Spatial representations in blind people: The role of strategies and mobility skills

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The role of strategies and mobility skills

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Abstract

The role of vision in the construction of spatial representations has been the object of numerous studies and heated debate. The core question of whether visual experience is necessary to form spatial representations has found different, often contradictory answers. The present paper examines mental images generated from verbal descriptions of spatial environments. Previous evidence had shown that blind individuals have difficulty remembering information about spatial environments. By testing a group of congenitally blind people, we replicated this result and found that it is also present when the overall mental model of the environment is assessed. This was not always the case, however, but appeared to correlate with some blind participants' lower use of a mental imagery strategy and preference for a verbal rehearsal strategy, which was adopted particularly by blind people with more limited mobility skills. The more independent blind people who used a mental imagery strategy performed as well as sighted participants, suggesting that the difficulty blind people may have in processing spatial descriptions is not due to the absence of vision per se, but could be the consequence of both, their using less efficient verbal strategies and having poor mobility skills.

Keywords: Blindness; Spatial representations; Mobility skills; Strategy use.

1. Introduction

The association between visual perception and visuospatial imagery, and the role of vision in the construction of spatial representations have been the object of numerous studies and heated debate, and many issues still remain controversial (see Cattaneo & Vecchi, 2011, for a review). The core question of whether visual experience is necessary to form spatial representations has found different, often contradictory answers (e.g. Byrne & Salter, 1983; Eimer, 2004).

A paradigm widely used in this research area consists in analyzing blind people's spatial abilities by considering different aspects of spatial representation. Research has focused particularly on two main types of spatial representation of the environment: route and survey (e.g. Byrne, 1979; Loomis et al., 1993; O'Keefe & Nadel, 1978; Thinus-Blanc & Gaunet, 1997). Route representation is based on a ground-level perspective, seen from the point of view of a person moving in a given environment. It is characterized mainly by an internal frame of reference (bodily axis) and egocentric coordinates such as "to the right", "to the left", "ahead", "behind". This type of representation is formed by a sequential encoding of spatial information (Blalock & Clegg, 2010). Survey representation adopts a bird's-eye view and is global, referring to the person's knowledge of the topographic properties of the environment, such as the location of objects relative to an allocentric fixed coordinate system ("north", "south", "east" and "west"). It relies on spatial relations between perceptible external cues and is characterized by an external frame of reference (Thinus-Blanc & Gaunet, 1997). This type of representation encodes a spatial layout from an external perspective (an aerial or map-like view) and contains information that is not obtainable by means of a direct environmental experience.

Based on the above-described characteristics of these two types of spatial representation, several researchers (e.g. Noordzij, Zuidhoeka, & Postma, 2006; Steyvers & Kooijman, 2009) have wondered whether blind people can use both types of representation, and whether they can form well-organized spatial maps of an environment on the basis of a survey description. Without the aid of vision, the perceptual modalities that remain available are essentially egocentric, based on proprioceptive and kinesthetic information (Cattaneo et al., 2008). Ruotolo, Ruggiero, Vinciguerra, and Iachini (2012) suggested that these modalities enable the diachronic reception of information, which could, in turn, facilitate the formation of route-like representations. On the other hand, the lack of visual information might affect blind people's chances of generating representations of an environment that they have not experienced directly, thereby impairing their ability to develop effective survey representations.

The results of several studies seem to confirm this hypothesis, showing that participants with congenital blindness perform worse in survey representation-based tasks than those with late-onset blindness or sighted participants (e.g. Rieser, Guth, & Hill, 1986). Moreover, research on the influence of blindness on the efficient use of route and survey descriptions suggests that, in the construction of spatial mental models, blind people are facilitated by route descriptions, whereas the sighted are more efficient when they receive survey descriptions of the environment (Noordzij & Postma, 2005; Noordzij et al., 2006). Conversely, results of other studies have challenged the causal relationship between visual experience and survey representational skills (e.g. Klatzky, Golledge, Loomis, Cicinelli, & Pellegrino, 1995; Landau, Spelke, & Gleitman, 1984; Loomis et al., 1993; Tinti, Adenzato, Tamietto, & Cornoldi, 2006), showing that even blind people are not entirely lacking in simultaneous spatial knowledge (Hill et al., 1993; Millar, 1994; Passini & Proulx, 1988; Thinus-Blanc & Gaunet, 1997), and may be able to construct survey representations (Morrongiello, Timney, Humphrey, Andreson, & Story 1995; Tinti et al., 2006).

