The Production of Route Instructions in Underground and Urban Environments

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Abstract. The investigation reported here is part of a project to design navigational aids for the Paris subway system. Users of the subway were asked to describe the route to be followed from the platforms of subway stations to specific buildings in the city of Paris. The descriptions thus included two parts : one underground (from the train platform to the exit) and the other in the urban environment (from the exit to the building). Most studies of route directions have been conducted in open environments (campus, city, etc.). The aim here was to contrast the types of description specific to the two contexts. Forty-eight participants (24 male, 24 female) took part in the experiment. Verbal descriptions were analyzed using the procedure proposed by Denis (1997). The results showed that participants relied extensively on signs for the underground part of the route. This was true for subway stations displaying either newly designed or older signs. The paths were rarely referred to in the subway environment, but they were frequently used in the urban environment. The patterns of landmark distribution along the routes were similar in both environments, in that they were more frequent at the nodes where reorientation was needed.

Keywords : spatial cognition, route directions, underground and urban environments.

1 Introduction

We have several modes of communication for helping people to navigate in an unknown environment. The most obvious is pointing. This can be used only when the designated objects are visible, that is, in the proximal environment (De Vega, Rodrigo, & Zimmer, 1996 ; McNeill, 1992). Another mode uses graphic information like schemas, maps or depictions (Pearce, 1981 ; Tversky, 1995 ; Wright, Lickorish, Hull, & Ummelen, 1995). The main advantage of graphics is that they provide the receiver with an analog, global representation of the environment in which he or she has to navigate. However, this mode of communication has limitations such as distortions in the representation of relative distances.

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Furthermore, maps generally require complementary verbal comments.
Finally, verbal aids, which interest us here, are a major mode of communication, particularly for describing routes.
Route directions provide cognitive psychologists with a method of studying the cognitive processes involved in the production and comprehension of discourse, and the mental representations on which these processes are based. They allow examination of the interactions between language and mental representation. Route directions also interest the linguists, as they are a form of spatial discourse linked to specific references and situations. Finally, the study of route directions in the context of artificial intelligence can help in the design of computer systems for assisting navigation (Chown, Kaplan, & Kortenkamp, 1995 ; Gapp & Maass, 1994 ; Glasgow & Papadias, 1992).

1.1 Specificity of Route Directions

Route directions are specific in their function, their internal organization and the processes involved in using them. The description of a route is a discourse with a specific aim : to allow the receiver to navigate from a starting point to an arrival point in an unfamiliar environment. It is thus a procedural discourse. It is also a composite discourse, that is, a combination of descriptive and prescriptive information. The descriptive information includes the nature and position of landmarks; the prescriptive information indicates the actions to be taken. The route described has an intrinsic linear structure. The sequence of the discourse adheres to the sequence of steps to be followed by the person moving along the route. Linearizing is an inherent feature of route directions. Closely related to their linear structure is the spatial perspective imposed on both the describer and the user of route directions. This is a typical "route perspective", which has a strong dynamic component, in contrast with the "survey perspective", in which an environment is viewed from above (Taylor & Tversky, 1992).
To produce route directions, the person describing them has to implement three sets of cognitive operations : the activation of an internal representation of the environment in which the journey is to take place, the definition of the route in the subspace of that mental representation, and the formulation of the procedure (including steps and actions) that the user will have to follow to reach the destination (Denis, 1997).
The linguistic structure of route directions, studied especially by Klein (1982) and Wunderlich and Reinelt (1982), is principally determined by a combination of two sets of elements : the landmarks and the actions to be executed.

1.2 Environments Studied

Studies carried out on this topic have used two broad classes of environment : closed spaces such as buildings or rooms (Shanon, 1984), and open spaces such as campuses (Gryl, 1995) or cities (Denis, Pazzaglia, Cornoldi, & Bertolo, in press). The routes examined in the present study are located in two distinct environments which are separate, but have a vertical connection. They begin in an underground space (subway station) and end in an urban environment (the city of Paris).

