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Strategies of processing spatial information in survey and landmark-centred individuals

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This study investigated differences between individuals with survey and landmark-centred spatial representations in different visuo-spatial tasks and in two way-finding tasks. The Mental Rotation Test (MRT; Vanderberg & Kuse, 1978), and the Minnesota Paper Form Board Test (MPFB; Likert & Quasha, 1941) were administered to two groups of high-survey and landmark-centred undergraduate students. The groups also performed two way-finding tasks where they were required to study the route they were going to take, in one case with a map and in the other with a verbal description. Differences between the two groups emerged; high-survey individuals performed the MRT better than the landmark-centred ones. In the way-finding task an interaction, instruction by group, was found, supporting the idea that the two groups are influenced differently by the format (map or verbal description) of instructions. The landmark-centred group made fewer errors than the high-survey group with the verbal descriptions.

Several studies on sense of direction and way-finding ability have revealed great differences between individuals (see for example Brown, 1932; Hirtle & Hudson, 1991; Kozlowski & Bryant, 1977; Montello & Pick, 1993; Weisman, 1981). These differences were often found to be related to gender, with men and women performing differently in imagery (e.g., Denis, 1996; De Vega, 1994; Linn & Petersen, 1985), and spatial tasks, such as *way-finding*, *pointing*, and comprehension of verbal descriptions of spatial configurations (see Devlin & Bernstein, 1995, 1997; Harris, 1981; Lawton, Charleston, & Zieles, 1996; Newcombe, 1982; Perrig & Kintsch,

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1985; Ward, Newcombe, & Overton, 1986). A second factor often found to be related to performance in spatial tasks is the individual attitude to paying selective attention to specific items of environmental information, which results in different forms of spatial knowledge. The literature distinguishes between *configuration knowledge*, or understanding the spatial relationship between location, and *knowledge of places and the routes that connect them* (Evans, 1980; Golledge, 1987; Hart & Moore, 1973; Russel & Ward, 1982; Siegel & White, 1975). This mirrors the widely accepted distinction between survey and route representations (Taylor & Tversky, 1992; Tversky, 1991, 1996). Survey representations provide an overview of spatial layout and have an extrinsic frame of reference. They are required either from studying maps or by inspection of an environment from above. Route representations assume the point of view of a person moving through an environment and are anchored to a number of salient landmarks.

These distinctions are supported by several studies, which have found that the two kinds of representation are related differently to performance in spatial tasks. For example, Thorndyke and Hayes-Roth (1982) found that individuals who acquire information about an environment from a map were more efficient in estimating the distance as a crow flies between landmarks than individuals who navigated in it. By contrast, the latter gave more accurate judgements of the route distance between landmarks. Streeter, Vitello, and Wonsiewicz (1985) found that route instructions were more efficient than maps in giving directions for long, non-linear routes.

Route and survey representations could be related to different strategies used in way-finding tasks. Lawton (1994, 1996) has distinguished between *route strategy*, based on information about a route to be followed, such as when and where to turn, and *orientation strategy*, based on reference to global reference points, such as compass directions in outdoor environments, or the general building configuration in indoor environments. Route and orientation strategies were often equally efficient in way-finding tasks, even if route strategy is more frequently associated to a high level of spatial anxiety (Lawton, 1994). Furthermore, a gender difference was found, with more men than women using the survey strategy (Lawton, 1994, 1996).

