

## **DEVELOPING SPATIAL KNOWLEDGE IN THE ABSENCE OF VISION: ALLOCENTRIC AND EGOCENTRIC REPRESENTATIONS GENERATED BY BLIND PEOPLE WHEN SUPPORTED BY AUDITORY CUES**

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The study of visuospatial representations and visuospatial memory can profit from the analysis of the performance of specific groups. In particular, the surprising skills and limitations of blind people may be an important source of information. For example, converging evidence indicates that, even though blind individuals are able to develop both egocentric and allocentric space representations, the latter tend to be much more restricted than those in blindfolded sighted individuals. However, no study has explored yet whether this conclusion also holds when people receive practice with the spatial environment and are supported by auditory stimuli. The present research examined these issues with the use of an experimental apparatus based on the Morris Water Maze (Morris et al., 1982). In this setup, blind people and blindfolded controls were given the opportunity to develop knowledge of the environment with the support of simultaneous auditory cues. The results show that even in this favourable case blind people spontaneously maintain to rely on an egocentric spatial representation.

### Introduction

While interacting with the environment people construct cognitive maps of the space in which they are situated, and the locations of the objects they perceive. The literature on spatial knowledge suggests that the construction of spatial representations involves two different kinds of mapping: allocentric and egocentric (Feigenbaum & Morris, 2004). Egocentric mapping relies upon the point of view of the person who is moving inside the environment. It is characterised by an internal frame of reference (bodily axis) and egocentric coordinates such as right, left, ahead, behind. This kind of sequential mapping is especially useful for orientation when the person each time moves from the same starting point. Allocentric mapping relies upon the spatial relations among perceptible external cues. It is characterized by an external frame of reference and may produce a sophisticated representation of the space (Thinus-Blanc & Gaunet, 1997). This more global, maplike kind of spatial representation allows people to orient themselves when starting from different positions and to generate novel paths or shortcuts.

The results of different studies suggest that vision is important for the acquisition of spatial knowledge (e.g. Eimer 2004; Byrne & Salter, 1983). In particular, several studies with blind persons have shown that although the absence of vision does not hinder the creation of spatial representations, these are mainly limited to egocentric representations (Coluccia et al., 2007; Thinus-Blanc & Gaunet, 1997), even though allocentric spatial knowledge is not completely absent in blind people (Hill et al., 1993; Millar, 1994; Morrongiello et al., 1995; Passini & Proulx, 1988; Thinus-Blanc & Gaunet, 1997; Tinti et al., 2006).

A limitation of the studies showing the reliance on egocentric information in blind people is that they were focused on the spatial abilities associated with the absence of vision, without taking into account the contribution of other factors, such as practice and the support of auditory information, which are available to the blind to the same extent as to the seeing individuals. A recent study by Overman et al. (2006) and Cornoldi et al. (2009) specifically addressed this issue by systematically interviewing blind and sighted individuals at the end of a spatial task. The authors found that the differences between the sighted and the blind people were correlated with the type of strategy used, suggesting that the spatial abilities of blind individuals should be studied in contexts where they have enough opportunity to develop the best strategy for solving the task. In this respect, multi-trial learning tasks would seem to be more adequate than single trial tasks to study the spatial abilities of blind people.

In addition, in the above studies the participants were not encouraged to develop an overall representation of the environment. In the absence of vision, space can only be experienced sequentially, by successively exploring different locations within the space. Only when participants start from different locations and are guided by sounds coming from different parts of the space, does it become interesting for them to develop a simultaneous perception of the environment. Therefore, one can wonder whether the preference of the blind for an egocentric representation would still be present when they are offered the possibility to perceive the environment in a synchronic manner and to develop stable spatial representations through a series of repeated trials.

To examine which space representations blind people create when the space is experienced through a series of trials and with the support of auditory stimuli, in the present study we created an experimental apparatus based on the Morris Water Maze (MWM). The original maze (Morris et al., 1982) was developed to study spatial strategies in animals, especially rats, and consisted of a circular swimming pool filled with murky water in which an invisible platform was situated that allowed the animal to rest. The platform is situated in a constant position relative to one or more extramaze

cues (pictures, doors, windows,...). The rat's task consists of learning, over a series of trials, the platform's location in order to be able to escape from the water. If the starting point is constant, the rat can solve the problem by means of an egocentric strategy, learning the sequence of movements necessary to reach the platform. If the starting points are different over the series of trials, the rat is forced to adopt an allocentric strategy, that is to learn the position of the platform with respect to the extramaze cues.

