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Allocentric and contra-aligned spatial representations of a town environment in blind people

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ABSTRACT

Evidence concerning the representation of space by blind individuals is still unclear, as sometimes blind people behave like sighted people do, while other times they present difficulties. A better understanding of blind people's difficulties, especially with reference to the strategies used to form the representation of the environment, may help to enhance knowledge of the consequences of the absence of vision. The present study examined the representation of the locations of landmarks of a real town by using pointing tasks that entailed either allocentric points of reference with mental rotations of different degrees, or contra-aligned representations.

Results showed that, in general, people met difficulties when they had to point from a different perspective to aligned landmarks or from the original perspective to contra-aligned landmarks, but this difficulty was particularly evident for the blind. The examination of the strategies adopted to perform the tasks showed that only a small group of blind participants used a survey strategy and that this group had a better performance with respect to people who adopted route or verbal strategies. Implications for the comprehension of the consequences on spatial cognition of the absence of visual experience are discussed, focusing in particular on conceivable interventions.

1. Introduction

The generation of spatial representations of environment is a daily and very important human activity, which enables to move efficiently in large- and small-scale environments (Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006). Representations of space, for example of a city, are important to reach different locations, to memorize the localization of different places, and to know the spatial relationships between them.

In this framework, some studies focusing on spatial representations used by people to move in a locomotion's space, distinguished between route and survey representations. In particular, route knowledge of environment is based on a serial representation of subsequent landmarks, while a survey representation entails an aerial or map-like view, also including information not obtainable from the direct experience with the environment (Brunyé & Taylor, 2008; Taylor & Tversky, 1992). The use of one rather than the other of these types of representations depends on the preferred cognitive style of the person or on external factors (e.g., survey representation is necessary when there are obstacles on the usual way that require a deviation). The route representation, in particular when moving in the space, uses the subject's body as reference and is egocentric, while the survey representation can be independent from the observer and, in this case, it can be allocentric. More in detail, allocentric representation permits an objects-to-objects type of representation, independently from the subject's position (Ekstrom, Arnold, & Iaria, 2014). Therefore, an allocentric representation can refer also to the mental image created from a different viewpoint with respect to the own real position. For instance, according to Sholl (2001), to point at object B from the position of object A, people use the allocentric system to translate the represented self in the position of object A, and to re-represent the correct location of object B (Avraamides & Kelly, 2008).

Several studies investigated these cognitive abilities (e.g., Denis & Loomis, 2007; Proulx, Todorov, Aiken, & de Sousa, 2016), and some of them also focused on the role of vision by comparing sighted and blind participants (for a review see Cattaneo et al., 2008, and Pasqualotto & Proulx, 2012). In general, results showed that blind people prefer route-like representations, while sighted individuals have the tendency to code spatial information in form of externally, survey-based representations (Millar, 1994; Noordzij, Zuidhoek, & Postma, 2006), although sometimes blind people may be successful also in survey-representation tasks (Tinti, Adenzato, Tamietto, & Cornoldi,

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2006).

The blind people's preference to use route representations could be linked to their tendency to rely on an egocentric frame of reference (Latini Corazzini, Tinti, Schmidt, Mirandola, & Cornoldi, 2010; Thinus-Blanc & Gaunet, 1997), maybe also due to the few opportunities offered to them to create survey representations. Blind people's spatial exploration is indeed mainly based on serial information, like auditory, tactile, motor and kinesthetic information (Postma, Zuidhoek, Noordzij, & Kappers, 2008). Moreover, the guidance offered to them, when accompanied by sighted people, is typically route based. This sequential exploration of space seems to have a direct link with the egocentric frame of reference (Ruotolo, Ruggiero, Vinciguerra, & Iachini, 2012). On the contrary, topographical knowledge of space, such as the survey one, is global and synchronous and generally implies an allocentric frame of reference, which is hardly accessible by a sequential exploration of space. Therefore, mainly relying on body-centered coding systems, blind individuals may have difficulties with processing allocentric spatial relations (Coluccia, Mammarella, & Cornoldi, 2009; Gaunet & Rossetti, 2006; Iachini, Ruggiero, & Ruotolo, 2014; Ruggiero, Ruotolo, & Iachini, 2009).

Indeed, in a study by Pasqualotto, Spiller, Jansari, and Proulx (2013) involving a pointing task, late blind and sighted participants showed better performance in the allocentric condition, while congenitally blind persons showed better results in the egocentric condition, suggesting that visual experience may be a requisite for the generation and the use of allocentric representations. However, there are studies which suggest that also blind individuals may solve tasks which require the adoption of an allocentric perspective (Eardley, Edwards, Malouin, & Kennedy, 2015; Ittyerah, Gaunet, & Rossetti, 2007; Ruggiero, Ruotolo, & Iachini, 2012). These contrasting results could be explained considering the different factors which may influence blind people's performance, such as their mobility skills (Fiehler, Reuschel, & Rösler, 2009; Schmidt, Tinti, Fantino, Mammarella, & Cornoldi, 2013), the strategies they use to perform the tasks (Cornoldi, Tinti, Mammarella, Re, & Varotto, 2009; Szubielska, 2014), or the difficulty of the tasks (Kozhevnikov & Hegarty, 2001).