The sheer diversity of the findings in this field seems to prevent any clear-cut conclusions from being drawn about the effects of early blindness on spatial cognition. Moreover, most of the above-cited studies focused on the spatial abilities associated with the absence of vision, without considering the role of specific encoding strategies and experience of moving autonomously in space. The implications of using different strategies (e.g. verbal versus imagery strategies), to process spatial information have been largely neglected, although they appear crucially important when spatial information is obtained from spoken language as is often the case in blind people. Indeed, visuospatial mental imagery might improve recall of verbal spatial information (Paivio, 1971), whereas the use of a verbal strategy might lead to a poorer memory of the same information. A recent study by Cornoldi, Tinti, Mammarella, Re, and Varotto (2009) examined this issue by systematically interviewing blind and sighted individuals after they had completed a task that involved generating spatial representations from verbal descriptions: the participants were able to explain what strategies they had adopted (their reports were consistent with the classifications adopted by experts on the basis of the interview protocols) and the differences between the sighted and blind people were affected by the types of strategy they used (see also Vanlierde & Wanet-Defalque, 2004). In particular, the differences between the sighted and blind participants' performance were related to the latter making a lower and less effective use of a mental imagery strategy (the differences disappeared when both groups used verbal strategies, such as text memorization). According to Cornoldi et al. (2009), the use of a given strategy is not the inevitable consequence of the absence of vision; it could also be associated with contextual and partially modifiable factors. One factor that could account for the different use of strategies by blind individuals (and for some of the diversity in the findings emerging from different studies) could relate to the level of these individuals' mobility skills (Loomis et al., 1993; Ungar, Blades, & Spencer, 1996). As suggested by Loomis et al. (1993), we cannot rule out the possibility of spatial competence depending more on people's expertise in independent travelling than on their visual experience. Surprisingly, this aspect has received little attention in previous studies and, to our knowledge, no research in the field of spatial imagery has systematically analyzed the influence of mobility skills.

1.2. Objectives of the present study

The aim of this study was to compare the performance of congenitally blind and sighted people in tasks requiring the construction of spatial models starting from verbal survey and route descriptions, considering the underlying effect of the strategies the people used and their mobility skills. We investigated: whether the performances of congenitally blind participants differed for the survey versus the route texts (as reported by Nordzji et al., 2006); whether these eventual differences are correlated with the use of a verbal rather than a visuospatial strategy; and whether the use of the latter strategy correlated with the participants' mobility skills. More in detail, the study had the following objectives:

1) to shed further light on the issue of whether blind people have more trouble processing survey texts than route texts;
2) to establish whether the strategies used by blind people are mainly verbal (based on memorizing the spatial description) or spatial (based on spatial imagery);
3) to test the hypothesis that, given a verbal spatial description, using a text memorization strategy is less efficient than a spatial imagery strategy for the purposes of creating a spatial mental model;
4) to examine whether blind people's different usage of strategies correlate with their levels of mobility skills.

To reach these objectives, we compared the performance of participants with congenital blindness and blindfolded sighted participants in a complex spatial task that involved the following sequence: 1) participants listened to the description of a landscape; 2) they were asked to represent the landscape by placing different landmarks on a three-dimensional model; 3) they said whether several statements about the landscape were true or false; 4) they were asked about the strategies they had used to complete the task.

Each participant repeated these four steps twice, once after hearing the description of a landscape from a route perspective, and once a landscape had been described from a survey perspective.