In the last decades, various versions of the MWM have been developed for the study of spatial knowledge in humans. Some researchers created virtual versions of the water maze (Kallai et al., 2005), others used open space versions consisting of a huge circle with a concealed target, or a pool filled with small plastic balls instead of water for the study of spatial orientation in children (Overman et al 1996).

For the present research we created a maze with auditory cues to provide frames of reference in the absence of vision and we administered a series of trials to blind and blindfolded participants to address the following questions:

- Will the performance of blind and blindfolded sighted persons differ in an allocentric task when the two groups have the possibility to repeatedly explore the environment and to simultaneously perceive external cues? Will sighted persons still be advantaged by their usual experience of simultaneous perception through vision?
- Will blind people still show a benefit in a condition that favours an egocentric strategy if they have the possibility of developing simultaneous perception based on allocentric cues?

## Method

### Participants

Twelve congenitally blind and 12 sighted adults participated in the experiment. The group of blind participants consisted of 7 males (mean age: 39.1,  $SD = 7.9$ ) and 5 females (mean age: 41.4,  $SD = 12.9$ ). The control group of sighted participants also consisted of 7 males (mean age = 35.9;  $SD = 6.8$ ) and 5 females (mean age: 34.2,  $SD = 14.3$ ). The blind participants had no residual sight and no other deficit. Their blindness was due to various aetiologies: optic nerve atrophy ( $n = 3$ ), retrolental fibroplasia ( $n = 2$ ), congenital glaucoma ( $n = 3$ ), childbirth trauma ( $n = 2$ ), congenital cataract ( $n = 1$ ), and oxygen therapy ( $n = 1$ ).

### Setting

The experiment was run in a large room containing a circular space (diameter of 4 m) delimited by a metallic net (height = 70 cm). Around the circle,

at equal angular distances ( $120^\circ$ ), three audio speakers connected to a PC made it possible to generate sounds. Inside the circle, a target consisting of an easily perceptible plastic carpet (30 cm  $\varnothing$ ) was placed.

#### Experimental design and procedure

The experiment comprised six trials in each of two conditions: egocentric and allocentric, the order of conditions being balanced across the participants. Sighted participants were blindfolded before entering the experimental room. Each participant explored the maze for some minutes in the absence of the target before the beginning of the experiment to familiarize themselves with the experimental apparatus. In each condition, participants had to find the target as quickly as possible. The target was placed at the same position across the six experimental trials.

In the egocentric condition, the starting point for the six trials was the same, located at the border of the maze (Figure 1). When the participant had found the target, the experimenter went to him/her, disorientated him/her by means of some clockwise and anticlockwise rotations on a turn chair and brought him/her back at the starting point for the next trial. During the six trials, the three audio speakers displayed the same continuous sound. Therefore participants could orient themselves only on the basis of their body coordinates.

In the allocentric condition, participants started each trial from one of three different starting points at the border of the maze (Figure 1). From the moment a trial began until the target was found, each of the three audio speakers displayed a distinct continuous sound, the three sounds being easily distinguishable and always the same. Once the target was found, the sound tracks were stopped, the participant was disorientated using the turn chair, and then conducted to another starting point for the next trial.

Learning was estimated by comparing the time necessary to find the target at the first and the sixth trial.

