CPC, 1997, 16 (4), 409-458

The description of routes: A cognitive approach to the production of spatial discourse

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Abstract. This paper provides a general framework for the analysis of descriptions of routes, in order to account for the way in which spatial cognition is externalized through discourse. Three cognitive operations are assumed to be involved in the generation of this form of spatial discourse: (a) activation of an internal representation of the environment in which navigation will take place; (b) the planning of a route in the subspace of the mental representation currently activated; and (c) the formulation of the procedure that the user should execute to reach the goal. Two major components of the descriptions of routes are considered, those by which speakers refer to landmarks and those which consist of prescribing actions. Descriptions of two routes in a natural environment were collected from 20 undergraduates. A detailed analysis of the protocols was used to establish a classification of items, in which five classes were defined: prescription of actions without referring to any landmark, prescription of actions with reference to a landmark, reference to landmarks without referring to any associated action, description of landmarks, commentaries. Individual protocols were then used to construct more abstract (skeletal) descriptions, reflecting the essentials of the navigational procedure. Skeletal descriptions confirmed that landmarks and their associated actions were key components of route descriptions.

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Additional analyses indicated that the similarity of individual descriptions to the skeletal description of a route predicted the rated quality of these descriptions. Female subjects provided descriptions containing more landmarks than did males. Lastly, the descriptions provided by high visuo-spatial imagers contained more frequent references to landmarks, which is consistent with the expectation that subjects who are more likely to retrieve visuo-spatial information from their memories should include more references to such information in their verbal productions.

Key words: Description of routes, spatial cognition, discourse production, communication, visuo-spatial imagery.

INTRODUCTION

The research reported in this paper involves the investigation of two cognitive domains, the domains of *spatial cognition* and *discourse production*. Each of these has been the subject of a great deal of research and theory in cognitive psychology. Although some connections between these domains have produced significant research (e.g., De Vega, 1995; Herskovits, 1986; Laudau & Jackendoff, 1993; Levelt, 1989; Tversky, 1991), many aspects of their relationships are still in need of clarification. From an ecological point of view, the ubiquity of communication situations in which natural language is used to convey spatial knowledge justifies the development of research in this domain. From a theoretical point of view, there is need for more documented accounts of the way in which two representational systems endowed with different properties interact, in many cases, successfully. The research reported here was designed to account for these interactions by developing a heuristic framework and collecting data to evaluate the validity of the assumptions derived from this general framework.

The concept of spatial cognition refers to the subset of people's knowledge that represents their immediate or remote environmental space. The concept also subsumes the set of processes responsible for the construction, storage, and retrieval of such knowledge (cf. Lynch, 1960). Spatial knowledge is primarily used by people during navigation to reach a goal, while avoiding any costly or risky experience with their environment. It is also used for manipulating objects in the environment. Spatial knowledge is externalized during communication, in particular to assist people who must navigate in an unfamiliar environment. Externalizing spatial knowledge may involve a variety of media. Depictions are frequently used to convey spatial knowledge (through maps, sketches, etc.; cf. Pearce, 1981; Tversky, 1995; Wright, Lickorish, Hull, & Ummelen, 1995). The informational value of maps resides to a large extent in their structural analogy with the environments they depict, although maps also include some conventional information. Discourse is another useful medium communicating spatial information. It is generally used to transmit navigational information to a person immersed in a new environment. Obviously, the nature and structure of the linguistic medium are different from those of the spatial entities it refers to. Appropriate use of "spatial language" thus depends on the addressee's capacity to translate linear linguistic information into multidimensional internal representations which incorporate veridical topological relations among the described objects (cf. Denis, 1996; Levelt, 1982; Linde & Labov, 1975; Ullmer-Ehrich, 1982).

In order to account for the production of spatial discourse, it is important to consider both the processes that are implemented in discourse in general and those that are specific to communication about space. In particular, pragmatic or situational factors are likely to shape the content and structure of spatial discourse, depending on whether the speaker intends to provide the addressee with instructions on how to move in an environment, or simply a description of a territory which is not to be traversed by the user of the description, but viewed from above. The research reported here focuses on discourse that is produced to assist a person in finding his/her way in an unfamiliar environment. To be complete, such a research program should take both speaker's and addressee's productions into account, and analyze the role of the latter as a partner in the elicitation of speaker's spatial knowledge (in particular, when the addressee helps the speaker to be specific by pointing to discourse indeterminacies) (cf. Garrod & Anderson, 1987; Isaacs & Clark, 1987; Lloyd, 1991; Wunderlich & Reinelt, 1982). This initial investigation focuses on speaker's contribution in the pseudo-interactive situation where a speaker produces a message which is to be used later by another person. The communication framework is thus preserved during data collection, but the analysis is centered on the production side of the situation.

Route instructions, like any other form of discourse, are subordinated to *planning activities* (cf. Levelt, 1989). The initial step, macroplanning, consists of elaborating a communicative intention as a sequence of subgoals, and selecting the information required to realize these goals. The speaker must place the information in sequence in order to express it. The conceptual activity involved during this initial step results in a preverbal message. Once the first step of preparing the message is completed, the second step, microplanning, is begun. It mainly consists of assigning a propositional format to information which is to be communicated. This step is a transition from the preverbal message to formulation, which consists of transforming a conceptual structure into a linguistic structure. Microplanning implies access to a mental lexicon and grammatical encoding in order to determine the surface structure of discourse, and phonological encoding in order to build an articulatory program.

Besides these general processes, which are not specific to route instructions, there are three features specific to this type of discourse. First, route instructions are a type of discourse which is closely linked to subject's *knowledge* available in long-term memory. Part of spatial knowledge is stored in declarative or language-like formats (e.g., "Paris is the capital of France"), but another, potentially very large part is non-linguistic in nature. This subset of spatial knowledge is sometimes subsumed by the convenient metaphor of "cognitive maps". Cognitive or mental maps are thought to be analog representations of spatially extended entities, although they may be hierarchically organized (cf. McNamara, Halpin, & Hardy, 1992; Sholl, 1987) or contain distortions (cf. Giraudo & Pailhous, 1994; Moar & Bower, 1983; Stevens & Coupe, 1978; Tversky, 1981). A large part of human knowledge of environmental space is stored in the form of non-linguistic (presumably visuo-spatial) representations, which may be retrieved in the form of visuo-spatial images.

Secondly, regarding the *content* of route instructions, the most important statements are instructional statements that prescribe actions to be performed by the user of these instructions (e.g., "Turn right after the drugstore", or "Go along this street for 150 meters"). Because of these components, route instructions can be considered to be a variant of procedural discourse (cf. Dixon, 1987; Heurley, 1994). However, route instructions contain other components, in particular those pertaining to descriptive discourse. These components typically specify the topological relations of the virtual mover to landmarks to be found along the route (e.g., "On your right, there is a bookshop"), or the relations of landmarks to each other ("To the right of the bookshop, there is a bank"), or by describing landmark properties ("There is an automatic teller on the front of the bank"). Still other components of route instructions provide the addressee with evaluative comments or express encyclopaedic knowledge that may not be immediately relevant to the instructional purpose. Route instructions are thus a composite of various discourse ingredients. They contain linguistic units fulfilling different purposes for the speaker, and presumably call for different forms of cognitive processing by the addressee.

Thirdly, route instructions must be considered for their *structure*. In this respect, route instructions are a very special case of spatial discourse. While descriptions of static spatial configurations require speakers to make choices among a variety of linearization strategies (cf. Daniel, Carité, & Denis, 1996; Shanon, 1984), determining a sequence for describing a route is not in principle a crucial issue. The successive steps along a route are typically reported in the order of their appearance for the moving subject. In other words, discourse linearization results from direct mapping of one structure (the sequence of verbal outputs) onto another structure (the sequence of landmarks where specific actions are to be executed). Discourse linearity thus completely adheres to the linearity of the described entity. However, although speakers do not have to solve any special "linearization problem" (cf. Levelt, 1989), they have to make other significant choices, in particular the choice of which landmarks will be mentioned as sites for the execution of appropriate actions.

A GENERAL FRAMEWORK FOR THE ANALYSIS OF DESCRIPTIONS OF ROUTES

Although a number of articulated approaches to spatial language are available (e.g., Herskovits, 1986; Landau & Jackendoff, 1993; Taylor & Tversky, 1992, 1996), there have been few studies specifically dedicated to the analysis of route descriptions. From a linguistic point of view, the description of routes was considered by Wolfgang Klein

(1982) to be a privileged domain for the analysis of local deictics. Klein has been mainly concerned with the connections of spatial language with cognitive processes. His analysis of data collected from children has pointed out the deficiencies of young children's planning strategies and their difficulties in the manipulation of local deictics (cf. Klein, 1983). Wunderlich and Reinelt (1982) analyzed the interactive setting in which one person provides another with route directions. Their analysis of a selected set of dialogues has formed the basis for a model of the interactional scheme of giving directions. More recently, a study by Golding, Graesser, and Hauselt (1996) stressed the importance of establishing common ground through the use of counter-questions that verify common knowledge of the described environment between the questioner and the answerer.

Analysis of natural route descriptions has also been the starting point in the development of formal models, including AI models, for representing spatial knowledge and its use in navigational aid systems (cf. Chown, Kaplan, & Kortenkamp, 1995; Kuipers, 1978; Kuipers & Byun, 1991; Maass, 1993; Riesbeck, 1980). These studies were done to provide specifications for the design of human-machine interactive systems capable of assisting drivers in real-life situations (e.g., Briffault & Denis, 1996; Streeter, Vitello, & Wonsiewicz, 1985). The analysis of spatial terminology available from large corpora has been conducted in an effort to provide classifications of linguistic items used in the description of routes, in particular motion verbs (cf. Gryl, 1995; Sablayrolles, 1995).

While linguists and AI researchers have developed their models without much concern for quantitative analysis of their corpora, the few empirical studies relying on controlled methodology were conducted by psychologists mainly interested in the development of communication in children (rather than in spatial cognition per se). Waller (1985) showed that older children respect the linear structure of route descriptions more than do younger ones when they have to describe how to reach a hidden object in a room (see also Waller & Harris, 1988). In a study on the description of routes from a map, Lloyd (1991) reported that the strategies used to communicate route descriptions vary with age. Children tend to refer to directions less than do adults. None of these studies, however, has documented the strategies used by children to describe routes in natural large-scale environments. In the study by Golding, Grasser, and Hauselt (1996), the analysis of route directions collected on a campus revealed that answerers interpret direction-giving questions as hybrid questions calling both for the procedures to reach the goal (i.e., path specification) and descriptive information that identifies the destination (i.e., destination specification).