We collected verbal descriptions of the route from the closed space of the stations to the open space of the city. Two features had to be expressed : the movement from a lower level to an upper level, and the transition from underground to outside. Because of the nature of the subway stations, it was interesting to study the descriptions of these specific spaces. The design of underground stations is such as to prevent people inside them seeing the outside world and, because of corridors ans stairs, seeing much of the route ahead. Furthermore, the users have no information on the position of the stations with respect to the outside world. In addition, these spaces have their own information system for guiding users.
We studied how these spaces were perceived, how the signs displayed were integrated in the descriptions provided by the participants, and whether or not the nature of the route directions in the stations differed from those followed outside. Stations were selected according to two criteria : their spatial structure, and their signs (newly designed or old). Five stations were chosen : one, very complex, Châtelet ; two, less complicated, Nation and Place d'Italie ; and two simple, Saint-Mandé and Saint-Ambroise. The older signs were displayed at Châtelet, Nation and Saint-Mandé, and the newly designed at Place d'Italie and Saint-Ambroise.

1.3 Two Different Signing Systems

The two signing systems coexist in the subway network. They differ in several respects. Here, we consider only the differences affecting the studied routes. The routes inside the stations have to lead people to the exterior. So we are concerned only with the exit signs and their distribution.
With the old system, the exits are identified by a name corresponding to the name of a street in the city above the station. Under the new system, the name is associated with a number. This is intended to help both regular and occasional users. Foreigners would be assumed to remember a number more easily than a long name. Under the old system, the exit signs are located only on sites where several choices are possible. Under the new system, exit signs are still located at these points, but also along the route to the exit.
We examined the use of the exit number and the integration of the signs according to these two standards in the route directions.

2 Method

2.1 Participants

The participants were 24 men and 24 women aged 20-45. Each group of participants was divided according to their familiarity with the subway, i.e. 12 people familiar and 12 not. A participant was rated as familiar if he or she used the subway every day, and not familiar if less than once a month. No one knew the five stations being studied. The participants were paid for taking part.

2.2 Procedure

The participants were tested individually in all five stations. After a period spent learning each route, they were asked to describe it.

Learning phase. - At each station, the experimenter guided the participants on a pre-arranged route beginning on the station platform and ending in the city. To ensure that participants knew the route, the experimenter accompanied them along it three times. Each route took about 10 minutes. During practice, participants were guided back to the departure station by a route, other than the one under study.

Description of route. - The participants had to describe the route as if they were speaking to someone on the platform needing to reach the destination. Two modes of production were contrasted. Half participants had to describe the route from memory, and the other half formulated their descriptions during the journey. In the first condition (from memory), participants who had completed the learning phase had to describe the route orally in a neutral place. In the second condition (description made during the journey), participants described the route during their third and last journey. The descriptions were recorded on a dictaphone. By comparing these two conditions, we aimed to examine the features which are most easily memorized, and so the most relevant.
We then carried out two orientation tests. On a drawing representing the platform, participants had to indicate the direction from the platform to the arrival point. They had to locate the arrival point in reference to the train platform. Similarly, on a drawing representing the exit stairs of the station, they had to indicate the direction from the top of the stairs to the arrival point.
Because of the length of the experiment (one hour for each route), two sessions were required, one of two hours and the other of three hours.

Analysis of individual protocols. - The method of analysis was adapted from that proposed by Denis (1997). The oral descriptions were transcribed. The analysis relied on transforming participants' original linguistic expressions into minimal units of information. A unit of information comprised a few words expressing a minimal package of information.
We drew up a list of codes identifying the elements in each unit of information, mainly actions and landmarks. We distinguished two types of landmark : three-dimensional objects, like shops and other buildings, and two-dimensional entities on which displacements are executed, like streets, squares and subway corridors. In some units, actions were combined with landmarks. For the underground route, we used the same codes, but added new ones for the exit signs.
Five classes of information units were considered :

Class 1 : Actions without reference to any landmark ("Go straight ahead") ;

Class 2 : Actions associated with a landmark ("Follow Exit 5", "Proceed toward the ticket office") ;

Class 3 : Landmarks without reference to any action ("There is a newspaper stand") ;

Class 4 : Non-spatial properties of landmarks ("The stand is painted blue") ;

Class 5 : Landmarks located with reference to another landmark ("The newspaper stand is in front of the ticket office").