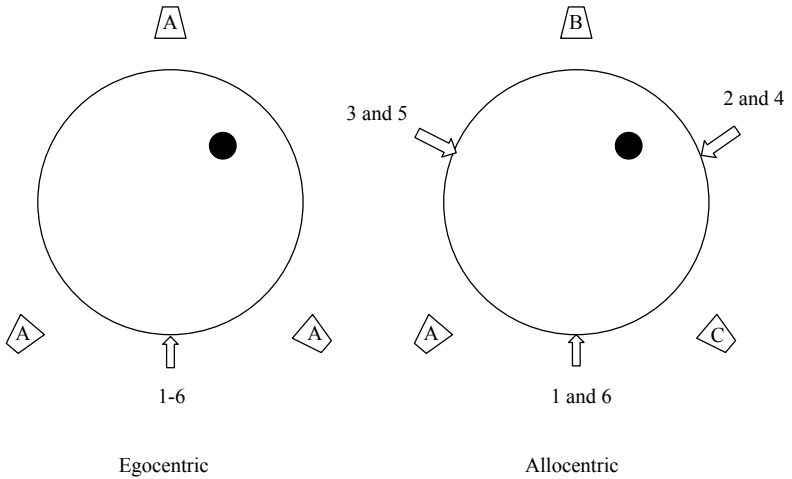


Figure 1.

*Schematic representation of the experimental setting in the egocentric and in the allocentric condition. The small black circle represents the target*

## Results

To compare the training effects of both groups with reference to the two types of cues (ego vs allo), we ran a 2 x 2 x 2 mixed ANOVA contrasting the times required for finding the target in the first and the sixth trial. The ANOVA showed that experience produced a significant improvement,  $F(1, 22) = 5.68$ ,  $MSe = 1873.56$ ,  $p = .026$ . Furthermore we found the predicted significant interaction between groups, experience and type of cues,  $F(1, 22) = 4.56$ ,  $MSe = 620.43$ ,  $p = 0.044$ . As can be seen in Table 1, the blind showed a substantial practice effect only with the egocentric cues, whereas for the controls the advantage was smaller and similar with the two types of cues.

Table 1  
*Time (in sec.) needed to reach the target in the two conditions (ego vs allo)  
 in blind and sighted participants*

Condition	Blind		Sighted	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Egocentric				
Trial 1	56.25	50.51	46.17	34.58
Trial 6	15.17	17.38	28.33	24.43
Allocentric				
Trial 1	38.08	39.48	62.83	41.53
Trial 6	35.50	40.41	40.08	47.33

## Discussion

Results from previous studies suggested that blind people prefer egocentric spatial cues (Coluccia et al., 2007; Thinus-Blanc & Gaunet, 1997) even though blindness does not make the creation of simultaneous, holistic spatial representations on the basis of allocentric cues impossible (Hill et al., 1993; Millar, 1994; Passini & Proulx, 1988; Thinus-Blanc & Gaunet, 1997; Tinti et al., 2006). This conclusion derived from studies in which the performance of blind and blindfolded sighted persons was compared in single-trial spatial orientation tasks, in which both groups had to rely on sequential spatial exploration to construct holistic representations and, therefore, had no incentive to develop an allocentric representation of the environment. Furthermore, in these studies there were no stationary cues upon which the blind could rely (as may happen in everyday life when for example the sounds of the traffic, the train and the church bells describe the arrangement of a complex spatial layout).

The present study aimed to determine what happens when both groups have the possibility to construct spatial representations by using simultaneously perceived allocentric landmarks. We created a modified version of the Morris Water Maze in which participants had to find a target using an allocentric frame of reference constituted by auditory landmarks. Moreover, the performance of the blind and the blindfolded sighted participants in this allocentric task was compared to that in a similar task requiring the participants to rely on egocentric cues.

Our results indicate that, although the task was rather difficult and showed a great variability between subjects, there was a clear practice effect in three conditions: The conditions with the egocentric and the allocentric cues in the

blindfolded participants, and the egocentric condition in the blind participants. There was no evidence for learning in the allocentric condition with the blind participants. Whereas the greatest improvement was observed in the blind egocentric condition, supporting previous observations of a preference for egocentric representation in blind people (Coluccia et al., 2007; Thinus-Blanc & Gaunet, 1997), no practice effect was observed in the blind allocentric condition, despite the fact that our new experimental setup encouraged the creation of good allocentric representations. This result suggests that the preference for egocentric representations in blind people is rather stable. Presumably the constraints produced by the absence of vision have generated a general attitude in the blind to develop egocentric representations, which is maintained also in the less frequent cases that do favor an allocentric representation.

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