Developmental studies (cf. Siegel & White, 1975) also support the existence of different kinds of spatial representations. These studies demonstrate that children's spatial representations pass from a first level, where they can represent only isolated landmarks, to a second phase where they can represent the route that connects these salient landmarks, to a third phase when they are able to make a more complex and general survey representation. Recently, Pazzaglia, Cornoldi, and De Beni (2000) have suggested that a similar threefold distinction, from non-spatial to spatial and very structured global representations, is also effective in explaining differences in adults' mental representations. After administering a Questionnaire on Spatial Representation (Pazzaglia et al., 2000; see Appendix 1) to a sample of undergraduate students, the authors were able to distinguish between three kinds of spatial representation: survey, route, and landmark-centred representation. The latter focused on detecting a number of salient landmarks not allocated on a network of routes connecting them (route representation), nor were they included in a more global, extrinsic configuration (survey representation). Spatial references are scarce, and focus in particular on the visual features of landmarks, such as their shape, colour, and verbal labelling. Landmark-centred representation is similar to that found in individuals on their very first approach to a non-familiar environment (Evans, Marrero, & Butler, 1981; Ferguson & Hegarty, 1994). In Pazzaglia et al. (2000) a number of undergraduate students reported their preference for this sort of representation, not only as their first approach to a non-familiar environment, but as their usual approach in spatial representation of both familiar and non-familiar places. Despite the fact that this form of representation is very poor in its spatial components, landmark-centred individuals performed a way-finding task in the city of Venice better than the high-survey ones (Denis, Pazzaglia, Cornoldi, & Bertolo, 1999). This confirms Passini's (1984) study, which demonstrated that some individuals with poor configurational understanding of an environment can successfully move inside it.

Despite the fact that individual differences in spatial representations are well established, it is less clear whether they are related to different cognitive strategies in processing spatial information. Linn and Petersen (1985), in a meta-analysis of gender differences in spatial tasks, have distinguished between purely spatial tasks that require items to be processed considering them as gestalt-like configuration (such as the Mental Rotation Test and Water-level Task) and tasks, such as the Minnesota Paper Form Board, that can be resolved using visual and verbal strategies, even if rotating of items is required. In Voyer, Voyer, and Bryden's (1995) meta-analysis, the Mental Rotation Test and Minnesota Paper Form Board were inserted in two different categories: the mental rotation category for the Mental Rotation Test and spatial visualisation for the Minnesota Paper Form Board. Comparing the performance of survey and landmark-centred individuals in the Mental Rotation Test (MRT) and the Minnesota Paper Form Board (MPFB) could lead to understanding which strategies are usually adopted to resolve a spatial task. In fact, if the two groups use mixed (spatial, visual, and verbal) strategies they will perform the two tasks similarly. However, if, as expected, the survey group is better able to adopt spatial strategies, its performance will be better in the MRT.

For the same reasons it could be expected that the format of the instructions given before following a route could influence the performance of the two groups differently. In fact, verbal information focused on landmarks could facilitate landmark-centred individuals. By contrast, survey individuals could be facilitated by a representation of the route on a map, which induces the spatial code of each single landmark and also their respective positions.

In summary, the goal of the present research is to demonstrate that individuals with a preference for survey and landmark-centred representations process visuospatial information differently, with survey individuals preferring to adopt spatial strategies and landmark-centred individuals, visual and verbal ones. A further, minor goal is to investigate the relationship between gender and spatial representations, in order to analyse these two factors in relation to performance in visuospatial tests and the way-finding task.

To test our hypotheses, we selected two samples of survey and landmark-centred undergraduate students, checking that there were the same number of males and females in the two groups. Participants were tested on the MRT (Vanderberg & Kuse, 1978) and the MPFB (Likert & Quasha, 1941). We expected that the two groups would perform differently in the MRT, with the survey group performing better.

The two groups also performed two way-finding tasks, with two instructions. They were required to study the route either from a map, or from a verbal description. We expected the survey group to perform better with the map, and the landmark-centred group to do better with the verbal description (see Appendix 2).

We also wanted to distinguish between the roles of spatial representation and gender in the way-finding tasks and visuospatial tests, and to check whether some dependent variables are more sensitive to gender differences, and others to differences in spatial representation.