3 Results and Discussion

We conducted two types of analysis. We calculated the frequencies with which the different classes and the different types of landmarks were used. We conducted an analysis of variance on the mean number of information units, the mean number of mentioned objects, and the mean number of mentioned roads.

3.1 Underground routes

In the five classes previously described, Class 2 (actions associated with a landmark) dominated the descriptions of the underground routes (cf. Table 1). This class was itself mainly represented by the actions associated with the signs. In the case of landmarks associated with or not associated with an action, the signing pannels were the landmarks cited most frequently. Then came the three-dimensional objects, and finally the roads (cf. Table 2).

Table 1. Frequency of occurrence of items of each class (%)

	Actions only	Actions associated with a landmark	Landmarks only	Describing landmarks	Relations between landmarks
Underground routes	13	65	16	6	0
Outside routes	10	37	18	29	6

Table 2. Frequency of occurrence of different types of landmark (%)

	Landmarks only		Landmarks with action	
	Underground routes	Outside routes	Underground routes	Outside routes
Three-dimensional objects	38	66	37	75
Two-dimensional entities	49	34	10	25
Signs	13	/	53	/

The participants used largely the information offered to them by the environment. The signs seemed to be the most relevant information to the displacement in the subway. Most of the mentioned signs (87%) were associated with an action. The signs were not apparently used as fixed landmarks, but they were strongly linked to the displacement. Thus, they answered the users' need for guidance.

The three-dimensional objects seemed to be used to confirm the information given through the signs. Roads were seldom mentioned. We may suppose that two-dimensional landmarks, like corridors, were not very distinctive. So, they were not felt to be relevant and easily identifiable landmarks. This was especially true for the largest stations, where several corridors were followed.

Data from the five routes were submitted to an analysis of variance. Of the independent variables considered, the main factors (mode of production, familiarity, and gender) had different effects according to the route. Bearing in mind the differences in the studied environments, these variations are not surprising.

The analysis on the five routes showed a significant effect of the mode of production on the number of units of information ($F(1,40)=4.22$, $p=0.04$). The descriptions produced during the journey contained more information than those produced from memory. Moreover, we found a significant interaction between gender, familiarity, mode of production and routes (the five routes were taken as repeated measures) ($F(4,160)=2.84$, $p=0.02$). When giving route directions during journey, the women unfamiliar with the subway gave more information than the familiar, but the unfamiliar men gave less information than the familiar.

We also found the same interaction in the analysis of the number of objects mentioned ($F(4,160)=3.13$, $p=0.01$). Here, familiarity seemed to have an opposite effect on men and women. Not being familiar with underground spaces seemed to encourage women to enrich their descriptions, whereas men were more selective in the information they chose.

Analysis of the number of roads mentioned (the five routes being taken together), showed a significant interaction between gender, mode of production and routes ($F(4,160)=3.90$, $p=0.01$). When relying on memory, women used fewer roads than when creating instructions during journey . With men, the reverse applied.

In summary, first, as we expected, the route descriptions produced during the journey contained more information than those produced from memory. Secondly, the familiarity effect was not the same for women as for men. Thirdly, women tended to give more information about three-dimensional objects than men. This latter observation is in agreement with previous studies (Denis, 1997 ; Galea & Kimura, 1993).

Few estimates of distance were given. There was a significant interaction between gender and routes ($F(4,160)=3.30$, $p=0.01$). No women gave estimates of distance underground, while men did so, but only when the stations were complex.

Use of signs. In the five stations, only an average of 40% of the signs displayed along the route were used. This was the case for both modes of production.