This review of the few published studies on the description of routes indicates the need for a more extensive investigation of materials collected in real (or realistic) situations with controlled methodology. In the cognitive approach favored here, discourse is viewed as an output of cognitive operations (some of which are not linguistic in nature). The objective, for the researcher, is to identify the cognitive acts which govern the production of this type of discourse. Furthermore, while most previous research has highlighted the variety of strategies used in the description of routes, it is appropriate to maintain this concept of variability within the scope of the research and develop a quantitative approach to its measurement, thus facilitating comparison of individual descriptions in a corpus with a reference description. This requires methodological principles to build such reference descriptions from empirical data (rather than defining them a priori on the basis of a researcher's intuition).

Cognitive operations involved in the description of routes

The description of a route is generally produced in response to a request, the general form of which may be stated as follows: "Starting from a given point in a pluridimensional spatial environment, what actions should be executed to reach another specified point in this environment?". This request explicitly calls for instructions for a set of actions. The formulation of these instructions comes as the last of a succession of three (macro-) operations. The following proposal outlines the information processing stages that may underlie the construction of route descriptions.

Activating a representation. The first operation is the activation by the speaker of an internal representation of the territory in which the proposed displacement will be made. People have a repertoire of representations of spatial environments. Interpreting the request results in circumscribing and activating the relevant subset of this repertoire. However, no suggestion is made that there would be a single stored representation for any route description. In response to a specific request, an activated representation is more likely to result from piecing together a set of more elementary representations.

Available spatial representations include visual aspects of the environment, as explored from the subject's egocentric perspective, but also procedural components, derived from the moves that the subject has experienced in this environment (cf. McNamara, Halpin, & Hardy, 1992; Sholl, 1987; Thorndyke, 1981; Thorndyke & Hayes-Roth, 1982). Visuo-spatial imagery has been shown to contribute to the elaboration of internal representations of environments learned from maps as well as from verbal descriptions (cf. Denis & Cocude, 1997; Denis & Denhière, 1990; Thorndyke & Stasz, 1980).

The notion that route descriptions use visuo-spatial representations as inputs is supported by the studies on patients whose cognitive deficiencies affect their verbal production (although their linguistic capacities are intact). For instance, neuropsychological data on hemineglect indicate that not only do patients tend to "ignore" the left part of visual scenes that they reconstruct from memory, but that they have more difficulty in evoking reorientations towards the left when they describe a route in a familiar environment. They even redefine routes in the form of uneconomical itineraries which only require reorientations towards the right (cf. Bisiach, Brouchon, Poncet, & Rusconi, 1993). The assumption that route descriptions reflect spatial knowledge activated in the form of visuo-spatial representations can be tested empirically in normal subjects, by examining the effects of manipulating visual imagery on the content of route descriptions.

Planning a route. The second operation consists of planning a route in the subspace of the mental representation currently activated. Defining a route means defining a sequence of segments which connect the starting point to the destination and are to be followed by the person in move. The succession of route segments will directly command the succession of actions to be undertaken by the user of the description. Note that the speaker's objective is not to communicate to the addressee his/her whole representation of the environment wherein the displacement is to take place. A restriction on the representation is operated, resulting in the activation of the relevant part of spatial knowledge. The definition of a specific route results from a selection among a set of variants. It is based on criteria like the shortest route, or the route with the smallest angular discrepancy with respect to the goal at each intersection, and so on (cf. Cornell, Heth, & Alberts, 1994; Gärling, 1989; Golledge, 1995; Pailhous, 1970).

In principle, linguistic factors are not relevant for this set of operations. However, although route planning is mainly a preverbal operation, the choice of some routes or segments of routes may be constrained by criteria linked to their communicability. For instance, a detour may be easier to describe than a shortcut devoid of distinctive landmarks. As a consequence, the definition of a route not only takes into account the ease of its execution, but also the fact that the route has to be described verbally. The description is intended to be easy to process and compatible with the cognitive resources of its user.

Formulating a procedure. The ultimate operation consists of formulating the procedure that the user will have to execute to move along the route and eventually attain its end. This operation results in a verbal output, which reveals the intimate interfacing achieved between the speaker's spatial knowledge and his/her linguistic capabilities. Once the route has been defined, one theoretically possible procedure might consist of describing exhaustively the succession of visual scenes that will appear along the route and describing every step to be done until the goal is reached. This, obviously, is never the case. In practice, the person describing a route produces a limited number of statements (if only because he/she takes into account the limited processing capacities of the addressee). Formulation of the procedure is based on the subdivision of the route into segments (or paths) which connect reorientation points. If this subdivision is not directly available from the previous operation (route planning), it must be done to facilitate the production of the verbal output.

The objective of the speaker is to make the user progress along segments of appropriate length and execute reorientations of the axis of progress at critical points, according to appropriate angles. In fact, the formulations in a route description never come down to a succession of prescriptions of progress and reorientation (which in principle could be expressed in purely metric terms), but they give central importance to the mention of landmarks to be encountered along the route. The sites where reorientation is to occur are generally indicated by referring to landmarks rather than in terms of exact distances to cover until reorientation.

A critical problem is then the *selection of the landmarks* that are to be mentioned. Only a limited number of the very large number of buildings, signs, and other landmarks that punctuate a route are eventually mentioned. Why are some landmarks mentioned and all the others discarded? Are some geographical objects better candidates than others as landmarks for describing routes? The selection may be guided by the intrinsic value of some objects in the environment, such as their visual salience (cf. Conklin & McDonald, 1982), but also by their informative value for the actions to be executed. In particular, those parts of the route where reorientations are needed are expected to be those where more landmarks are mentioned. This is a testable hypothesis, although some landmarks may also be mentioned independently of their reorienting function.

Another point of interest is the variations in the way individual subjects tend to mention landmarks in route descriptions. Female subjects mention more landmarks than male subjects (cf. Galea & Kimura, 1993; McGuinness & Sparks, 1983; Miller & Santoni, 1986). Other individual characteristics are also likely to affect the probability of mentioning landmarks. In particular, high visual imagers will probably mention more visual landmarks than low imagers when they describe routes.

Referring to landmarks and prescribing actions

There are two essential components of route descriptions. The first are those which refer to *landmarks*, mainly three-dimensional physical objects, of which some are natural parts of the environment (church, drugstore, bus stop, etc.) and some are artifacts designed to signal directions (signposts, etc.). The two-dimensional entities on which displacements are executed can also be used as landmarks (streets, squares, roads, etc.). The second set of components are those which prescribe *actions* (go straight ahead, turn right, skirt around, etc.). What makes a route description functional is the adequation between these two sets of discourse components, that is, prescribed actions are to be executed at specific sites within the environment, which are designated by referring to their characteristic landmarks.

Three key functions are typically assigned to landmarks in the description of routes. The first is *signaling sites where actions are to be accomplished* ("Then you will see a church; go around it on the right").

A variant of this function is that in which the landmark signals the site where ongoing actions are to be modified, the most typical case being cessation of a current action. In contrast to singular landmarks ("the church"), sets of landmarks may be referred to in order to quantify the extent of progress along a lengthy linear segment ("You pass three traffic lights", "Take the fifth street on the left"). The second function of landmarks is to help *locate other landmarks*, which are supposed to trigger a new action ("You will see a church; to the right of the church is a memorial; just to the right of the memorial is a path; take this path"). In this case, there is a hierarchy in the visibility (or salience) of landmarks, with the most visible being used to locate the less visible. The third function is that of *confirmation*, which occurs during the carrying out of lengthy actions, when the speaker mentions landmarks situated along the route, to provide confirmation that the person is still on the right route ("Walk for about 500 meters on the same street; you will pass a newspaper stand; then you will arrive at a crossroads where you will turn right").

Prescriptions apply to two main classes of actions: *changing orientation* ("Turn left"), or *proceeding* ("Walk straight ahead"). Three-dimensional landmarks (e.g., buildings) are more frequently mentioned to signal points where a change of orientation should be executed. Two-dimensional or linear entities (e.g., streets) are more typically used to specify the axis of progress, although they may also be used as landmarks for changing orientation (e.g., crossroads). A third kind of prescription is also found in route descriptions, prescriptions of *positioning*, which allow users of a description to check that their current orientation matches the intended one. Such perspective verification is based on the description of the visual scene (or "local view") that the user ought to have on reaching a specific point of the route ("When you arrive here, you should have the school on your left and the market on your right"). Prescriptions of *inspection* may be attached to prescriptions of positioning, so that subjects can check that their orientation is correct.

Assumptions on the structure of route descriptions

The route which is the easiest both to describe and to follow is the route which is the closest to a straight line. In fact, this case is exceptional (and is of modest cognitive interest). The interposition of material obstacles generally makes routes into sequences of segments that connect points where changes of orientation are required. A route therefore is a linear structure that includes a sequence of nodes connected by oriented segments. When a mover proceeds along a route, each successive view is seen from a particular perspective, containing one or several landmarks. The best procedure for producing a description consists of matching the verbal outputs to this basic structure, alternating descriptions of nodes and segments. It is an empirical task to extract from the data the underlying structure of descriptions. The following outline is based on a succession of statements reflecting iterations of basic commands.

0. Locate and orientate the addressee at the starting point. The initial step is to locate the addressee at the starting point. The speaker must define this point verbally and unambiguously, and check that the addressee correctly places him/herself cognitively at this point. The speaker must also orientate the addressee in the appropriate direction, for example by using a visible landmark (typically, the landmark towards which progress should then be directed) or in a variant, the landmark from which to walk away.

1. Start progress. This is the first prescribed action, although in most cases implicitly. It can be expressed in the minimal form: "Walk straight ahead". As a consequence of the gradual change of subject's position, the visual scene around the subject changes, and new features appear in his/her visual field. These features are potential landmarks for describing forthcoming actions. Progress continues until such a landmark is reached (marking the first "step" or intermediate node of the route).