METHOD

Participants

Participants were 46 undergraduate students (19 males, 27 females). They were selected on the basis of their answers to a Questionnaire on Spatial Representation (Pazzaglia et al., 2000). The Questionnaire (see Appendix 1) comprises 11 items on different spatial abilities: general sense of direction, knowledge and use of cardinal points, outdoor and indoor orienting ability, preference for survey, route, or landmark-centred representations. In particular, it permits two different scores of spatial representation to be recorded: landmark-centred and survey scores, derived from summed scores of the items 3b + 4c, 3c + 4a, respectively. The psychometric characteristics of the Questionnaire tested on a sample of 285 undergraduate students are reported in Pazzaglia et al. (2000). The factor analysis revealed the existence of 5 factors. Factor 1 grouped items on general sense of direction in open and closed environments (items 1, 2, 3c, 8, 9, 11); Factor 2 the use of compass directions in orienting tasks (items 5, 6, 12); Factor 3 grouped items on preference for a survey representation of space and a spatial coding of verbal descriptions (items 3c, 4a, 7a); Factors 4 and 5 grouped items on landmark-centred (items 3b, 4c) and route preference of spatial representation (items 3a, 4b) respectively. Reliability measured by the split-half method (corrected by Spearman-Brown) was .75; distinct alpha-Cronbach were computed separately on items with high saturations in the first three factors. Alpha values were .76, .75, and .62, respectively.

In the present study the entire Questionnaire was given to 228 undergraduate students (70 males, 158 females). On the basis of their answers to the questions on spatial representation, each participant had two distinct scores for their preference for landmark-centred or survey spatial representation, represented by Factors 3 and 4 of the factor analysis. A differential score was computed, derived from the survey minus the landmark-centred scores. The median of this differential score, computed on the scores of 220 participants who answered the questions, was –3. Participants with scores lower than or equal to the median score (27 males, 89 females) were considered landmark-centred, and participants with scores higher than –3 (40 males, 64 females) were considered survey.

In the landmark-centred group only individuals with very high landmark-centred scores were selected (scores higher than 8, corresponding to 43% of the distribution; 13 males, 36 females) and in the survey group individuals with very high survey scores (scores higher than 7, corresponding to 28% of the distribution; 11 males, 18 females). Nine males and 14 females of the survey group, and 10 males and 13 females of the landmark-centred group agreed to take part in the research.[1] The participants were not familiar with the routes used in the experiment as they had no knowledge of the areas of the building that were used in the study.

[1]In order to increase the number of males in the landmark-centred group, four participants of the landmark-centred group with the landmark-centred score equal to 8 were added to the sample.

Materials and procedure

(1) Mental Rotation Test (Vanderberg & Kuse, 1978). This is a paper-and-pencil version of the Shepard and Metzler (1971) mental rotation task, using three-dimensional objects.
(2) Minnesota Paper Form Board (Likert & Quasha, 1941). In this test participants must decide which of five, two-dimensional line-drawings of shapes can be made out of a set of fragmented parts.

The tests were administered to groups of about 20 participants in a 30-minute session. Each test comprised a short time for instructions and 8 minutes to perform the task. Scores were 1 point for each item completely correct.

For the way-finding task, maps and descriptions of two different indoor routes were given (see Appendix 2 for examples of maps and descriptions). Both routes were to be found inside a building of the Faculty of Psychology. The building has seven floors and a basement. In one case the route involved the basement and second floor, in the other, the basement and first floor. The two routes were similar in length (150 and 158 metres), and number of turning-points (9 and 8). Two maps were made for each route (one map for each floor). The maps were taken from official plans of the building and the scale was 1/200. Verbal descriptions were from a route perspective and had the same number of words in the original Italian (189).

At the beginning of the way-finding task each participant was told that he/she would have to follow two different routes inside the building, one with the help of a map and the other from a verbal description. They were also told that they had only 5 minutes to study the map and description. The study time was recorded. They could ask to see the map (or description) whenever they wanted during the route, but were told that each request would decrease the level of performance. Immediately after studying the map (or description) the participant started to move along the route, followed by the experimenter who recorded errors (when the wrong direction was taken at a turning point), hesitations (when the participant corrected an error immediately), pauses (when the participant stopped and looked around to find the correct direction) and requests to have another look at the map or description. When a participant went the wrong way he/she was stopped after a few steps and guided back in the correct direction. The order of instructions and routes was balanced.