The numbering of the exits is a new development affecting only Place d'Italie and Saint-Ambroise stations. Numbers were used alone in 6% of the cases for Place d'Italie and 9% for Saint-Ambroise, and they were used with the exit name in 29% of cases for Place d'Italie, and 27% for Saint-Ambroise. So, the number, with or without the name, was used in 35% of the cases for Place d'Italie, and 36% for Saint-Ambroise.

For the descriptions at Place d'Italie and Saint-Ambroise, the analysis showed a significant interaction between gender and mode of production ($F(1,40)=5.00$, $p=0.03$, for Place d'Italie ; $F(1,40)=4.29$, $p=0.04$, for Saint-Ambroise). In contrast to men,

women made little use (or no use in the case of Saint-Ambroise) of the numbers in their descriptions from memory. The use of numbers increased significantly in instructions produced during the journey. However, the mode of production did not affect the use of numbers by men. It seems that exit numbers were not spontaneously memorized by women.
Lastly, familiarity had no effect on the use of the number. We had expected that familiar participants, having already seen this new information on the network, would have made greater use of it. The results could reflect the two genders' different cognitive preferences.

Description of the underground exit. The five stations studied were very different, and so too were the routes which operated on several levels. In Châtelet, Saint-Mandé and Saint-Ambroise, the routes went through two levels, in Place d'Italie, three, and in Nation, four.
Few participants described the passage from the underground to exterior. However, there was an effect of routes on the number of transitions to the outside mentioned ($F(4,160)=3.31$, $p=0.01$). The specification to outside depended on the station and the route length in the station. This information was especially given for Nation.
The act of leaving the station was expressed differently for the five studied. For Nation, the formulation most frequently used was "to arrive outside". Presumably, the length of the route in this station prompted the participants to specify the change of space. For Place d'Italie, Saint-Mandé and Saint-Ambroise, several expressions were used : "to go out from the subway", "to follow the exit X", "to go out", "to take the stairs", and "to arrive outside".

3.2 Outside routes

The analysis of variance showed a significant effect of the mode of production on the number of information units of description ($F(4,176)=5.02$, $p=0.03$). Production during the journey increased the number of units. There was also a significant interaction between gender and routes ($F(4,176)=3.23$, $p=0.01$). Women gave more information than men. The differences between the two groups depended on the route concerned.
The distribution of the items over the five classes was more regular for the outside routes than for the underground routes. Roads were used more frequently than three-dimensional objects (buildings). Descriptions produced during the journey included more mentions of buildings than those produced from memory ($F(1,43)=8.67$, $p=0.005$). The analysis of the number of buildings used also showed a significant interaction between gender and routes ($F(4,172)=3.05$, $p=0.01$). Women's descriptions included more buildings than those of men. The differences between the two groups depended on the route concerned. Finally, there was an effect of gender on distance information ($F(1,44)=11.55$, $p=0.001$). Men gave more estimates of distance than women.
To summarize, for the outside routes, first, producing a description during the journey increased the amount of information given. Secondly, women gave more landmarks like buildings than did men. Thirdly, men gave more estimates of distance than

women. These two last observations are in agreement with previous studies (Denis et al., in press ; Galea & Kimura, 1993).

3.3 Performance on orientation tests

To measure participants' performance, we considered three levels of success. The participants located the arrival point in a circle representing all the possible orientations, the reference point being the middle of the circle. The responses were rated according to their position in the correct half of the circle (corresponding to a 180° margin error), in the correct quadrant (corresponding to a 90° margin error) or in the correct half quadrant (corresponding to a 45° margin error). The best responses were those located in the correct half quadrant of the circle. Because of the special complexity of Châtelet, the results for this station were not taken in consideration.
Few participants succeeded in giving the correct orientation when the estimate was made from the platform (cf. Table 3). As expected, to locate a point outside from the underground is a difficult task, irrespective of the complexity of the station. Only five participants out of the 48 succeeded and different participants succeeded on the different stations. If we consider the responses located in the correct quadrant and in the correct half quadrant, only seven participants (five women and two men) succeeded at least twice. One man gave three, and one woman four correct responses. Chi-square tests showed no differences for mode of production, gender, and familiarity.