2. Announce landmark. This landmark was visible from the starting point or it has appeared during progress. It is typically used as a signal of termination of progress, as well as a reference point for reorienting the subject. Mention of the landmark may be associated with the description of the local view corresponding to the node ("You will reach a crossroads [mention of landmark]; there are buildings on the right, and a park on the left [description of local view]"). In such a case, the local description has a confirmation function.

3. ***Reorientate addressee***. Reorientation is done by using the landmark just attained and its alignment with secondary landmarks. It is executed within the angular width delimited by subject's frontal plane (180°). Reorientation rarely exceeds this angular width (such as in detour behavior associated with skirting round an obstacle). Reorientation, in fact, is rarely prescribed in terms of angular quantities, except for remarkable angular values ("Turn to your right 90 degrees"). The conventional codes of aerial navigation may also be useful ("Take the street at 10 o'clock").

4. ***Start further progress***.

5. ***Announce further landmark***, etc.

Most descriptions of routes can be accounted for by iteration of this triplet of instructions: (a) (re)orientate addressee; (b) start progress; (c) announce landmark (which both signals the end of progress and site for the next reorientation). Descriptions end by mentioning the ultimate landmark that constitutes the arrival point, optionally with an additional description of landmark properties. This structure is obviously an ideal one, which may include a number of variants. Discourse generally delivers more than one instruction in the same sentence ("Cross the road that arrives at right angles and take the street which is close to the bookshop").

EMPIRICAL OBJECTIVES

The present research began with the collection of a corpus of descriptions of two routes in a natural context. Descriptions were obtained from subjects who had a good knowledge of the area crossed by these two routes. Subsequent operations consisted of data analysis and elaboration, and collection of new data intended for a more in-depth interpretation of the previous analyses. These operations can be divided in two groups.

The first group of operations was the analysis of the *content and structure of the descriptions* to collect evidence, if any, for the main features of the framework outlined above. Would descriptions reflect the distinction between reference to landmarks and prescription of actions?

Would they follow the predicted structure of reorientation, progress, and reference to landmarks? The objective was to provide a first account of the general characteristics of route descriptions (see subsections 1.1 through 1.5 of the Analysis of results). This analysis was then continued to identify common features beyond the many different descriptions that were expected to occur when the same route was described by different subjects. In short, behind the variety of individual descriptions, the objective was to capture the schematic outline followed by all (or the majority of) describers and to identify the subset of landmarks and prescriptions forming the "core" of a set of descriptions. A method was devised to reduce the variability inherent in the original data and delineate the skeletal description underlying the variety of individual protocols. The study involved further data collection that required the participation of additional subjects to establish the skeletal description on the basis of their evaluations of the relevance of the various components of route descriptions (subsections 1.6 and 1.7).

The second group of operations still focused on the differences among individual descriptions. However, while the previous analysis was essentially a non-evaluative account of the subjects' productions, this step involved *evaluating individual protocols* to find evidence of measurable qualitative differences. Because even an optimal route may be described in a variety of ways, from very clearly to very poorly, the analysis attempted to capture this variety by having the individual descriptions rated for clarity by judges (subsections 2.1 and 2.2). Individual protocols were then compared with the reference skeletal description established in the first step. The value of this comparison was that the reference description was not the product of any arbitrary decision made by experts or by the experimenter. The skeletal description was constructed from inputs resulting from subjects' actual verbal behavior. Thus, by producing individual descriptions, the subjects helped to elaborate the reference norm, and their descriptions were subsequently analyzed in terms of their proximity to this norm. The additional question was whether this proximity was correlated with the ratings provided by the judges (subsection 2.3). Finally, gender differences and differences in visuo-spatial capacities were examined for their effects on the quality and structure of subjects' descriptions (subsections 2.4 and 2.5).

DATA COLLECTION

The environment used for this experiment was the Orsay campus of the Université de Paris-Sud. The subjects were undergraduates living in the dormitories of the campus, who were expected to have good knowledge of this environment. Twenty subjects, 10 men and 10 women, aged between 19 and 26, took part in the experiment.

Two routes familiar to most people living on the campus were selected. Route 1 was the route between the train station at Bures-sur-Yvette (one of the three stations that serve the campus) and the dorms located in Building B of the Students' Residence (Building 232) (Figure 1). It was 510-meter long and traversed part of the city of Bures-sur-Yvette before reaching the campus (Building 232 is located close to the edge of the campus). This route contained three nodes connected by two main segments. The first segment included one of the main streets in Bures-sur-Yvette. It connected the starting node (the station) to a crucial intermediate node where the mover had to leave the street to use a secondary network, specifically, a footpath. The beginning of this path was not easily visible, and locating it was expected to require some description of the neighboring landmarks (a church, a driving school, etc.). The second segment connected the intermediate node to the terminal node, which was located at one of the entries to the campus. The end of this segment, in which the mover was approaching the goal (Building B), contained a distinctive landmark (a bridge over a river). One difficulty, however, was to provide the relevant information to allow the mover to identify the goal building from among other, similar looking buildings.

Route 2 connected Building B of the Students' Residence and Building 300, the Presidence Building (also known as "the Castle"; see also Figure 1). It was 1320-meter long and laid entirely within the campus. Four nodes were identified, which were connected by three segments. The mover first left the starting node (Building B) via several intricate paths to reach a main road. The first segment started there. Progress along this road rapidly brought the mover to the first intermediate node, a crossroads on a bend of the main road surrounded by a number of buildings and other landmarks (in particular, a parking lot). This site marked the starting point of the second segment. The mover walked along a long straight road, at the end of which was the Castle. Along the way, the mover passed a variety of buildings on both sides of the

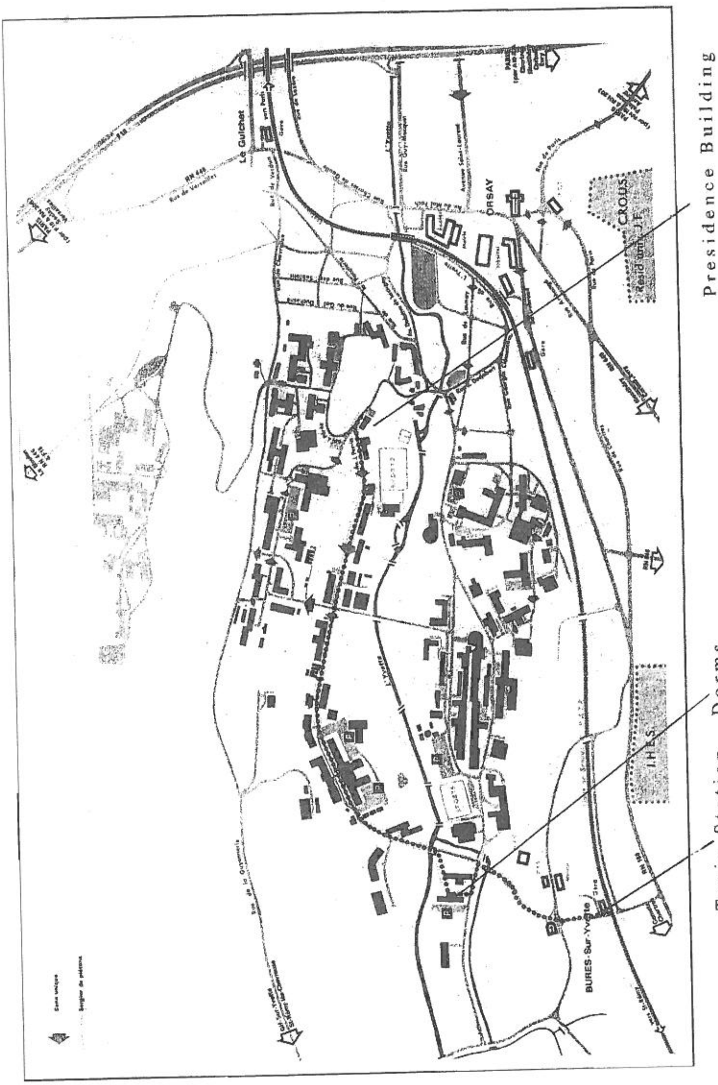

Figure 1. Routes 1 (from the train station to the dorms) and 2 (from the dorms to the Presidence Building) in the city of Bures-sur-yvette and the Orsay campus. Dotted lines show the routes.

road. About half way along, the mover should encounter a crossroads with traffic lights and another road of similar size leaving at right angles. This was the second intermediate node along the route, marking the starting point of the third and last segment. The terminal node was the Castle.

The students were recruited by placing advertisements in their residence building. Those who agreed to participate were interviewed by the experimenter in their rooms without any visual access to the surroundings of Building B (thus preventing the subjects from producing any pointing gestures in addition to their verbal descriptions). Instructions were given orally by the experimenter and read as follows: "Suppose that you are to be visited by a person who has never been to the Orsay campus before. This person comes from Paris by train and gets off at the Bures-sur-Yvette station. He/she has to meet you in the entrance hall of Building B of Students' Residence. What description would you give this person to be sure that he/she finds his/her way?". The subjects' responses were recorded on audiotape for further transcription. Instructions for the second route were then given: "Suppose that the same person has to go from the Students' Residence to Building 300 (the Castle). What instructions would you give this person to be sure that he/she reaches his/her goal correctly?". Responses were recorded. The experimenter was instructed to remain as neutral as possible, in particular to avoid any interventions, comments, or calls for specification.

Finally, the subjects completed the Minnesota Paper Form Board (MPFB; Likert & Quasha, 1941). Previous research has shown that this test provides reliable measures of subjects' visuo-spatial imagery capacities (cf. Denis, 1996; Mellet, Tzourio, Denis, & Mazoyer, 1995). The whole experimental session took 25 to 35 minutes.

ANALYSIS OF RESULTS

1. Analyzing individual protocols and building skeletal descriptions

1.1. Generating propositional expressions. The 40 descriptions were first transcribed in a printed form. The expression was unified by using the infinitive mode for the parts of descriptions that prescribed actions. For instance, expressions using the third person (e.g., "The person should then turn right") were rewritten in the canonical infinitive form, which has (in French) an explicit prescribing function in this context ("Turn right").