2. **Method**

2.1. Participants

Twenty-five congenitally blind and 25 sighted adults took part in the experiment. Both groups consisted of 12 males and 13 females, and the two groups were matched for age (Blind: $M = 46.5$, $SD = 12.8$, range 27-73; Sighted: $M = 45.1$, $SD = 12.8$, range: 26-70, $F(1,49) = .149$, $p = .701$), and years of education (Blind: $M = 14.3$, $SD = 2.9$, range 10-17; Sighted: $M = 14.9$, $SD = 2.8$, range: 11-20, $F(1,49) = .711$, $p = .403$). The blind participants had no residual eyesight at all, and no other neurological or sensory-motor impairments. In order to assess the role of mobility, particular attention was paid to collecting information concerning this aspect. Participants were considered non autonomous in terms of their mobility if they needed someone's help to cover a considerable distance indoors or out. The assessment of their mobility skills was based on family's reports and confirmed during interviews with the experimenter (no ambiguous cases emerged). Among the 25 blind participants, 7 were non autonomous in terms of their mobility.

2.2. Materials

2.2.1. Spatial descriptions

Four texts, adapted from existing material (De Beni, Pazzaglia, Gyselinck, & Meneghetti, 2005; Taylor & Tversky, 1992), were recorded using audio software (Audacity): two describe a nature park (Park), once from a route and once from a survey perspective; the other two describe a tourist resort (Resort) from the same two perspectives. Route descriptions of the landscapes unfold in a stepwise fashion from the point of view of a person on the move and using relative spatial terms such as "to your right", "in front of you" (e.g. "As you go along the road, there is a lake to your right, and the quiet town of Carpognano to your left."). Survey descriptions develop from a global description of the whole environment to a gradual specification of the local relationships between specific landmarks, using absolute spatial terms such as "north" and "south" (e.g. "The tourist resort is situated around a little lake, and its boundaries are marked by Highway No. 5 to the north and the

Sunny hills to the south”). The four texts consist of 12 sentences each and are comparable in terms of number of words and recording time (Park Route: 309 words, 3’14”; Park Survey: 298 words, 3’8’’; Resort Route: 330, 3’17’’; Resort Survey: 321 words, 3’7’’).

2.2.2. Three-dimensional models of the landscapes

Participants were asked to reconstruct the landscapes described to them on a wooden panel (48x40x1 cm in size), with a grid drawn on it (for scoring purposes) of 12x9 cells (4x4 cm each) and upper and lower borders covered with a strip of Velcro (2x48cm) (Figures 1 and 2). Each landscape contained 13 wooden landmarks, two of which (the “Chamois road” and the “Wild mountains” in the nature park, and the “Sunny hills” and “Highway No. 5” in the tourist resort), were attached to the Velcro strips by the experimenter at the beginning of the reconstruction task. For each landscape, there were also 11 wooden blocks of various sizes which represented the landmarks that participants were asked to place on the models. In particular, there were ten blocks 4x4 cm in size and one 4x2 cm (Path 131) for the nature park, while for the tourist resort there were eight blocks 4x4 cm, one 4x12 cm (Horse-racing track), one 4x16 cm (Holmwood) and one 6 cm in diameter (Lake).

Insert Figures 1 and 2 about here

2.2.3. Spatial description verification questionnaires

For each of the four spatial descriptions, a questionnaire was prepared comprising 30 statements (15 true, 15 false), which were presented in a randomized order. Participants had to say whether each statement was true or false. Correct answers scored 1 point and were added to obtain a final score ranging from 0-30. To succeed in this task, participants could not rely on verbatim memory alone, they needed to make inferences. For example, the description of the tourist resort included the following sentence: ‘As you go along, the lake is on your right. At the foot of the Sunny Hills, on your left, there is a spa with sulfurous water and, just beyond it, a large medical center specializing in the treatment of respiratory diseases’. In the verification task, participants had to judge whether the sentence ‘You will find the spa on your left, just before you come to the medical center ’ is true or false.

2.2.4. Non-spatial control text

To control for non-specific text processing difficulties, a non-spatial text (adapted from De Beni, et al., 2005) was also included in the experiment. This text described the different stages of wine-making, from the grape harvest to bottling, and consisted of 14 sentences (302 words for a recording time of 3’3’), and was again associated with 30 verification statements (15 true and 15 false).