RESULTS

Visuospatial tests

Table 1 shows the means of correct answers and standard deviations for males and females, and for the landmark-centred and survey groups for each spatial test.

Two 2 × 2 ANOVAS with gender and group (survey and landmark-centred) as independent variables performed on the scores of the visuo-spatial tests revealed the following results: For the Mental Rotation Test a significant effect of the factors gender, $F(1, 42) = 28.53$, $MSe = 10.78$, $p < .001$, and group, $F(1, 42) = 7.85$, $MSe = 10.78$, $p < .01$, with a better performance by males ($M = 10.68$, $SD = 4.56$) than females ($M = 5.55$, $SD = 2.52$), and survey group ($M = 8.87$, $SD = 4.55$) than landmark-centred group ($M = 6.48$, $SD = 3.76$); for the Minnesota Paper Form Board, a significant effect of the factor gender, $F(1, 42) = 6.10$, $MSe = 17.58$, $p < .05$, with a better performance by females ($M = 23.22$, $SD = 3.73$) than males ($M = 20.10$, $SD = 4.79$); no significant effect of group factor was found.

Way-finding task

The following analyses were performed for 44 participants, because two participants did not perform this task. Table 2 shows the average errors

TABLE 1
Mean scores of correct answers and standard deviations in the visuospatial tests for males and females in the survey and landmark-centred groups

	Groups			
	Survey		*Landmark-centred*	
Test	*Males (9)*	*Females (14)*	*Males (10)*	*Females (13)*
Mental rotation test (3-dimension)				
M	12.55	6.50	9.00	4.53
SD	4.75	2.38	3.86	2.33
2 main effects: gender, group				
Minnesota Paper Form Board (2-dimension)				
M	19.55	24.28	20.60	22.08
SD	5.72	2.78	4.03	4.37
1 main effect: gender				

TABLE 2
Mean scores of errors and standard deviations in the way-finding task for males and females in the survey and landmark-centred groups

	Groups			
	Survey		*Landmark-centred*	
Instructions	*Males (8)*	*Females (13)*	*Males (10)*	*Females (13)*
Verbal descriptions				
M	0.87	2.85	0.90	1.23
SD	0.83	1.57	0.74	1.36
Maps				
M	0.75	1.46	1.00	2.08
SD	1.16	1.56	1.05	1.85

performed by males and females and by survey and landmark-centred participants during the way-finding task.

A $2 \times 2 \times 2$ ANOVA (Gender $\times$ Group $\times$ Instruction) performed on the total number of errors revealed a significant effect of the gender factor, $F(1, 40) = 11.91$, $MSe = 1.85$, $p < .005$, with a better performance by males ($M = .88$, $SD = .23$) than females ($M = 1.90$, $SD = .19$), and the interaction Group $\times$ Instruction, $F(1, 40) = 4.12$, $MSe = 1.93$, $p < .05$. Newman-Keul's post hoc comparison revealed that in the description condition the landmark-centred group ($M = 1.09$, $SD = 1.12$) performed better than the survey group ($M = 2.09$, $SD = 1.64$), when no differences between the two groups were found in the map condition (landmark-centred group: $M = 1.61$, $SD = 1.62$; survey group: $M = 1.19$, $SD = 1.43$).

A problem that arose from these data was that generally the mean errors in the different conditions were quite low. A tendency towards a floor effect may make interpretation difficult. In order to make our results clearer we considered the frequencies of people who had a very good and a very poor performance with the verbal description in the landmark-centred and survey groups. In doing so we considered the number of people who made 0 errors (total = 11) and the number who made 3 or more errors (total = 12) with the verbal description. Of the 11 people with a very good performance, only 3 belonged to the survey group and 8 to the landmark-centred group. By contrast, of the 12 people with a very poor performance 9 belonged to the survey group and only 3 to the landmark-centred group, chi-square = 5.23, $df = 1$, $p < .05$. In contrast, considering the performances with the map, we found that of 17 people