The descriptions were rewritten in a standard format for further processing by expressing the content of each individual description in a proposition-like format (cf. Kintsch, 1974). This procedure was considered to guarantee equivalent processing of items produced by individual subjects. An effort was made to phrase propositional expressions as analytically as possible. Propositions were designed as minimal informational units combining a predicate and one or two arguments. The principle that guided the production of propositional expressions was thus to have in any item n+1 the smallest piece of information additional to item n. For example, a sentence like "You will arrive at a wooden bridge which you must cross" was considered to be the combination of three statements: "You will arrive at a bridge", "The bridge is made of wood", and "You will have to cross the bridge". In propositional terms, this resulted in the following three items:

1. ARRIVE AT (YOU, BRIDGE)
2. WOODEN (BRIDGE)
3. *CROSS (YOU, BRIDGE)

In this example, a distinction must be made between Propositions 1 and 3, despite their similar surface structure. Proposition 1 summarizes a statement of the type "You arrive at X". The purpose of such statement is to introduce a new landmark to the person. The sentence thus describes the situation experienced by the mover as a result of executing the previous steps. If the mover has correctly executed the instructions, the landmark that should come into view is X. On the other hand, a statement of the type "You cross X", as expressed by Proposition 3, has a prescriptive meaning. The mover is told the action he/she must execute. To avoid ambiguities, propositional expressions corresponding to prescriptions were marked with an asterisk.

Parts of individual descriptions that contained prescriptions generally used the imperative mode. In propositional expressions, the argument YOU was made explicit. "Proceed" was rendered as *PROCEED (YOU), and "Follow the street" resulted in *FOLLOW (YOU, STREET). The same principles were used to generate propositions that did not involve YOU:

4. PERPENDICULAR TO (STREET, RAILTRACK)
5. BESIDE (MEMORIAL, CHURCH)
6. PASS OVER (BRIDGE, RIVER)

However, items will be expressed in natural language in this paper for the sake of readability.

1.2. Classifying items. Once the data had been standardized in this way, the content of the items was examined and a classification was set up. The propositions were expected to mainly reflect two components, landmarks and action prescriptions, although these two components would not be isolated from each other in propositional expressions. There appeared to be three main classes of propositions, based on different combinations of the two sets of components. Class 1 included propositions prescribing an action without referring to any landmark, such as "Turn left" or "Walk straight ahead". Propositions in Class 2 contained an action and a landmark. In the most typical case, the predicate asserted the prescribed action, one argument was the landmark to which the action applied, and the other argument was YOU (for example, "You cross the parking lot"). Lastly, propositions in Class 3 introduced a landmark without referring to any associated action. The most typical expressions were those positing a landmark by an introductory formula like "There is an X" or "Then you come across an X". As will be specified below, further differentiation was made within this class (depending on whether or not location information was provided).

Table 1 shows the frequencies at which these three classes of items occurred, which altogether accounted for most of the propositions (for the whole set of descriptions of the two routes, 86.4%). Because these values are based on a total number of 609 propositions, they may be considered to be reliable data. Two further classes were defined. Class 4 was also linked to landmarks, but whereas items in Class 3 introduced new landmarks (optionally locating them in the environment), the items in Class 4 described the non-spatial properties of landmarks (for instance, providing their proper names, such as in "The name of the bar is The Last Minute"). These items accounted for 11.3% of all propositions. Finally, Class 5 contained a few propositions which were essentially commentaries (for instance, "The walk requires 15 minutes at a good pace"), but they occurred rarely (2.3%).

Table 1 shows the frequencies of each class of items for Routes 1 and 2 separately. The overall distributions for the two routes were in fact quite similar. The slightly larger number of Class 1 prescriptions for Route 2 (and conversely the relative decrease in Class 3 items) may be explained by the fact that this route was longer, with a lower density of landmarks, which resulted in more frequent instructions like "Go on" or "Proceed straight on".

Table 1
Frequencies of each class of items for Routes 1 and 2, and for both routes

	Route 1	Route 2	Both
Class 1: Prescribing action	14.1	19.6	16.9
Class 2: Prescribing action with reference to landmark	35.0	32.1	33.5
Class 3: Introducing landmark	39.7	32.4	36.0
Class 4: Describing landmark	9.8	12.8	11.3
Class 5: Commentaries	1.3	3.2	2.3

1.3. Analyzing the contents of each class of items

Class 1: Prescribing action without reference to landmark. Not surprisingly, the items fell into two clear subclasses, according to whether the mover was instructed to proceed straight on, or execute some reorientation. The first subclass contained mainly items like "Go straight on", "Proceed for 700 meters", "Continue in a straight line", while the second was essentially made up of items like "Turn right" or "Make a left". An unexpected feature was that the frequency of items referring to moving straight ahead (77.7%) greatly exceeded that of reorientation items (22.3%). Speakers instructed their addressees to carry straight on about three times for every time they told them to change direction. Given that reorientation is so crucial in following routes, this was the first suggestion that route describers rely on other procedures for prescribing reorientation.

Class 2: Prescribing action with reference to landmark. Six subclasses were identified within this class of items. They are listed below with their frequencies of occurrence:

- "Go to X" and "Go in the direction of X" (X = any landmark): 15.7%;
- "Cross X" (X = a street, a bridge, a place, etc.): 27.0%;
- "Take X" (X = a street, a road, a path, etc.): 30.4%;
- "Come out of X" (X = typically, a building): 7.8%;
- "Go past X" (X = typically, a building): 14.7%;
- "Turn left/right at X" (X = any landmark): 1.5%;
- Special cases (including "negative" prescriptions): 2.9%.

Again, reorientation was rarely expressed in terms of the new direction to take (left or right). Reorientation appeared in fact to be done by making the mover take a specific path ("Walk along the main street") or aim at a specific landmark ("Go towards the church").

Class 3: Introducing landmark. These items referred to a new landmark without any correlated reference to an action to be executed. Linguistically, landmarks were mainly introduced by "There is" or "One finds". In some cases, the expression "You will see X" described the visual scene that was to appear to the mover at this point in his/her journey. Two main subclasses were identified. In the first one, the landmark was introduced without any further specification of its spatial location, in the typical form: "There is an X" (this represented 48.4% of the items of the class). In the other subclass, the landmark was introduced with an explicit reference to its spatial location (51.6% of the items). This latter case had two variants. In one variant, spatial location was ensured by using an egocentric framework, in that the location of the new landmark was specified by reference to the viewer's intrinsic frame of reference (his/her right or his/her left). For instance, "There is a photocopy shop on your right" or "There is a road in front of you". This accounted for 35.6% of the items of Class 3. In the other variant, the landmark was located by referring it to another, previously introduced landmark. This location mode could either be determinate ("To the right of the church, there is a path") or indeterminate ("There is a memorial beside the church"). The mode in which a landmark was located relative to another was less frequently used than the previously described one (16.0% of the items in Class 3). Different subjects sometimes used different frames of reference to locate the same landmark (for instance, "To your right, there is a driving school" and "In front of the bar, there is a driving school").

Class 4: Describing landmark. Non-locating descriptions of landmarks mainly included denominations ("This building is Building 300"), description of visual features ("It is a big pink colored building") or specification of informational content ("The signpost indicates the campus"). The description could also operate by attracting the attention of the addressee to highly significant, but poorly discernible landmarks ("The path is difficult to see").

Class 5: Commentaries. Statements incidentally providing overall summaries of routes were classified as commentaries ("Follow the main roads of the campus"). The few metric or pseudo-metric evaluations were also included among commentaries ("The route is about 2 kilometers", "It will not take long").

The clear feature that emerged from these data was the special importance given to landmarks in route descriptions. It is often thought that the act of describing a route mainly consists of monitoring the mover's orientation in a pluridimensional space. This is actually implemented in contexts where operators have to control the displacements of sightless movers, using purely procedural commands like: "Proceed along x meters; stop; rotate 45 degrees to the right", and so on. But the protocols reveal the cognitive prominence given to landmarks by speakers. Beside the items in which both actions and landmarks were mentioned (Class 2), the contrast was evident between the relatively few Class 1 prescriptions and the much greater number of mentions of landmarks in Class 3 (twice as many). The importance of landmarks was also confirmed by the number of items that provided additional details about them (Class 4). All this suggested that landmarks play an important role in guiding actions and that their probability of being selected and verbally expressed by route describers depends on their perceptual or cognitive salience.

These remarks are correlated with the fact that the protocols gave very little information about distances (items containing metric information represented 1.1% of the total, and only rough information was provided in this case). This clearly illustrated that route descriptions exploit topological rather than metric information. One important consequence is that the spatial information provided by route descriptions mainly lends itself to qualitative reasoning (cf. Freksa, 1992; Ligozat, 1993).

1.4. Considering the structure of descriptions. The framework outlined in the introduction included assumptions about the iteration of three operations: reorienting the mover at a node, starting his/her progress along the next segment, mentioning landmark at further reorientation node. This sequence is valid from observing a mover's displacements in an environment. The question, here, was to establish whether the data in the descriptions followed a similar sequence.

The protocols indeed contained examples of this sequence in its "purest" form, but there were no cases in which the sequence was simply iterated throughout a protocol. If this had occurred, it would have dramatically altered the "naturalness" of the descriptions. An examination of the overall structure of protocols in fact provided no indication invalidating the general structure of this ideal schema, but the descriptions were always much more complex. Inspection of the protocols gave the following features for each of the three postulated operations.

Progress. The instructions for progressing from a given node towards a specified landmark were exceptionally restricted to themselves. The most characteristic additional element was the mention of landmarks that were to be found along the segment. Their location could be determinate or indeterminate (such as in "Go past X", without specifying whether X is to the left or to the right of the mover). Not surprisingly, these elements mainly appeared in long walking distances without reorientation. This was well illustrated in the last two segments of Route 2, where they had a clear confirmatory function. However, they were also found along much shorter segments in quite unambiguous environments, for instance along the first segment of Route 1.

Reaching critical sites. According to the framework, critical sites where reorientation are to be executed are signaled by announcing the landmark that both means interruption of progress and reorientation before new progress. These critical sites are those where landmarks should take on special importance. This was indeed the case in quite significant proportions. Analysis of the protocols revealed that descriptions became much denser (that is, contained more landmarks) at reorientation nodes. For example, in Route 1, the intermediate node was especially important in that it connected two paths belonging to two networks (ordinary city streets and footpaths). This single node contained 33.0% of all the mentions of landmarks in the protocols, showing the extent to which speakers took pains to provide information to ensure correct reorientation at this critical point.