2.2.5. Meta-cognitive interview about the strategies participants used

For each of the two spatial texts administered (one from a route, the other from a survey perspective), participants were questioned about the strategy they had used to complete the task: they were asked to choose one of the following options: 1) I tried to memorize the text; 2) I tried to imagine the position of the landmarks in space; 3) other strategies (see Cornoldi et al., 2009). When participants chose the third option or did not report using any strategy (n = 14 in the route condition, n = 4 in the survey condition), they were asked to describe how they proceeded and two independent judges classified the answers they gave. The judges agreed for all cases in the survey condition and all but one in the route condition; this last case was discussed with one of the authors to reach an agreement. The interviews revealed that participants who chose the third option or did not answer had tried to imagine their body or hands moving in space from one landmark to the next. These strategies were pooled to form a third category of strategies labeled “Imagining oneself moving in space”.

2.3. Experimental design and procedure

Sighted participants were blindfolded before the experiment. All participants completed the tasks in individual sessions, in a quiet room. At the beginning of the experiment, they were invited to explore the perimeter of the wooden panel to enable them to imagine the size and shape of the model. Then they listened twice to the first and successively the second spatial description. The perspectives (route versus survey) and landscapes (nature park versus tourist resort) were counterbalanced across participants, so there were four randomly-assigned orders of spatial text presentation: 1) Park Route – Resort Survey, 2) Park Survey - Resort Route, 3) Resort Route - Park Survey, 4) Resort Survey - Park Route. More in detail, each participant listened to two different spatial descriptions (Park and Resort), one from a route and the other from a survey perspective. When the description of a given landscape finished, the experimenter placed the corresponding two fixed landmarks (Park: Chamois' road, Wild mountains; Resort: Sunny hills, Highway No. 5) on the wooden panel and read the names of the other 11 landmarks to locate on the panel in a randomized order. Participants were asked to construct a model of the landscape by placing the 11 wooden blocks representing the landmarks on the wooden panel. To be more specific, participants asked the experimenter to hand them one landmark block at a time, in whatever order they wished, so that they could position it on the model. When participants thought they had completed the task, the experimenter reminded them of any landmarks they had forgotten. Finally, the experimenter read each of the 30 statements on the previously-described landscape and asked participant to say if they were true or false.

The same procedure was repeated for the second landscape as seen from the other perspective. After the two spatial texts had been presented, and the two models had been constructed, participants were also presented with the non-spatial text and corresponding true/false statements. Finally, they were asked about the strategies they had used to process the two spatial descriptions. The whole experiment lasted about one hour.

2.4. Assessment of the models constructed by participants

On the basis of the descriptions of the landscapes, it is possible to determine an approximately correct, but rather rough location of the landmarks. To identify more precise ideal locations of the landmarks, we therefore conducted a pilot study in which 80 university students (37 males and 43 females, mean age = 24.9, *SD* = 8.7) were asked to complete the model construction task. The students were randomly assigned to four groups of 20 participants, and each group had to read one of the four spatial descriptions (Park Route, Park Survey, Resort Route, Resort Survey) and then construct the corresponding model. There were no time limits and the spatial description remained available for them to consult while they completed the task. For each landscape and each perspective, the ideal locations of the landmarks were established by calculating the mean and standard deviations of their locations in relation to the grid drawn on the wooden panel. More in detail, the mean X and Y coordinates, and their standard deviations were computed, and a region containing the ideal location of each landmark was identified. As an example, the ideal regions for the proper location of the church in the survey and the route versions of the task are illustrated in Figure 1.

To ascertain how correctly participants positioned the landmarks, two scores were calculated for each participant: (i) accuracy scores based on the appropriate positioning of the landmark in the same quadrant as the correct location (2 points for each landmark), or in an adjacent quadrant (1 point) (see Meneghetti & Mammarella, 2011); (ii) error measures defined as the mean of the Euclidian distances between the perimeters of the ideal regions (established from the pilot study) and the barycenter of the landmarks placed by the participants. To give an example, as shown in Figure 1, if the barycenter of the church positioned by participant A in the Park Survey condition was at x = 0.7, y = 4.0, then the error vector was 1.72 (i.e. sqrt [$\{x\_ideal – x\_participant\}^2$+ $\{y\_ideal – y\_participant\}^2$], in the present case: sqrt [$\{1.7\text{-}0.7\}^2 + \{2.6\text{-}4.0\}^2$], where x_ideal and y_ideal are given by the point where the line linking the barycenters of the church in its ideal position and in the position chosen by the participant crosses the perimeter of the ideal region). A given participant’s total error amounted to the mean of the 11 error vectors, corresponding to the placement errors for the 11 landmarks vis-à-vis their ideal location regions. For each participant, a meanerror vector for the route and a mean error vector for the survey model, were obtained.