The allocentric representation assumes high relevance especially in situations in which people have to move in locomotion spaces such as a city and are required to go beyond the routinary pathways. Moving in the streets, we change our position with respect to the one held at the moment of encoding; the localization of the buildings with respect to ourselves continuously changes, and sometimes specific landmarks shift behind our own body. In these cases, the importance of a global and allocentric spatial representation, essential to apprehend the space from different points of view decentralized from the egocentric one, appears evident. However blind people only rarely are offered the opportunity of developing this type of representation and the learning material typically used is relatively abstract (e.g., Iachini et al., 2014; Schmidt et al., 2013).

Taking into account both the importance of an allocentric representation for moving across towns and the partly contradictory results of previous research, a first aim of the present work, associated with the administration of a first task, was to explore the capacity of blind and blindfolded sighted people to form allocentric spatial representations of a city starting from the exploration of a 3D tactile map. In particular, the participants' abilities to understand the relationships between different landmarks and to form representations of the space from different points in the environment were explored, by asking them to imagine how the environment appears from different locations (e.g., "Imagine that you are in A, point to B") (Hegarty & Waller, 2004). Since the contrasting results found in previous studies could be related to the difficulty of the task (Kozhevnikov & Hegarty, 2001), more than to a general incapacity to form allocentric representations, in the present study the degree of rotation necessary to perform the task was varied (0°, 90°, 180°). We expected to find a decrease in the performance with the increase of the degrees of the mental rotation required to perform the task in both groups (Wraga, Creem, & Proffitt, 2000), but we intended to examine whether the difficulty was greater in the case of blind people also considering their reduced opportunity of developing survey representations of the environment.

However, a difficulty in the representation of the locations of a town can be present even if the person can maintain the position. In fact, moving in a city not only requires the construction of spatial representations from viewpoints different with respect to the egocentric one, but also the representation of the environment as it appears behind the person. In this case, the necessary representation is egocentric but contra-aligned (also called 'rotation condition', Rieser, 1989), i.e., a representation of a not directly perceivable space, involving the construction of correct spatial relations between landmarks opposed with respect to the orientation typically assumed, is required. Therefore, a second aim of the present study, associated with a second task, was to investigate how people represent space as it appears behind the own body. Results present in literature suggest that generally the representation aligned with the own body is more accurate than the contra-aligned representation (Borella, Meneghetti, Muffato, & De Beni, 2015; Cerles, Gomez, & Rousset, 2015; Pazzaglia & De Beni, 2006), defining the so-called "alignment effect" (Kelly, Avraamides, & Loomis, 2007; Levine, Jankovic, & Palij, 1982). Apparently, the contra-aligned task should entail a similar difficulty for both sighted and blind participants as the egocentric frame of reference can be maintained. However, it has been demonstrated that the success in the contra-aligned tasks is related with the ability to generate survey representations (Borella et al., 2015), and therefore it is possible that also in this case blind individuals meet more difficulties than the sighted ones. Just a few studies investigated blind people's ability to represent the space behind their body and results are rather contradictory. In particular, in a study in which blind and sighted participants were asked to relocate objects on a table, the two groups showed a good and comparable performance in the aligned condition, while blind participants performed worse than the sighted ones in the contra-aligned condition (Coluccia et al., 2009). On the contrary, in a study by Giudice, Betty, and Loomis (2011), blind and sighted participants showed similar performances not only in the aligned but also in the contra-aligned condition after the haptic learning of a map.

In sum, given the variability of results and the methodologies used in different studies, there is need of further evidence concerning the ability of people, and especially of people without vision, to represent the locations of landmarks from a perspective different from the assumed one. Therefore, in this study we further investigated the ability of blind and blindfolded sighted participants to form spatial representations either from a different perspective or in a contra-aligned condition, using two pointing tasks.

In addition, considering previous results about the influence of the strategy used to achieve the task (Schmidt et al., 2013), and the implications of the cognitive style observed for the alignment effect (Nori & Giusberti, 2003; Nori, Grandicelli, & Giusberti, 2006), for both tasks we tested the possible influence of the strategies used by distinguishing two spatial types of strategies (construction of a survey representation, or a route representation), and a verbal strategy based on the memorization of a verbal description of the environment. We expected a better performance in participants using a survey strategy than in the ones using a route or a verbal strategy and we examined whether a predicted poorer performance of the blind in the tasks was associated to a minor use of the survey strategy as suggested by Schmidt et al. (2013).

For the construction of a spatial representation of a town, in order to make the testing situation comfortable, concrete and plausible for the participants, we took advantage of the availability of a tridimensional realistic map representing the city center of the town of Turin (96 cm × 132 cm, 1:1000 scale), capital of the region where the participants live. The map represents buildings of the city, streets and squares in a three-dimensional way, so as to give the explorer a