Reorientation. This operation normally intervenes at critical sites. In the example given above, reorientation was prescribed by engaging the mover in a way whose location was described carefully because it was not clearly visible. Reorientation was thus accomplished by exploiting landmarks that were more visible. This confirms the significance of landmarks in descriptions. Good descriptive strategies thus exploit visible landmarks to a maximum.

To summarize, Table 2 lists the frequencies of landmarks mentioned in successive portions of Route 1. The environment offered a large number of potential landmarks. Landmarks were distributed unevenly throughout the descriptions and concentrated where they could play a role in reorientation. The figures in Table 2 indicate that landmarks were mostly mentioned at nodes (91.0%), while the remaining 9.0% landmarks were mentioned along segments that connected nodes. Table 3 provides similar information for Route 2, where 74.5 % of the references to landmarks occurred at nodes (and the remaining 25.5% along segments). Although the structure of Route 2 differed from that of Route 1 (with more extended linear segments calling for confirmation landmarks), the trend was the same.

Table 2
Frequencies of landmarks mentioned in successive portions of Route 1

1) Landmarks at starting node (station):	22		
– reference to way to take (main street):	13	35	18.6%
2) Landmarks along the first segment (main street):	6		3.2%
3) Landmarks at intermediate node (transition to pedestrian network):	46		
– reference to way to take (footpath):	16	62	33.0%
4) Landmarks along the second segment (footpath):	11		5.9%
5) Landmarks at terminal node (approaching the goal building):	55		
– the goal building itself:	19	74	39.4%

Table 3
Frequencies of landmarks mentioned in successive portions of Route 2

1) Landmarks at starting node (Building B):	32		
– reference to ways to take (path + main road):	19	51	31.7%
2) Landmarks along the first segment (main road):	19		11.8%
3) Landmarks at first intermediate node (crossroads on a bend):	29		18.0%
4) Landmarks along the second segment (main road):	10		6.2%
5) Landmarks at second intermediate node (crossroads with traffic lights):	17		10.6%
6) Landmarks along the third segment (main road):	12		7.5%
7) Landmarks at terminal node (approaching the goal building):	7		
– the goal building itself:	16	23	14.3%

A few additional points on the structure of descriptions deserve consideration. First, as expected, the sequential structure of descriptions closely matched the sequence of operations to be executed by the moving subject. Reference to landmarks followed their exact order of appearance along the routes. The single exception to this "no-backtrack" procedure was found in one protocol where after mentioning traffic lights at the second intermediate node in Route 2, the subject (Subject 7) mentioned: "Before the traffic lights, there are greenhouses." This sounded in fact like a spontaneously generated correction when the subject realized (possibly from closer inspection of her internal representations) that she had omitted mentioning this very salient landmark.

Secondly, there were very few statements reflecting the speakers' intention to provide an overview or macrostructural description giving the addressee an anticipatory overall plan or any advance information about key landmarks. In short, route descriptions contained no expression of "macroroutes", and they kept very close to linear descriptions reflecting a "route perspective" (cf. Taylor & Tversky, 1996). Only one subject

(Subject 3) stated that Route 2 crossed the whole campus, and another, after positing the arrival point at the end of Route 2, provided a summary statement of the prior segment: "Between the crossroads and the Castle, that's straight on."

Lastly, the fact that actions were closely linked to landmarks was attested by the presence of Class 2 items in all 40 protocols, without any exception. A landmark was more frequently mentioned with an associated action than simply without any additional (in particular, locating) information.

*1.5. **Building megadescriptions***. One of the purposes of the investigation was to use the protocols to build a reduced version of the descriptions. These reduced versions were expected to contain the essential prescriptions and landmarks useful to a mover, while standing midway from the two extremes, each of which were in fact illustrated in individual protocols, of excess or lack of information.

The first operation was therefore to compile all the pieces of information that had been given by all the subjects. The union of all individual descriptions for a given route resulted in what was called a "megadescription", that is, the addition of every statement that was actually produced by all the subjects about this route. The items that had been given by several subjects were entered only once in the megadescription (using the formulation that was the most frequent in the protocols). The megadescription also contained every piece of information that had been given even by a single subject.

Items in the megadescriptions were phrased as natural language expressions to facilitate processing by judges. All prescriptions were expressed in the infinitive mode. All 20 protocols were used to build the megadescription of Route 1. For Route 2, four protocols could not be used because the descriptions partly followed an alternative itinerary (this itinerary, although plausible, was not the majority choice). As shown in Tables 4 and 5, the resulting megadescriptions contained 58 items for Route 1 and 105 items for Route 2.

Table 4
Megadescription for Route 1

1. Leave the station.
2. Cross the rail track.
3. It will take 10 minutes.
4. The path goes downhill.
5. Walk down the street.
6. Go straight on.
7. This street is at right angles to the rail track.
8. Go past a bar.
9. The name of the bar is "The Last Minute".
10. Go past a photocopy shop.
11. Continue to the bottom.
12. You reach crossroads.
13. There is a bar on your right.
14. The name of the bar is "The Sports".
15. There is a road on your right.
16. There is a road on your left.
17. In front of you, there is a war memorial.
18. To your left, there is a church.
19. To your right, there is a driving school.
20. There is a footpath between the two.
21. The path is in front of you.
22. The path is difficult to see.
23. There is a pedestrian crossing.
24. Cross the street.
25. The way is indicated.
26. There is a signpost.
27. The signpost indicates the campus.
28. Take the path.
29. The path slopes downward.
30. There is a turn to the right.
31. The path runs between apartment blocks.
32. There is a residence on the right.
33. Proceed for 50 meters.
34. There is a turn to the left.
35. There is a steep slope.
36. Continue walking down to a little bridge.
37. The bridge passes over a river.
38. Its name is the Yvette River.
39. The bridge is made of wood.
40. It is a footbridge.
41. Cross the bridge.
42. There is a road in front of you.
43. Do not take it.
44. There is a road on your left.
45. There are two buildings on the left.
46. These are dorms A and B of Bures-Sud.
47. These are Buildings 231 and 232.
48. Below Building A, there is a courtyard.
49. Cross the road.
50. Turn left.
51. There is a parking lot.
52. It is not the building in front of you.
53. Follow a little red asphalt path.
54. Proceed toward the leftmost building.
55. It is the farthest building.
56. It is Building 232.
57. You can't miss it.
58. There is nothing else.

Table 5
Megadescription for Route 2

1. It is a brisk 15 minute walk.
2. The route is about 2 kilometers.
3. Follow the main roads.
4. Leave Building B.
5. Take the path immediately to your left.
6. The path runs across the lawn.
7. You can see Building A.
8. Go toward the courtyard below Building A.
9. Walk below Building A.
10. Walk across the parking lot of Building A.
11. Take a path.
12. The path runs across a lawn.
13. Walk along the path between hedges.
14. Get back to the road.
15. Turn left.
16. There is a signpost.
17. The signpost indicates Building 333.
18. Follow the direction of the signpost.
19. Walk along the road.
20. You are on a road for cars.
21. This road leads to the university buildings.
22. It is one of the main roads of the campus.
23. There is a footpath.
24. Go straight on for 60 meters.
25. You reach a bridge.
26. The bridge is to your left.
27. The bridge passes over the Yvette River.
28. Cross the bridge.
29. Go past a building.
30. This is Building 233.
31. The dorms of Bures-Nord are in this building.
32. Keep going.
33. It will not take long.
34. Go straight on.
35. Turn slightly to the right.
36. Continue to a crossroads.
37. At the crossroads, turn right.
38. Walk past a lawn.
39. Walk past prefabricated buildings.
40. There are graffiti on these buildings.
41. To the right of the crossroads, there is a parking lot.
42. The buildings are beside the parking lot.
43. Walk past the entrance to the parking lot.
44. Do not enter.
45. The road is now one-way.
46. Walk towards the oncoming traffic.
47. Keep going straight on.
48. Walk past some buildings.
49. These are Buildings 332, 333, and 336.
50. Keep going straight on.
51. Walk past two lecture halls on the right.
52. The lecture halls are visible through picture windows.
53. Keep going straight on.
54. You arrive at the second entrance to the parking lot.
55. Walk past the second entrance to the parking lot.
56. Stay on the same side.
57. The road bends at the parking lot.
58. There is a building on the left.
59. There is a white and red gate.
60. The road continues for 500-600 meters.
61. Continue on the road.

62. It is a bit long.
63. The footpath ends.
64. Go straight on.
65. Walk past greenhouses.
66. Continue to a crossroads.
67. There are two traffic lights.
68. Walk across the intersection.
69. Keep going straight on.
70. Walk for 700-800 meters.
71. The road is one-way.
72. Walk in the direction opposite to that of the cars.
73. The road slopes gently upwards.
74. There is a forest on the left.
75. Keep going straight on.
76. Walk past some buildings.
77. This is the group of Buildings 350.
78. These are chemistry labs.
79. Walk past a building.
80. This is Building 310.
81. It is a gymnasium.
82. Keep straight on.
83. Walk past a building.
84. On the front of the building is a Crédit Lyonnais bank sign.
85. This is Building 301.
86. There are steps on your left.
87. The steps disappear into the forest.
88. Do not take them.
89. Keep on the same sidewalk.
90. The sidewalk makes a slight bend to the right.
91. You reach a crossroads.
92. The road curves to the left.
93. At the crossroads is the cafeteria to the left and high.
94. To the right of the crossroads, there is the Castle.
95. The road slopes gently upwards.
96. Go to the right.
97. The Castle is about 20 meters farther.
98. This building looks different from all the others.
99. It is clearly visible.
100. It is a big pink colored building.
101. There is a gravel drive all around it.
102. In front of it, there is a lawn with flowers.
103. This is Building 300.
104. Between the crossroads and the Castle, that's straight on.
105. It is about 500-meter long.