3. Results

3.1. Preliminary analyses

A preliminary ANOVA computed to control for non-specific difficulties in text processing showed that blind (M = 26.48, SD = 2.73) and sighted (M = 27.40, SD = 2.14) participants did not differ significantly in terms of their scores for the non-spatial text, $F(1,48) = 1.76$, $p = .191$.

A further preliminary analysis examined whether the error vector measure was consistent with the outcome given by the accuracy scores in assessing how accurately the landmarks were located in the model construction task. The correlations (for the group of participants as a whole) between the vector scores and the accuracy measures were high for both perspectives, i.e. $r(50) = -.89$, $p < .001$, for survey, and $r(49) = -.95$, $p < .001$, for route, so subsequent analyses were conducted considering the error vector measure alone.

3.2. Differences between blind and sighted participants in the spatial description verification task and the model construction task

Table 1 shows the blind and sighted participants' performance in the spatial description verification task and the model construction task in the route and survey conditions. A 2 (blind/sighted groups) x 2 (route/survey conditions) mixed ANOVA on the scores obtained in the spatial description verification task showed no significant main effect of condition, $F(1,48) = 1.37$, $p = .248$, and no interaction condition x group, $F(1,48) = 0.18$, $p = .666$, whereas the main effect of group was significant, $F(1,48) = 5.12$, $p < .05$, $\eta_p^2 = .096$, in that sighted people (EMM = 25.72, ESD = 0.74) performed significantly better than blind people (EMM = 23.34, ESD = 0.74).

A second 2 (blind/sighted groups) x 2 (route/survey conditions) mixed ANOVA computed on the means of the error vectors for the model construction task showed a main effect of condition, $F(1,48) = 6.62$, $p < .05$, $\eta_p^2 = .121$, but no interaction condition x group, $F(1,48) = 0.11$, $p = .738$. More in detail, whether the participants were blind or sighted, constructing the model on the basis of a route description proved more difficult (EMM = 1.66, ESD = 0.18) than when the description was provided from a survey perspective (*EMM* = 1.26, *ESD* = 0.14). Furthermore the analysis showed a significant main effect of group, $F(1,48) = 4.21$, $p < .05$, $\eta_p^2 = .081$, due to the fact that also in the model construction task sighted people (*EMM* = 1.17, *ESD* = 0.20) did significantly better than blind people (*EMM* = 1.75, *ESD* = 0.20).

Insert Table 1 about here

3.3. Efficiency of strategies

The meta-cognitive interview on the strategies used by participants revealed that, for the route tasks, 11 participants relied on a verbal strategy to memorize the landscapes described, 25 imagined the position of the landmarks in the space, and 14 imagined themselves moving in the space described (see Table 3, row "Total Route"); for the survey tasks, 8 participants used a verbal strategy, 38 tried to imagine the position of the landmarks in the space, and 4 imagined themselves moving in the space (see Table 3, row "Total Survey"). Table 2 shows how the whole group of participants performed as a function of the strategies they used in the route and survey conditions. Regarding the route condition, a 3 (strategies) x 2 (tasks) ANOVA showed that the strategy used did not significantly affect the verification task, $F(2,47) = 0.79$, $p = .480$, whereas its effect on the model construction task was significant, $F(2,47) = 4.77$, $p < .05$, $\eta_p^2 = .169$. In particular, Bonferroni post-hoc tests showed that participants who imagined the landmarks' position in the space did significantly better than those who tried to memorize the text, while the performance of those who tried to imagine themselves moving in the space came in between the two (not differing significantly from the performance achieved using the other two strategies). As for the survey condition, a further 3 (strategies) x 2 (tasks) ANOVA showed a significant effect of the strategy used on both the verification task, $F(2,47) = 11.53$, $p < .001$, $\eta_p^2 = .329$, and the model construction task, $F(2,47) = 18.46$, $p < .001$, $\eta_p^2 = .440$: participants who imagined the landmarks' position in the space did better than those using the other two strategies.