TABLE 3
Mean scores of hesitations and standard deviations in the way-finding task for males and females in the survey and landmark-centred groups

	Groups			
	Survey		*Landmark-centred*	
Instructions	*Males (8)*	*Females (13)*	*Males (10)*	*Females (13)*
Verbal descriptions				
M	1.62	1.69	0.90	1.53
SD	1.68	1.60	0.87	1.66
Maps				
M	0.37	1.38	0.60	1.00
SD	0.74	0.77	0.84	0.58

with a very good performance, 9 belonged to the survey group and 8 to the landmark-centred group; of 10 people with a very poor performance 7 belonged to the landmark-centred group and only 3 to the survey group, chi-square = .25, *df* = 1, n.s. Therefore, considering frequencies we found results supporting the analysis performed on average values.

A similar ANOVA performed on hesitation scores revealed a significant effect for the instruction factor, $F(1, 40) = 6.48$, $MSe = 1.17$, $p < .05$, with a better performance with map than with description (description: $M = 1.45$, $SD = 1.48$; map: $M = 0.91$, $SD = 0.80$). Table 3 shows the average hesitations performed by males and females and by survey and landmark-centred participants during the way-finding task.

An analysis of variance performed on the time (in seconds) for studying maps or descriptions revealed a significant effect for the instruction factor, $F(1, 40) = 39.06$, $MSe = 3630.35$, $p < .001$, due to shorter times with maps ($M = 136$, $SD = 79$) than with verbal descriptions ($M = 212$, $SD = 74$), and of the interaction instruction by gender, $F(1, 40) = 4.36$, $MSe = 3630.35$, $p < .05$. Table 4 shows the average times performed by males and females and by survey and landmark-centred participants during the way-finding task. Post hoc comparison revealed that females were faster than males in studying verbal descriptions (males: $M = 244$, $SD = 67$; females: $M = 189$, $SD = 71$), whereas males and females did not differ when studying the map (males: $M = 137$, $SD = 74$; females: $M = 134$, $SD = 83$).

TABLE 4
Mean scores of study times (in seconds) and standard deviations in the way-finding task for males and females in the survey and landmark-centred groups

	Groups			
	Survey		*Landmark-centred*	
Instructions	*Males* (8)	*Females* (13)	*Males* (10)	*Females* (13)
Verbal descriptions				
M	228	179	258	199
SD	84	75	53	68
Maps				
M	100	138	167	131
SD	48	86	80	84

DISCUSSION

The idea, well established in the literature (Lawton, 1994, 1996; Tversky, 1996), that individuals differ in the way they represent space is confirmed by the present research. In contrast to previous research, we did not investigate the classical distinction between route and survey representations, but studied a third, landmark-centred, spatial representation. As with the route representations, importance is given to landmarks and their verbal labelling, but landmark-centred representations differ in spatial components. In the route representations landmarks are inserted in a route that connects them, and can be mentally represented and clearly described. Individuals with landmark-centred representations affirmed that they usually do not represent routes connecting different landmarks, but prefer to maintain isolated images of single landmarks. The current results support the idea that high-survey and landmark-centred individuals adopt different strategies in processing spatial information. The better performance of high-survey participants in the MRT suggested that they were more capable of adopting spatial-holistic strategies in performing psychometric spatial tasks. When constructing a survey representation it is important to refer to a stable, gestalt-like configuration, and to rotate it while maintaining an extrinsic point of view. This may explain the relationship between survey representation and performance in the mental rotation test. When the task required both spatial and verbal strategies the two groups gave a very similar performance.