1.6. Abstracting skeletal descriptions. The skeletal descriptions for the two routes were constructed using the judgments of a new group of subjects on the relevance of each item in the megadescriptions. The instructions stated that the subjects would be given pieces of information describing the itinerary that connected the station of Bures-sur-Yvette and Building 232. All these pieces of information were exact, but it was emphasized that they far exceeded the information necessary to guide a traveler who did not know this environment. Subjects were asked to read all the items for Route 1, then to read them again and cross out all those that they considered to be superfluous or unnecessary. Only the pieces of information necessary and sufficient to guide a walking traveler should be kept, so that the traveler reaches his/her goal without any help other than this written information. The same instructions were used for the megadescription of Route 2.

The subjects in this part of the investigation were 20 students from the Orsay campus who had not taken part in the first part of the research. Their responses resulted in frequencies of choice for each item of the megadescriptions. A stringent exclusion criterion was used. Only items that were selected by at least 14 subjects (70% of possible choices) were considered to contribute to the construction of skeletal descriptions. For Route 1, 15 items met this criterion (25.9% of the items composing the corresponding megadescription). For Route 2, there were 19 such items (18.1%). Tables 6 and 7 show the skeletal descriptions for Routes 1 and 2, respectively.

In spite of their superficial resemblance to descriptions in individual subjects' protocols, the skeletal descriptions should not be considered to be of the same nature as these descriptions. They are abstractions, which do not correspond to the output of any specific subject's behavior. Nevertheless, they reflect the essence of each route, distilled from actual descriptions. The skeletal descriptions are fully informative, while containing the minimal set of landmarks and instructions needed to navigate appropriately. In short, they contain the essential of the navigational procedure, without any extra embellishment. Lastly, they can be used as reference points for analyzing individual descriptions (see section 2 below).

A remarkable feature was that, given the selection criterion used, the sizes of the skeletal descriptions were quite similar to the average sizes of descriptions in individual subjects' protocols. The average number of items in the individual descriptions of Route 1 was 14.9, while the skeletal description of this route contained 15 items. Descriptions of Route 2 contained an average of 19.5 items, while the corresponding skeletal description included 19 items. However, there were important differences in contents. The items most frequently deleted from the megadescriptions were prescriptions of proceeding straight on (Class 1), references to secondary landmarks (Class 3), and descriptions of landmarks (Class 4). The skeletal descriptions, in contrast, contained a larger proportion of Class 2 items. Over half the items in the skeletal descriptions of the two routes (20 out of 34) combined an action prescription and a reference to a landmark. Only one third of the subjects' averaged data (11.5 out of 34.4) fell into this category. Considering in addition the items in Class 3 referring to important landmarks, the skeletal descriptions appeared to be largely saturated with references to landmarks. This selection bias probably reflected the judges' inclination to treat landmarks and their associated actions as key components of route descriptions.

Table 6
Skeletal description for Route 1

2. Cross the rail track.
5. Walk down the street.
11. Continue to the bottom.
12. You reach crossroads.
18. To your left, there is a church.
19. To your right, there is a driving school.
20. There is a footpath between the two.
28. Take the path.
36. Continue walking down to a little bridge.
41. Cross the bridge.
45. There are two buildings on the left.
47. These are Buildings 231 and 232.
49. Cross the road.
54. Proceed toward the leftmost building.
56. It is Building 232.

Table 7
Skeletal description for Route 2

4. Leave Building B.
9. Walk below Building A.
13. Walk along the path between hedges.
14. Get back to the road.
15. Turn left.
19. Walk along the road.
25. You reach a bridge.
28. Cross the bridge.
43. Walk past the entrance to the parking lot.
47. Keep going straight on.
48. Walk past some buildings.
53. Keep going straight on.
66. Continue to a crossroads.
68. Walk across the intersection.
69. Keep going straight on.
91. You reach a crossroads.
94. To the right of the crossroads, there is the Castle.
100. It is a big pink colored building.
103. This is Building 300.

Subsection 1.4 referred to the low, but substantial proportion of landmarks that subjects mentioned while moving (virtually) straight ahead. Interestingly, the judges who "edited" the megadescriptions tended to eliminate this information almost completely. Presumably, these items were listed in individual descriptions to provide route confirmation or facilitate error correction. They allowed the listener to monitor whether or not he/she was still on the intended route. Apparently, the "editors" had different assumptions about the need for continuous monitoring of position. This makes sense given their task was to produce minimally sufficient descriptions.

1.7. Checking skeletal descriptions. A final verification was included in this first set of operations. The judges involved in the operation described above were "expert" judges in the sense that they were familiar with the environment described and were quite prepared to evaluate the relevance of every landmark and prescription in the megadescriptions. However, it is likely that, in addition to decisions based on their knowledge of the environment, the judges used additional criteria independent of such knowledge in their treatment of the task. For instance, they may have followed the rule that it is not appropriate to overload the user of the description by referring to too many landmarks at a given site. Therefore, overspecification may have been restricted when judges completed the task without being directly related to their spatial knowledge.

The role of specific spatial knowledge in judgments was examined by asking another group of subjects to perform a similar selection from items in the megadescriptions, but these subjects were totally unfamiliar with the Orsay campus. If knowledge of specific spatial environment was crucial for determining the relevance of items in the megadescription, then the skeletal descriptions produced by these "non-expert" judges (non-expert of the specific environment) should differ considerably from the "expert" skeletal descriptions. If, on the other hand, the skeletal descriptions of the two sets of judges were similar, this could indicate that the selection of items involved more than knowledge of the environment.

A group of 20 undergraduates were contacted in another university located in downtown Paris. None of them had ever visited the surroundings traversed by Routes 1 and 2. They carried out exactly the same task as the previous judges. The same selection criterion was used. Items that were selected by 14 or more judges were used to build the skeletal description. These subjects' responses provided 13 items for Route 1 and 25 items for Route 2, as is shown in Tables 8 and 9, respectively.

Table 8
Skeletal description for Route 1 (as established from responses of judges who did not know the Orsay area)

2. Cross the rail track.
5. Walk down the street.
11. Continue to the bottom.
12. You reach crossroads.
26. There is a signpost.
27. The signpost indicates the campus.
28. Take the path.
36. Continue walking down to a little bridge.
41. Cross the bridge.
45. There are two buildings on the left.
47. These are Buildings 231 and 232.
54. Proceed toward the leftmost building.
56. It is Building 232.

Table 9
Skeletal description for Route 2 (as established from responses of judges who did not know the Orsay area)

4. Leave Building B.
8. Go toward the courtyard below Building A.
9. Walk below Building A.
14. Get back to the road.
15. Turn left.
16. There is a signpost.
18. Follow the direction of the signpost.
19. Walk along the road.
25. You reach a bridge.
28. Cross the bridge.
39. Walk past prefabricated buildings.
43. Walk past the entrance to the parking lot.
47. Keep going straight on.
55. Walk past the second entrance to the parking lot.
61. Continue on the road.
66. Continue to a crossroads.
68. Walk across the intersection.
69. Keep going straight on.
70. Walk for 700-800 meters.
79. Walk past a building.
82. Keep straight on.
83. Walk past a building.
91. You reach a crossroads.
94. To the right of the crossroads, there is the Castle.
103. This is Building 300.

Apart from the small change in the number of items in the skeletal descriptions, the most remarkable result was the overall similarity of the selections made by the two groups of judges. For Route 1, 11 items were common to the two skeletal descriptions. The only difference was that the second group of judges made no reference to three landmarks (church, driving school, and footpath), but referred to the signpost which contained the relevant information to go the right way. Similar information about a signpost in Route 2 was not selected by the first group of judges, but it was used by judges unfamiliar with the environment. In other respects, as for Route 1, the same set of items of Route 2 were retained by both groups of subjects (15 items were common to the two skeletal descriptions). Non-expert subjects tended to select a few more landmarks in the last part of the route, possibly reflecting their perception of the complexity of this route with a large number of landmarks distributed along a straight road.

The overall conclusion was that people have the capacity of judging the relevance of route instructions, irrespective of their actual knowledge of the environment in which routes run. They have the same capacity to select the key features of the environment and the main points where reorientation is needed. This capacity is probably linked to the capacity of anyone asking another person for spatial assistance to judge whether this person is good at communicating relevant information in clear discourse. This is also in line with the notion that the clarity of a route description can be perceived even by subjects who have no prior knowledge of the environment described (cf. Riesbeck, 1980).

2. Evaluating individual protocols and comparing them to skeletal descriptions

The previous section showed that it is possible to isolate a core structure from a set of individual descriptions. The resulting skeletal description has a sound content and structure. However, individual descriptions differ considerably from each other. The second part of the investigation examines the original protocols and considers their differences more closely.

Because route descriptions are intended to assist movers' navigation, an important property to consider is the speakers' capacity to create a favorable set for communication, in particular monitoring the amount of information transmitted, maintaining enough specification, but also refraining from overspecification. In sum, the describers have to adjust their outputs to the processing capacities of their addressees. Not only content should be exact, but the amount of selected content, as well as its organization, should not exceed the addressees' processing capacities. Indeed, strong demands are placed on the users' short-term memory capacities, since the description has to be maintained in memory during the execution of the displacement.

2.1. Collecting ratings for individual protocols. Five students who were familiar of the Orsay campus were asked to rate all the individual protocols. The exact context in which these protocols had been collected was explained to them and they were given the following written instructions: "Some of these descriptions will appear to be good or even excellent to you, in that they provide clearly and quite exactly the information to enable the person who reads them to obtain an accurate representation of the route, its landmarks, and actions to execute. Such descriptions contain all the useful information, but only the really useful information. Other descriptions, on the other hand, may create major difficulties for the person who reads them, so that he/she may not be able to correctly build a representation of the route, of the landmarks at their correct locations, or of the actions to execute. Some of these descriptions are too succinct, while others contain excess information. Between these extremes are descriptions of intermediate quality."

The judges were asked to rate each of the 20 descriptions of Route 1 on a seven-point scale, where 7 would be attributed to an adequate description enabling a reader to build easily a clear representation of the route and reach the goal without error or hesitation. At the opposite extreme, a score of 1 would be attributed to a poor description containing insufficient information or more information than is really useful, and does not enable the reader to build a consistent representation. The judges were asked to read the whole set of 20 descriptions of Route 1 without rating them, and then to re-read and rate them. The same procedure was used for the descriptions of Route 2. All the descriptions were presented as transcriptions with prescription verbs as infinitives.