Insert Table 2 about here

3.4. Relationship between strategies used, degree of autonomy and performance

Table 3 shows the number of blind (see the “All Blind” row) and sighted participants who used specific strategies to complete the tasks when confronted with a route or a survey description. Chi square tests showed that, in the route condition, the two groups chose much the same strategies, $\chi^2(2, N = 50) = 2.10$, $p = .349$, but in the survey condition, sighted people were more likely than blind people to use the strategy consisting in imagining the position of the landmarks in the space, $\chi^2(2, N = 50) = 11.13$, $p < .01$.

Eighteen of the blind participants were autonomous when moving indoors and out, while the other 7 needed to be accompanied when moving outdoors. These two subgroups of blind participants did not differ by gender, $\chi^2(1, N = 25) = 0.10$, $p = .748$, age, $F(1,23) = 3.34$, $p = .081$, or years of education, $F(1,23) = 0.03$, $p = .877$, but they did differ in their use of strategies. In the route condition, non autonomous blind participants preferred to memorize the verbally-delivered text in order to complete the task, whereas autonomous blind participants relied mostly, and in more or less equal proportions on the other two strategies: imagining the spatial position of the landmarks, or imagining themselves moving in the space, $\chi^2(2, N = 25) = 9.11$, $p< .05$. In the survey condition too, the non autonomous blind participants relied mostly on a text memorization strategy, whereas autonomous blind participants (like the sighted participants) tended more to imagine the position of the landmarks in the space, $\chi^2(2, N = 25) = 6.93$, $p < .05$.

Insert Table 3 about here

Table 4 shows how non autonomous blind, autonomous blind and sighted participants performed in the two tasks. A 3 (groups) x 2 (route/survey conditions) mixed ANOVA computed on the scores obtained in the verification tasks revealed no significant effect of condition, $F(1,47) = 0.51$, $p = .480$, and no interaction group x condition, $F(2,47) = 0.18$, $p = .833$, whereas the main effect of group was significant, $F(2,47) = 7.34$, $p< .01$, $\eta_p^2 = .238$. More in detail, non autonomous blind participants (*EMM* = 20.07, *ESD* = 1.30) did significantly worse than the sighted (*EMM* = 25.72, *ESD* = 0.69) and the autonomous blind participants (*EMM* = 24.61, *ESD* = 0.81). More importantly, the performance of the latter two groups did not differ significantly. A second 3 (groups) x 2 (route/survey conditions) mixed ANOVA on the scores obtained in the model construction task yielded similar results, i.e. a significant effect of condition, $F(1,47) = 4.39$, $p < .05$, $\eta_p^2 = .085$, the route perspective proving more difficult than the survey perspective for all groups; no interaction group x condition, $F(2,47) = 0.06$, $p = .945$; and a main effect of group, $F(2,47) = 21.79$, $p < .01$, $\eta_p^2 = .481$. Here again, non autonomous blind participants (*EMM* = 3.24, *ESD* = 0.29) did significantly worse than sighted (*EMM* = 1.17, *ESD* = 0.15) and autonomous blind participants (*EMM* = 1.17, *ESD* = 0.18), while the performance of the sighted and autonomous blind participants was almost identical.[1]

The small number of autonomous blind people who did not use imagery strategies prevented us from drawing statistical comparisons between them and the other autonomous blind participants, but analyzing their scores supports the importance of imagery strategies: the few autonomous blind people who adopted the less efficient strategy of memorizing the text ($n = 2$ in the route condition, $n = 3$ in the survey condition, see Table 3) performed less well (verification tasks: route $M = 20.00$, survey $M = 19.67$; model construction tasks: route $M = 2.56$, survey $M = 2.50$) than the autonomous blind participants who used the strategy of imagining the landmarks' position in the space (verification tasks: route $M = 23.44$, survey $M = 25.85$; model construction tasks: route $M = 1.28$, survey $M = 0.71$), or imagined themselves moving in the space (verification tasks: route $M = 26.57$, survey $M = 27.00$; model construction tasks: route $M = 1.11$, survey $M = 0.60$).

