
Kalakoski, V., & Saariluoma, P. (2001). Taxi drivers' exceptional memory of street names. *Memory and Cognition, 29*, 634–638.
Klein, W. (1982). Local deixis in route directions. In R. J. Jarvella, & W. Klein (Eds.), *Speech, place and action* (pp. 161–182). Chichester: Wiley.
Kulhavy, R. W., Pridemore, D. R., & Stock, W. A. (1992). Cartographic experience and thinking aloud about thematic maps. *Cartographica, 29*, 1–9.
Landau, B., & Jackendoff, R. (1993). 'What' and 'where' in spatial language and spatial cognition. *Behavioral and Brain Sciences, 16*, 217–265.
Lovelace, K. L., Hegarty, M., & Montello, D. R. (1999). Elements of good route directions in familiar and unfamiliar environments. In C. Freksa, & D. M. Mark (Eds.), *Spatial information theory: Cognitive and computational foundations of geographic information science* (pp. 65–82). Berlin: Springer.
Lucchelli, F., & De Renzi, E. (1992). Proper name anomia. *Cortex, 28*, 221–230.
McWeeny, K. H., Young, A. W., Hay, D. C., & Ellis, A. W. (1987). Putting names to faces. *British Journal of Psychology, 78*, 143–149.
Michon, P.-E., & Denis, M. (2001). When and why referring to visual landmarks in direction giving? In D. R. Montello (Ed.), *Spatial information theory: Foundations of geographic information science* (pp. 292–305). Berlin: Springer.
Munnich, E., Landau, B., & Dosher, B. A. (2001). Spatial language and spatial representation: a cross-linguistic comparison. *Cognition, 81*, 171–207.
Sadalla, E. K., Burroughs, W. J., & Staplin, L. J. (1980). Reference points in spatial cognition. *Journal of Experimental Psychology: Human Learning and Memory, 6*, 516–528.
Schmidt, H. G., Peeck, V. H., Paas, F., & Van Breukelen, G. J. P. (2000). Remembering the street names of one's childhood neighbourhood: a study of very long-term retention. *Memory, 8*, 37–49.
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.
Semenza, C., & Zettin, M. (1988). Generating proper names: a case of selective inability. *Cognitive Neuropsychology, 5*, 711–721.
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.
Thorndyke, P. W., & Goldin, S. E. (1983). Spatial learning and reasoning skill. In H. L. Pick, Jr., & L. P. Acredolo (Eds.), *Spatial orientation: Theory, research, and application* (pp. 195–217). New York: Plenum Press.
Tom, A., & Denis, M. (2003). Referring to landmark or street information in route directions: what difference does it make? In W. Kuhn, M. F. Worboys, & S. Timpf (Eds.), *Spatial information theory: Foundations of geographic information science* (pp. 384–397). Berlin: Springer.
Tversky, B., & Lee, P. (1998). How space structures language. In C. Freksa, C. Habel, & K. F. Wender (Eds.), *Spatial cognition: An interdisciplinary approach to representation and processing of spatial knowledge* (pp. 157–175). Berlin: Springer-Verlag.
Wright, D. B. (2003). Making friends with your data: improving how statistics are conducted and reported. *British Journal of Educational Psychology, 73*, 123–136.