The descriptions of Route 1 received higher ratings than descriptions of Route 2, 4.2 vs. 3.4, respectively, $t(19) = 3.40$, $p < .01$. The ratings for Route 1 were also less strongly correlated with each other than those for Route 2. Average correlation coefficients were $r(18) =$

.46 and $r(18) = .74$, respectively (both above the critical value for the .05 significance level). This suggested that the judges used very similar criteria. There was also a strong correlation between the average ratings of the 20 descriptions of Route 1 and those of Route 2, $r(18) = .73$, $p < .01$, indicating high degree of intra-individual consistency of the subjects who produced the descriptions. The fact that the two descriptions provided by a given subject received correlated ratings suggested that the subject's descriptive capacities may not be limited to one specific route, but that they have more general scope. This fact, however, should be confirmed in experimental contexts where subjects are required to produce more than two descriptions of different environments.

Table 10 shows the descriptions of Route 1 that received the highest and the lowest ratings. Protocol 14 provided a compact description, with landmarks clearly positioned, and a small number of very specific instructions. Most of the landmarks were those in the skeletal description for this route. In contrast, Protocol 13 did not refer to several key landmarks, and the describer wrongly relied on signposts.

Table 11 shows the best description of Route 2, which shares the same features as the best protocol for Route 1 (it was provided by the same subject). It differed more, however, from the skeletal description

Table 10
Protocols that received the highest and the lowest ratings for Route 1

Protocol 14 (rating: 6.4)

"*Leave the station. Cross the rail track. Walk down the street. There is a church in front of you and a bar to your right. Go straight on. Walk down along a steep slope which starts from the church. Cross a little bridge, then cross the street. There is a first building. It is not the right one. It will be the leftmost building.*"

Protocol 13 (rating: 2.0)

"*Get off the train. Cross the railtrack on the left. Take the first street on the left. That's straight on. The way is indicated.* At the crossroads, cross the street. There is a signpost. You will arrive at a little river. Cross the bridge. The building is to your left. You can't miss it. There is nothing else.*"

*Wrong information.

---

in the number of landmarks referred to. Two very poor descriptions of the same route are shown to illustrate two contrasting deficiencies. Protocol 12 is an extreme simplification of the route description, with very few landmarks, while Protocol 7 suffers from considerable overspecification, introducing an amount of information that is probably far beyond most users' processing capacities.

Table 11
Protocols that received the highest and the lowest ratings for Route 2

Protocol 14 (rating: 6.6)
"*Proceed below Building A. Get back to the road. Turn left. Walk past Buildings 332 and 336. You will see greenhouses. You will arrive at a crossroads, but keep straight on. There is forest on both sides. Keep going straight on. Proceed upward to the building with the Crédit Lyonnais sign on it. The cafeteria is to your left. Go on until you see a big building. The building looks different from all the others.*"

Protocol 12 (rating: 2.0)
"*Get back to the street which is in front of the footbridge. Go back up this road. At the end of this straight line, there will be a curve to the right. Be sure not to go back up to the parking lot. Walk alongside the buildings and go on for about 700 meters. The Castle is at the end of this road.*"

Protocol 7 (rating: 2.0)
"*Leave the building directly to your left. Walk across the lawn and go toward Building A in front of you. Walk across the parking lot and follow a passage which runs between two hedges. You reach a bridge which is to your left. Cross the bridge and go straight on. To the right, there are prefabricated buildings beside a parking lot. You reach the entrance of the parking lot. Do not enter. Walk across and go straight on. Walk past the teaching buildings 332 and 333. Keep going straight on. Walk past two lecture halls which are on your right and are visible through picture windows. Keep going straight on. Then, you arrive at the entrance of a second parking lot. To the left, across the street, there is a building and a red and white gate. Keep going straight on. Then, it is a bit long. You reach a crossroads with traffic lights. Before the traffic lights, there are greenhouses. Walk across the crossroads. Keep going straight on. Forest is on your left. Keep going straight on. Farther, on the left, there are steps disappearing into the forest. Do not take them. Follow the road, which makes a slight bend to the right. There, you will find the Castle.*"

2.2. Looking for correlation between the judges' ratings and other measures. While the judges were given explicit guidelines on how to use the rating scale, the criteria that they used remained largely implicit. Nevertheless, the significant agreement among the five judges, as well as the fact that their ratings resulted in highly correlated values within subjects, clearly indicated that the ratings captured the key features of the descriptions. The judged communicative value of the descriptions was a consistent feature, and this required further evidence of objective criteria likely to account for it.

Three measures were considered. The first was the richness of the descriptions, indicated by the number of propositions contained in corresponding protocols. Obviously, a description must be informative, and information is correlated with the number of items in a speaker's output. On the other hand, the sheer number of items in a description is probably of limited value, since a description may be numerically very rich and at the same time contain false or irrelevant information. The correlation coefficient between the judges' ratings and the number of propositions showed no significant relationship between the two measures, $r(18) = -.15$, for Route 1, and $r(14) = .07$, for Route 2.

Because previous analyses revealed the significance of landmarks in descriptions, another candidate predictor of the judges' ratings was the number of landmarks mentioned in the descriptions. The question examined was whether the rated value of a description would be correlated with its richness in landmarks. The corresponding coefficients again revealed no consistent correlation, $r(18) = -.04$, for Route 1, and $r(14) = .10$, for Route 2. This, in fact, was not surprising, for the very same reason as before. It is not the number of landmarks that makes a good description, but rather their relevance and selection.

The third measure considered was the number of propositions in which actions were associated with landmarks (Class 2 items). This was a plausible criterion, given the special role of these items as key components of skeletal descriptions. The correlation coefficients showed that there was no relationship at all between the judges' ratings and this measure, $r(18) = .14$, for Route 1, and $r(14) = .03$, for Route 2.

Thus, "good" descriptions cannot be accounted for simply in terms of their size, their richness in landmarks, or the number of occurrences of landmark-action associations. These findings were not surprising, and they led to further analysis of more sensitive measures reflecting the similarity of individual descriptions of routes to the corresponding skeletal descriptions.

2.3. Comparing individual protocols to skeletal descriptions. The hypothesis tested here was that the similarity of an individual description to an "ideal" one (the skeletal description produced by previous analyses) should be a sensitive predictor of the intrinsic quality of the description, as rated for its communication value. Two measures were considered. The first one was the number of items in an individual description that belonged to the set of items in the corresponding skeletal description. This measure (the Richness index) reflected the extent to which a specific description matched the skeletal one. It was expressed as the proportion of individual items relative to the number of skeletal items. The assumption was that the more items of the reference description would be in an individual description, the higher its communicative value would have been rated by the judges.

A second measure was also considered because of an obvious limitation of the Richness index. There were several ways in which a description could be judged to be poor. Relevant pieces of information may have been missing (this diminishing the value of the Richness index), or all relevant information may have been included in the description (resulting in maximal value of this index), but the description also contained excess irrelevant (non-skeletal) information. It was therefore necessary to consider the extent to which skeletal elements saturated an individual description. An individual description containing only skeletal elements (if only a subset of them) was considered to be better than a description containing the same skeletal items plus a number of idiosyncratic items. The Saturation index was designed to capture this aspect of individual descriptions by measuring the proportion of skeletal items in each individual protocol. The capacities of the Richness and Saturation indices to predict the evaluations made by the judges were examined.

For Route 1, there was no correlation between the Richness index and the judges' ratings, $r(18) = .05$, but the correlation between the Saturation index and judges' ratings was significant, $r(18) = .44$, $p < .05$. The latter correlation, in fact, seemed to be greatly affected by the individual score of one specific subject, Subject 1, whose protocol received one of the lowest ratings (2.8), but had the maximal value for the Saturation index (the 7 items in her description were all skeletal items).

Discarding the values for this single subject increased the correlation considerably to $r(17) = .80, p < .01$.

The protocols for Route 2 produced mixed results. The correlation coefficient between the Richness index and ratings was $r(14) = .37$. It was $r(14) = .31$, between the Saturation index and ratings. In both cases, the correlation was positive, but it remained below significance.

Lastly, calculations were made after combining measures for the two routes. A given subject was described by a measure that was the average value of the ratings that his/her two protocols received. Richness and Saturation indices were based on similar calculations as before, except that the two protocols of every subject were combined. This averaging procedure thus used exactly the same inputs, but could perhaps limit the possible "noise" effects resulting from limited sets of data. The results of this procedure were that the correlation coefficients reached $r(14) = .49$, $p < .06$, for the Richness index, and $r(14) = .46$, $p < .08$, for the Saturation index. Discarding Subject 1 from the computations resulted in $r(13) = .47, p < .08$, for the Richness index, and $r(13) = .63, p < .02$, for the Saturation index. Stronger correlations were obtained when the two indices were combined to express the richness and saturation of each protocol in items of the skeletal descriptions additively, $r(14) = .62, p < .02$. When Subject 1 was discarded, the correlation coefficient reached $r(13) = .67, p < .02$.

The conclusion from these analyses was that objective measures reflecting the similarity of individual protocols to the skeletal descriptions predicted the judged quality of descriptions. This correlation received mixed support when the index used reflected only the richness of a protocol in skeletal items. Stronger evidence was obtained from considering an index reflecting the extent to which a protocol was saturated in skeletal items. The clearest evidence was obtained when the two indices were combined. These analyses also validated the construct of skeletal description. This concept in fact proved to be a meaningful one. Far from being a pure abstraction reflecting an artificial entity, it captures the essential components of a description.

2.4. Considering gender differences. The protocols produced by the male and female subjects were compared because there have been several suggestions that spatial cognition is sensitive to gender differences. Several experiments on route descriptions have indicated that female subjects tend to mention more landmarks than their male counterparts, whereas males are more inclined to process metric and directional information (cf. Galea & Kimura, 1993; McGuinness & Sparks, 1983; Miller & Santoni, 1986).

The average scores based on the individual protocols of male and female subjects were computed for 11 critical measures: judges' ratings of the quality of descriptions, total number of propositions (including propositions prescribing actions, propositions associating actions and landmarks, propositions introducing landmarks, propositions describing landmarks, and commentaries), total number of landmarks mentioned, Richness index, Saturation index, and the two indices combined. Computations were based on the data of the 8 male and 8 female subjects who provided full protocols for both Routes 1 and 2. The two protocols of each subject were combined to produce a single score for each measure. The average scores for males and females are shown in Table 12.