Table 3. Results of the orientation test from the underground

	Out	Half circle	Quadrant	Half quadrant
Nation	31 (64.6%)	8 (16.6%)	4 (8.3%)	5 (10.4%)
Place d'Italie	33 (68.8%)	9 (18.8%)	1 (2%)	5 (10.4%)
Saint Mandé	24 (50%)	10 (20.8%)	7 (14.6%)	7 (14.6%)
Saint Ambroise	32 (66.6%)	7 (14.6%)	5 (10.4%)	4 (8.3%)

As expected, performance on the orientation test from the exit were better (cf. Table 4). On average, 20 participants out of the 48, located the arrival point in the correct half quadrant.

Table 4. Results of the orientation test from the exit

	Out	Half circle	Quadrant	Half quadrant
Nation	5 (10.4%)	16 (33.3%)	8 (16.7%)	19 (39.6%)
Place d'Italie	4 (8.3%)	2 (4.2%)	21 (44%)	21 (44%)
Saint Mandé	6 (12.5%)	6 (12.5%)	13 (27%)	23 (48%)
Saint Ambroise	18 (37.5%)	7 (14.6%)	6 (12.5%)	17 (35.4%)

We examined the relationship between the orientation responses and the descriptions of the exit. We considered the formulations given by the participants who positioned the arrival point in the correct quadrant and those given by the participants who positioned the arrival point in the correct half quadrant. For the first group, the most frequently used description was : "to arrive outside" and "at the top of the stairs". For the second group, no expression emerged. Combining the two types of response, three formulations were used most often : "to arrive outside", "to take the exit X", and "at the top of the stairs".
Thus, the responses to the orientation tests and the descriptions of the passage to the exterior were independent. Nevertheless, the obvious difficulty of the test from the underground allows us to make two comments. First, the participants did not have a single and global representation of each route but two unconnected representations : one of the underground section and one of the outside section. Second, the localization of underground structures with respect to the outside was not easily grasped, especially when the structures were complex. We may suppose that a longer learning period would be required for this information to be integrated.
Previous research has shown that the integration of vertical relations is possible and can be evidenced by using tasks like ours (Montello & Pick, 1993). The poor performance we have observed could have resulted from too short period of training, or it could have been due to the participants' difficulty in considering the stations, their extensions and their limits globally.

3.4 Features common to underground and outside routes

For each route, there was a great variability among participants in the length of their descriptions. The length was measured in information units (cf. Table 5). The differences probably reflected individual styles, at least in terms of the length of the descriptions. The correlation coefficients between the number of units used by the participants for the five underground routes and for the five outside routes were all significant at $p<0.05$ (cf. Tables 6 and 7). These significant values support the notion that participants tended to be consistent in their use of specific descriptive strategies, regardless of the route described.

Table 5. Number of information units on each route
(U = Underground ; O = Outside)

	Mean	Minimum	Maximum	SD
Châtelet U	5.83	1	14	3.47
Châtelet O	11.00	1	29	4.27
Nation U	12.94	3	38	7.21
Nation O	18.33	8	47	7.23
Place d'I U	8.42	1	26	5.84
Place d'I O	19.60	10	36	6.33
St-Mandé U	5.04	1	16	3.14
St-Mandé O	21.42	7	47	7.39
St-Ambr. U	4.52	1	11	2.92
St-Ambr. O	20.44	8	49	7.18

Table 6. Correlation coefficients between the number of information units given by the participants for the underground segments of routes

	Châtelet	Nation	Place d'Italie	St-Mandé	St-Ambroise
Châtelet	1	0.69	0.73	0.67	0.56
Nation		1	0.66	0.76	0.66
Place d'Italie			1	0.67	0.73
St-Mandé				1	0.77
St-Ambroise					1

Table 7. Correlation coefficients between the number of information units used by the participants for the outside segments of routes