Our results also highlighted a gender difference in the same task, with men performing better than women. This is widely documented in the literature, but the new results indicate that in addition to gender differences, there are differences between survey and landmark-centred groups for both men and women. There is a relationship between survey representation and performance in the MRT, not only for men, but also women. In contrast, in the MPFB females obtained a better performance. This test was included by Linn and Petersen (1985) and Voyer et al. (1995) as part of the category of spatial visualisation tests. In this category gender effect size was the smallest compared with that found for mental rotation and spatial perception categories. Voyer et al. (1995) reported many studies that did not find a gender effect in the MPFB, and a few studies that reported a male advantage. Features of the test, which is performed using different (visual, spatial) strategies and requires a wide range of cognitive abilities, could benefit males or females without a clear difference between groups.

In the way-finding task our results suggest which are, in general, the best type of instructions for navigating inside a building, following routes similar to those used in our research. Data suggest a general superiority of the map condition. In fact, even if there is no difference in number of errors between the two conditions, the map condition was found to be superior in both hesitations and study time. The participants with map instructions were more confident (lower number of hesitations) and in general they learnt the route faster.

Considering individual differences in number of errors, the expected instruction by group interaction was found, supporting the idea that survey and landmark-centred participants are influenced differently by the type of instructions. As expected, we found that the landmark-centred group made fewer errors than the survey group in the verbal description condition. With the map the average performance showed a tendency towards a better performance by the survey group, but the difference was not significant.

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APPENDIX 1

Questionnaire on Spatial Representation (Pazzaglia et al., 2000)

1. Do you think you have a good sense of direction?
   1 (not at all) 2 3 4 5 (very good)

2. Are you considered by your family or friends to have a good sense of direction?
   1 (not at all) 2 3 4 5 (very much)

3. Think about the way you orient yourself in different environments around you. Would you describe yourself as a person:
   a. who orients him/herself by remembering routes connecting one place to another?
      1 (not at all) 2 3 4 5 (very much)
   b. who orients him/herself by looking for well-known landmarks?
      1 (not at all) 2 3 4 5 (very much)
   c. who tries to create a mental map of the environment?
      1 (not at all) 2 3 4 5 (very much)

4. Think of an unfamiliar city. Write the name ....
   Now try to classify your representation of the city:
   a. survey representation, that is a map-like representation
      1 (not at all) 2 3 4 5 (very much)
   b. route representation, based on memorising routes
      1 (not at all) 2 3 4 5 (very much)
   c. landmark-centred representation, based on memorising single salient landmarks (such as monuments, buildings, crossroads, etc.)
      1 (not at all) 2 3 4 5 (very much)

5. When you are in a natural, open environment (mountains, seaside, country) do you naturally individuate cardinal points, that is where north, south, east, and west are?
   1 (not at all) 2 3 4 5 (very much)

6. When you are in your city do you naturally individuate cardinal points, that is do you find easily where north, south, east, and west are?
   1 (not at all) 2 3 4 5 (very much)

7. Someone is describing for you the route to reach an unfamiliar place. Do you prefer:
   a. to make an image of the route?
      1 (not at all) 2 3 4 5 (very much)
   b. to remember the description verbally?
      1 (not at all) 2 3 4 5 (very much)

8. In a complex building (store, museum) do you think spontaneously and easily about your direction in relation to the general structure of the building and the external environment?
   1 (not at all) 2 3 4 5 (very much)

9. When you are inside a building can you easily visualise what there is outside the building in the direction you are looking?
   1 (not at all) 2 3 4 5 (very much)

10. When you are in an open space and you are required to indicate a compass direction (north-south-east-west), do you:
    a. point immediately?
    b. need to think before pointing?
    c. have difficulty?

11. You are in a complex building (many floors, stairs, corridors) and you have to indicate where the entrance is, do you:
    a. point immediately?
    b. need to think before pointing?
    c. have difficulty?

APPENDIX 2

Examples of verbal descriptions and maps

Verbal description (the second part, corresponding to the basement, of route 1, which comprises the second floor and basement).
Go down the stairs and then turn right. In front of you there is a door and a corridor. Take the corridor on the right, go straight on for a short distance and then turn into the first corridor on the left. Continue straight on until the end of it and then turn right. Go straight on again, then turn left and left again and continue on until the end of the corridor where there is a French window. This is your final point.

Map of the basement