Table 12
Average values of 11 critical measures for male and female subjects (Asterisks mark significant differences, $p < .05$)

	Males	Females
Judges' ratings of the quality of descriptions	4.0	4.3
Total number of propositions	30.0	39.1
Propositions prescribing actions	5.1	7.3
Propositions associating actions and landmarks	12.4	14.0
Propositions introducing landmarks	8.0	12.9*
Propositions describing landmarks	3.5	4.4
Commentaries	1.0	0.6
Total number of landmarks mentioned in the protocols	16.3	22.3*
Richness index	39.5	50.0*
Saturation index	45.3	46.1
Richness and Saturation indices combined	84.8	96.1

The ratings of the descriptions for the males and females did not differ. Females tended to produce descriptions with more propositions than did males, although the difference was not statistically significant. The clearest contrast between the groups was in the number of propositions introducing landmarks, $t(14) = 2.33$, $p < .05$. Females referred to significantly more landmarks than did males, $t(14) = 2.55$, $p < .05$. This confirms the previous reports that females describing routes devote more attention to landmarks than males.

The indices reflecting the similarity of individual protocols to the skeletal descriptions revealed a significant effect for Richness. Females significantly surpassed males, $t(14) = 2.25$, $p < .05$. This superiority may be a further reflection of the consistent trend of females to produce richer protocols than males.

2.5. Relating individual protocols to subjects' visuo-spatial capacities. While the previous analyses mainly concentrated on descriptions as verbal outputs, the last analysis considered the link between the descriptions and the internal representations from which they are presumably generated. The framework outlined in the Introduction postulated that the long-term cognitive representations recruited for generating spatial discourse contain visuo-spatial components of subjects' spatial knowledge. Subjects are known to differ from each other in the richness and/or accessibility of these visuo-spatial representations (cf. McKelvie, 1995; Paivio, 1986; Poltrock & Brown, 1984). The question is whether these individual differences are reflected in subjects' verbal expressions of spatial knowledge. Because high imagers are more likely to access their internal visual knowledge than their counterparts, this would also be true when they access their spatial representations to describe routes. This bias towards visuo-spatial representations would then be reflected in more frequent references to the visual components of routes described by high visuo-spatial imagers (mainly landmarks).

The subjects were ranked as a function of their MPFB scores. Better contrast was obtained by selecting the 7 subjects with the lowest scores ("low visuo-spatial imagers") and the 7 subjects with the highest scores ("high visuo-spatial imagers"). The average MPFB scores were 18.6 for low imagers and 23.1 for high imagers. Table 13 shows the average scores for the 11 critical measures considered above (combining protocols for Routes 1 and 2) for both groups.

Table 13
Average values of 11 critical measures for low and high visuo-spatial imagers (Asterisks mark significant differences, $p < .05$)

	Low imagers	High imagers
Judges' ratings of the quality of descriptions	3.9	4.6
Total number of propositions	28.4	39.7*
Propositions prescribing actions	4.9	7.0
Propositions associating actions and landmarks	11.6	14.4
Propositions introducing landmarks	8.0	13.1*
Propositions describing landmarks	2.9	4.6
Commentaries	1.1	0.6
Total number of landmarks mentioned in the protocols	15.6	22.1*
Richness index	39.3	50.0
Saturation index	48.1	43.7
Richness and Saturation indices combined	87.4	93.7

There was no significant difference between the high and low visuo-spatial imagers in the rated quality of their descriptions or in the structural characteristics reflected by Richness and Saturation indices. The high imagers' descriptions contained more propositions than those of low imagers, $t(12) = 2.54$, $p < .05$. This effect was mainly due to the larger number of propositions that introduced landmarks, $t(12) = 2.23$, $p < .05$. Overall, high imagers referred to more landmarks in their descriptions than did low imagers, $t(12) = 2.85$, $p < .02$.

This analysis confirms that a significant source of differences in descriptions of routes is their richness in landmarks. The subjects most likely to retrieve visuo-spatial information from their memories were found to include more frequent reference to this information in their verbal descriptions. The fact that high visuo-spatial imagers mentioned more landmarks in their descriptions although their protocols did not receive higher ratings than those of poor imagers clearly suggests that a high imager may also be a poor describer. This confirms the lack of any close link between the rated quality of descriptions and their richness in landmarks (cf. subsection 2.2).

The effects reported in this section parallel those found in the analysis of gender differences. This may initially suggest that there is a relationship between gender and visuo-spatial capacity. In fact, there is good evidence for no systematic difference between the visuo-spatial capacities of males and females, as measured by MPFB scores (cf. Mellet, 1996). This was confirmed for the subjects who took part in the present experiment. The average MPFB scores were 20.1 for males and 21.6 for females whose performance was analyzed in the previous section, $t(14) = 1.01$. Thus, it is unlikely that the effects of visuo-spatial capacities can be explained simply in terms of gender effects, and vice versa. Each of these effects is in fact consistent with previous data.

CONCLUSIONS

Researchers have become interested in the description of routes in the last decade (cf. Klein, 1982; Lloyd, 1991; Waller, 1985; Wunderlich & Reinelt, 1982). Route descriptions are only a subset of spatial discourse, but they have a strong appeal because this is a ubiquitous form of human interaction that everybody has experienced, as both speaker and user. Early research in this domain focused mainly on the analysis of corpora collected in natural environments. The value of this approach is that it provides material generated by speakers in realistic situations. Its potential limitations, however, are that analyses are linked to the specific populations and environments where the data are collected, and can thus result in essentially monographical studies.

The present research used a new approach, which consisted of collecting a corpus of descriptions which were submitted to quantitative analysis. This approach was not adopted just for descriptive purpose. It was guided by a set of assumptions about cognitive operations that seem to be necessary for producing route descriptions. This, in fact, was already true for corpora-based previous research, but the empirical approach adopted here also provided measures that were explicitly related to the cognitive operations believed to be implemented by speakers when communicating about space. The cognitive approach illustrated here provides an opportunity to investigate the generation of verbal messages intended to externalize non-verbal components of human cognition.

This research also provides hints for further investigation of the cognitive characteristics of "good describers". Some characteristics can be readily identified. These can be summarized in the form of a set of prescriptions. When you describe a route, (a) produce a limited number of statements, (b) avoid redundancy and overspecification, (c) refer to visible, permanent, and relevant landmarks, (d) prefer determinate to indeterminate descriptions, and (e) be explicit when stating the associations between actions and landmarks which signal the sites where these actions are to be executed. Other prescriptions may be generated on the basis of further, more detailed analyses. An interesting open issue is whether people who have a spontaneous capacity to follow such rules in producing route descriptions have any special cognitive characteristics. The present research has collected some indications that subjects with rich visuo-spatial memories are more likely to refer to landmarks, which are crucial components of route descriptions, than are others.

Extensive analysis of the processes involved in route descriptions also provides documented accounts of cognitive functions that may be assisted by artificial cognitive systems. In particular, the recent increase in interest for navigational aids (including on-board systems designed to provide on-line assistance to drivers) calls for better understanding and modeling of the cognitive functions involved in communication about space (cf. Briffault & Denis, 1996; Chown, Kaplan, & Kortenkamp, 1995; Freksa, 1992; Maass, 1993). This specific application in the domain of human-machine communication may require more documented research on the part of cognitive psychologists.

ACKNOWLEDGEMENTS

This research was supported by the CNRS (Cogniscience Program, National Thematic Project on Representation of Space) and the Ministry of Research (PRC Communication Homme-Machine, DALI Project). The author is grateful to Cécile Joyes and Riadh Lebib for their contribution to data collection and analysis. A first draft of this paper was written during the author's research stay at the Department of Psychology of the University of Padova, supported by a Human Capital and Mobility grant (#CHRXCT940509) from the Commission of the European Communities. The author also thanks Cesare Cornoldi, Marie-Paule Daniel, Jose Miguel Diaz, Francesca Pazzaglia, Barbara Tversky, and four anonymous reviewers, for their comments and suggestions on previous drafts of this paper.

RESUME

Cet article propose un cadre général pour l'analyse des descriptions d'itinéraires, permettant de rendre compte de la manière dont les connaissances spatiales sont exprimées par le langage. Trois opérations cognitives sont postulées dans la production de cette forme de discours spatial : (a) activation d'une représentation interne de l'environnement dans lequel le déplacement doit être effectué ; (b) détermination d'un trajet dans le sous-espace temporairement activé de la représentation ; (c) formulation de la procédure que l'utilisateur doit exécuter pour atteindre sa destination. Deux composants principaux des descriptions d'itinéraires sont considérés, ceux qui se réfèrent à des repères et ceux qui consistent à prescrire des actions. Les descriptions de deux itinéraires dans un environnement naturel ont été recueillies auprès de 20 étudiants. Une analyse détaillée des protocoles a permis d'établir une classification des items, aboutissant à cinq catégories : prescription d'actions sans référence à un repère; prescription d'actions avec référence à un repère ; référence à des repères sans mention d'une action associée ; description de repères ; commentaires. Les protocoles individuels ont ensuite été utilisés pour construire des descriptions plus abstraites (ou "descriptions squelettes"), reflétant l'essentiel de la procédure de navigation. Les descriptions squelettes ont confirmé que les repères et les actions associées étaient les composants essentiels des descriptions d'itinéraires. Des analyses complémentaires ont indiqué que la similarité des descriptions individuelles à l'égard de la description squelette de l'itinéraire correspondant permettait de prédire la qualité de ces descriptions estimée sur échelle. Les sujets féminins ont fourni des descriptions comportant davantage de repères que les sujets masculins. Enfin, les descriptions fournies par les sujets présentant les capacités d'imagerie visuo-spatiale les plus élevées contenaient davantage de références aux repères, ce qui est compatible avec l'hypothèse selon laquelle les sujets qui ont le plus de chances d'accéder à de l'information visuo-spatiale en

mémoire ont une probabilité plus élevée d'inclure des références à cette information dans leurs productions verbales.

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Received 29 November, 1996
Accepted 21 July, 1997