Insert Table 4 about here

4. Discussion

[1] An anonymous reviewer rightly pointed out that age could have a relevant effect on performance, so our analyses on the differences between the three groups' performance were repeated considering age as a covariate. Age proved to have no effect, however, and the results remained substantially the same.

The present study aimed to investigate whether the absence of vision influences the ability to construct spatial mental models based on verbal survey or route descriptions. To achieve this aim, we tested how well blind and sighted people remembered information relating to spatial descriptions and represented the verbally-described environments by placing different landmarks on a wooden panel.

On the whole, our results showed that: 1) the blind participants performed significantly worse than the sighted participants, not only in the survey, but also in the route condition; 2) both groups performed worse in the route than in the survey condition; 3) the use of imagery strategies led to a better performance than text memorizing strategies: 4) the sighted and the autonomous blind participants were more likely to use imagery strategies than the non autonomous blind participants. These findings are not consistent with the results of studies (e.g. Noordzij & Postma, 2005; Noordzij et al., 2006) reporting that it is easier for blind people to create a spatial mental model when information about the environment is learned from a route perspective, i.e. when the data are processed from the bottom and, more importantly, in a sequential manner. Conversely, our blind participants' worse performance compared with sighted people in the survey condition is consistent with the results of other studies showing that blind people have more difficulty processing global, simultaneous information (Noordzij et al., 2006; Raz, Striem, Pundak, Orlov, & Zohary, 2007; Ruotolo et al., 2012; Vecchi, Tinti, & Cornoldi, 2004).

Furthermore, these results suggest some explanations about what could lie behind the blind participants' greater difficulty in this kind of spatial task. Considering the importance of the strategies used in visuospatial tasks, as confirmed in recent works (e.g. Cornoldi et al., 2009; Iachini & Ruggiero, 2010), one possible explanation could be that the difference lies not in blind people's inability to process spatial representations, but in their limited use of efficient strategies to construct and use this type of representation. Indeed, our results show that the spatial imagery strategies considered here (imagining the landmark's position in the space, imagining oneself moving in the space), despite their differences (see Iachini & Ruggiero, 2010), both give rise to a better performance than verbal strategies (memorizing the text), whatever the perspective (route versus survey) of the spatial description. Blind people's worse performance could therefore stem from their tendency to use a verbal strategy, which would be less efficient than a spatial imagery strategy for the purposes of constructing a spatial representation. This hypothesis would be consistent with the report from Ruotolo et al. (2012) that, when sighted people use the sequential strategy typically adopted by blind people, the differences in performance between the two groups disappear.

If the problem that blind people have lies in their weaker tendency to use efficient strategies for learning and using spatial representations (but not in their lacking the potential to do so), the different findings reported in the literature could stem from idiosyncratic factors influencing their acquisition of different strategies. One such factor could be their more or less adequate motor education during childhood (Loomis et al., 1993; Ochaita & Huertas, 1993), which would favor the development of strategies adaptable to the different demands relating to independent movement in space. Blind people who move unassisted could encounter conditions that require them to adopt a survey representation, such as when they come up against an obstacle that they have to detour around, or when they have to reach a place starting from a new, not usual, departure point.

Our results suggest that both mobility skills and strategy use have an important influence on the ability to process spatial descriptions, since our blind participants who were used to moving around the environment on their own fared significantly better in our experiment than those who needed a helper when they went out. Our autonomous blind participants did just as well as our sighted participants not only in the route, but also in the survey condition, and this result correlated with the strategies they reported using. In the route condition, non autonomous blind participants relied mostly on verbally memorizing the text, whereas the autonomous blind and the sighted participants used the other two strategies (imagining the spatial position of the landmarks, or imagining oneself moving in the space) in more or less equal proportions. It is noteworthy that, in the survey condition, non autonomous blind participants relied mainly on a text recall strategy, while autonomous blind participants (like the sighted participants) tended more to imagine the position of the landmarks in the space.