	Châtelet	Nation	Place d'Italie	St-Mandé	St-Ambroise
Châtelet	1	0.66	0.58	0.58	0.68
Nation		1	0.69	0.73	0.71
Place d'Italie			1	0.62	0.70
St-Mandé				1	0.80
St-Ambroise					1

Previous research has shown that landmarks mentioned in route descriptions are not uniformly distributed along them, but concentrate at critical points (Denis, 1997 ; Denis et al., in press). These points are nodes where reorientation is required and where a choice among several possibilities has to be made. This distribution showed up in our study of both underground and outside routes (cf. Fig. 1). It suggests that the

principle of the use of landmarks remains the same, regardless of the environment considered. The use of signs also seems to be based on this principle.

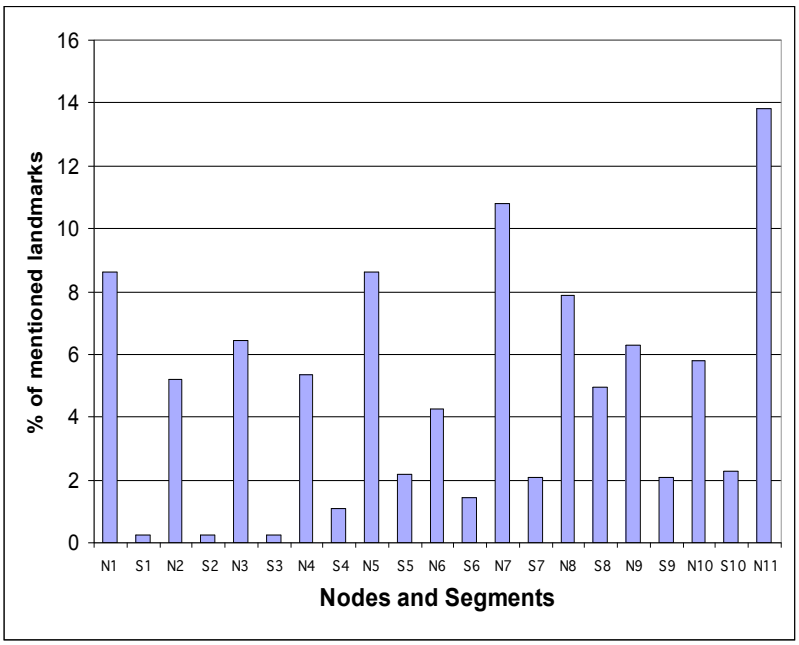

Fig. 1. Distribution of landmarks along a route : Place d'Italie
Nodes N1 to N11 are connected by segments S1 to S11. The underground route begins at node N1 and finishes at node N5. The outside route begins at segment S5 and finishes at node N11.

4 Conclusions

Beyond a number of similarities, the descriptions of underground and outside spaces differed in several respects. When underground, the actions associated with a landmark were most important ; outside, the pattern was different. The reference to two-dimensional entities to help navigation was different when underground was opposed to outside. They were used less in the stations, but they formed the essential element in the city. In addition, few three-dimensional landmarks were used in the stations. The rule underlying the underground descriptions seemed to be based on "follow the signs", this providing constant and reliable information. Outside, however, three-dimensional landmarks punctuated the journey, allowing reorientation and confirmation that the correct direction was being followed.
The results to the orientation tests showed that the verticality relation was not easily integrated by the users. We suggest that there is a strong dependence of the participants on signs. This dependence is probably due to the presence of a significant vertical component, the lack of visual access from level to level, and the sense of

"enclosure" which is difficult to acquire in a space that cannot be experienced from the outside (Montello & Pick, 1993).
An approach complementary to ours would be to examine real navigation in these spaces. In a future work, some of the descriptions collected here will be used. Participants will learn these descriptions, and they will have to walk along the route. Their moves along the routes will be analyzed. Thus, we will study objective qualities of the descriptions by relating them to behavior. It would also be instructive to test graphic forms of guidance which represent these vertical relationships between the underground levels, and between the underground and the city.

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