To conclude, in tasks involving the creation of a spatial mental model of the environment based on route or survey descriptions, sighted people do better than blind people in both conditions. These differences seem to be attributable not to the fact that being unable to see prevents the blind from using spatial descriptions, but to the adoption of a verbal rather than an imagery strategy to process the information available, which seems to correlate with the blind person's level of autonomy in their movements. This result suggests that blind people's capacity for spatial representation could be improved by developing their experience of independent movement and their inclination to use a mental imagery strategy. Our findings obviously need to be replicated with further material, in different situations, and with a larger group of non-autonomous blind participants before our conclusions can be generalized. Future studies should also clarify whether both, a good imagery strategy and good mobility skills are necessary to improve the quality of blind people's spatial representations. In particular, by studying larger groups of autonomous and not-autonomous blind individuals using different strategies, and testing the effects of training them to use spatial imagery strategies, it should be possible to examine whether spatial imagery strategies are fundamental to success in spatial tasks, as suggested here by the poor performance recorded in the handful of autonomous blind people who did not use a spatial imagery strategy.

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Table 1

Descriptive statistics for the spatial verification and model construction tasks for the two groups

Task	Condition	Blind		Sighted	
		M	*SD*	*M*	*SD*
Verification[a]					
	Route	23.12	4.95	25.24	4.00
	Survey	23.56	4.95	26.20	2.87
Model construction[b]					
	Route	1.93	1.38	1.39	1.19
	Survey	1.58	1.34	0.94	0.48

Notes.

[a] mean number of correct answers in the verification tasks (range: 0-30)

[b] mean error vectors: higher scores represent greater distances from ideal locations

Table 2

Performance according to the strategies used in the route and survey conditions

Condition	Task	Memorizing text		Imagining landmarks' position		Imagining oneself moving	
		M	*SD*	*M*	*SD*	*M*	*SD*
Route	Verification	22.73	4.54	24.36	4.39	25.00	5.02
	Model	2.65[a]	1.31	1.32[b]	0.96	1.49	1.48
Survey	Verification	19.75[a]	4.53	26.16[b]	3.18	23.00	4.69
	Model	2.58[a]	1.10	0.87[b]	0.53	2.27[a]	1.96

Note.

Means within rows with different superscripts differed significantly at p <. 05 in Bonferroni post-hoc tests.

Table 3

Strategies used by non autonomous blind, autonomous blind, and sighted participants in the route and survey conditions

Condition	Group	Memorizing text (%)	Imagining landmarks' position (%)	Imagining oneself moving (%)	Total (%)
Route	Blind NA	5 (71.4)	1 (14.3)	1 (14.3)	7 (100)
	Blind A	2 (11.1)	9 (50.0)	7 (38.9)	18 (100)
	All Blind	7 (28.0)	10 (40.0)	8 (32.0)	25 (100)
	Sighted	4 (16.0)	15 (60.0)	6 (24.0)	25 (100)
	Total Route	11 (22.0)	25 (50.0)	14 (28.0)	50 (100)
Survey	Blind NA	4 (57.1)	1 (14.3)	2 (28.6)	7 (100)
	Blind A	3 (16.7)	13 (72.2)	2 (11.1)	18 (100)
	All Blind	7 (28.0)	14 (56.0)	4 (16.0)	25 (100)
	Sighted	1 (4.0)	24 (96.0)	0 (0.0)	25 (100)
	Total Survey	8 (16.0)	38 (76.0)	4 (8.0)	50 (100)

Note.

NA: non autonomous; A: autonomous.

Table 4

Performance of non autonomous blind, autonomous blind, and sighted participants

Task	Blind NA		Blind A		Sighted	
	M	*SD*	*M*	*SD*	*M*	*SD*
Verification route	20.14	5.01	24.28	4.55	25.24	4.00
Verification survey	20.00	3.61	24.94	4.76	26.20	2.72
Model route	3.41	0.91	1.35	1.07	1.39	1.19
Model survey	3.07	0.93	0.99	0.98	0.95	0.48

Note.

NA: non autonomous; A: autonomous.

Figure captions

Figure 1. Model of the nature park.

Figure 2. Model of the tourist resort