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On my right or on your left?

Spontaneous spatial perspective taking in blind people

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Abstract

Spatial perspective taking is a human ability that permits to assume another person's spatial viewpoint. Data show that spatial perspective taking might arise even spontaneously by the mere presence of another person in the environment. We investigated whether this phenomenon is observable also in blind people. Blind and blindfolded sighted participants explored a tridimensional tactile map and memorized the localization of different landmarks. Then, after the presentation of sounds coming from three landmarks -positioned on the right, on the left, and in front- participants had to indicate the reciprocal position of the two lateral landmarks. Results showed that when the sound coming from the frontal landmark suggested the presence of a speaking (voice) or moving person (footsteps), several blind and sighted people adopted this person's perspective. These findings suggest that auditory stimuli can trigger spontaneous spatial perspective taking in sighted as well as in blind people.

Keywords: spatial perspective taking; blindness; spatial memory; tactile exploration; auditory stimuli.

Introduction

Since the pioneering works on mental rotation (Carpenter & Eisenberg, 1978; Marmor & Zaback, 1976), several studies support the idea that blind persons are able to construct quite accurate spatial representations (e.g., Thinus-Blanc & Gaunet, 1997) by exploiting senses other than vision (Morash, Connell Pensky, Alfaro, & McKerracher, 2012; Tinti, Adenzato, Tamietto, & Cornoldi, 2006). For example, they can construct spatial representations based on verbal descriptions of an environment (Noordzij, Zuidhoek, & Postma, 2006; Schmidt, Tinti, Fantino, Mammarella, & Cornoldi, 2013), and they can use auditory signals to facilitate self-positioning in space (Latini Corazzini, Tinti, Schmidt, Mirandola, & Cornoldi, 2010; Velten, Ugrinowitsch, Portes, Hermann, & Bläsing, 2016). Blind people can obtain spatial information also through touch, for example by exploring tactile maps (Espinosa & Ochaita, 1998) or matrices (Vanlierde & Wanet-Defalque, 2004; Vecchi, Tinti, & Cornoldi, 2004), to memorize the localization of different targets. Finally, they are able to acquire spatial information by directly moving in the environment (Tinti et al., 2006).

These capacities of blind people to generate spatial representations in absence of vision could be explained by the hypothesis of the existence of a supramodal spatial representation system (Barsalou, 1999; Bonino et al., 2015; Cattaneo & Vecchi, 2011; Pietrini et al., 2004; Struiksma, Noordzij, & Postma, 2009; Struiksma, Noordzij, Neggers, Bosker, & Postma, 2011), which exceeds modality-specific spatial information and activates both modality specific brain regions and other supramodal areas devoted to the processing of spatial representations.

However, although vision is not the unique source for spatial representation formation, its absence could cause lacks in some specific domains. For instance, several studies (e.g. Chiesa, Schmidt, Tinti & Cornoldi, 2017; Coluccia, Mammarella, & Cornoldi, 2009; Pasqualotto, Spiller, Jansari, & Proulx, 2013; Postma, Zuidhoek, Noordzij, & Kappers, 2008; Ruggiero, Ruotolo, & Iachini, 2009) evidenced that blind people are less accurate than sighted people when constructing allocentric (i.e., object-to-object) representations, whereas comparable accuracy can be observed for the egocentric (i.e., self-to-object) ones. In particular, studies that asked participants to create a representation of the space from different points of view, showed a general worse performance in blind than in sighted participants (e.g., Pasqualotto & Newell, 2007). In addition, Fortin and colleagues (2006) showed that in a tactile spatial orientation task, the early blind were able to create a good representation of the space, but their ability decreased more than that of sighted and late blind people when the task required mental rotation skills. Moreover, studies investigating route- and survey-based representations found that blind individuals had more difficulties to code spatial information using the second form of representations (Millar, 1994; Noordzij et al., 2006). Finally, studies on the spatial memory ability in blind people suggest that they encounter difficulties when the spatial task requires to maintain several elements simultaneously (Cornoldi, Bertuccelli, Rocchi, & Sbrana, 1993; Vecchi, Tinti, & Cornoldi, 2004). In order to investigate more in depth blind people's spatial knowledge, we focused on a particular type of non-egocentric representation, i.e. spontaneous Spatial Perspective Taking (SPT). Broadly speaking, perspective taking indicates the human capacity to adopt the point of view of another person in terms of his/her beliefs, desires or intentions (mental perspective taking), or in terms of how another person perceives the space (SPT) (Ferguson, Apperly, Ahmad, Bindemann, & Cane, 2015). In more detail, SPT is a form of spatial representation consisting in the adoption of another person's perspective judging/describing what is perceived from his/her position (Frith & Frith, 2010; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010).

Interestingly, SPT can be activated also spontaneously by the mere presence of another person (Duran, Dale, & Kreuz, 2011), and this phenomenon is common in many daily and social activities (e.g., Duran et al., 2011; Shelton, Clements-Stephens, Lam, Pak, & Murray, 2012). Moreover, the perception of the other's action or potential action seems to further enhance spontaneous SPT (Lozano, Hard, & Tversky, 2008; Mazzarella, Hamilton, Trojano, Mastromauro, & Conson, 2012; Tversky & Hard, 2009), evidence which could find an explanation in the embodied cognition theory (Barsalou, 2008; Wilson, 2002) and which sustains the hypothesis that spontaneous SPT has a fundamental role in the social context (Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013) where it allows to highly social species to anticipate the others' behavior (Frith & Frith, 2010).

SPT has been examined in different clinical populations as, for instance, autism (Pearson, Ropar, & Hamilton, 2013), and left neglect (Becchio, Del Giudice, Dal Monte, Latini Corazzini, & Pia, 2013), while, to our knowledge, only Koustriava and Papadopoulos (2012) investigated SPT in blind people, and spontaneous SPT has never been studied in this population.

The main aim of this study was to investigate spontaneous SPT in blind and in blindfolded sighted people by using an auditory-based paradigm. In fact, humans can perceive the presence and the spatial location of other persons not only by relying on vision but also by relying on other sensorial modalities. In particular, hearing other people's voice and/or movement could permit to understand their localization in the environment and the direction of their movement (Kohler et al., 2002). Hence one might wonder whether spontaneous SPT might be activated also by specific auditory inputs, like the voice of another person, and whether the auditory perception of another's movement might even enhance this effect.

To answer these questions, we examined spontaneous SPT in blind and blindfolded sighted people modifying a paradigm proposed by Tversky and Hard (2009) and using auditory rather than visual stimuli. In the study of Tversky and Hard (2009) participants were presented with three different pictures: the first showed two objects on a table with no person present (no person scene); the second showed a person looking at one of the two objects placed on a table (looking scene); and the third showed a person reaching out to one of two objects on a table (movement scene). When researchers asked participants where one of the two objects was located with respect to the other one, most participants used their own perspective in the 'no person' condition, while the tendency to adopt the perspective of another person emerged when a person was present in the scene, and this same tendency was particularly pronounced when the picture presented a person moving towards one of the objects.

By adapting the Tversky and Hard (2009) paradigm, in our study, blind and blindfolded participants had to explore a tactile map with different landmarks and then had to indicate the relative positions of two landmarks in three conditions: no person present in the scene, presence of a static speaking person, and presence of a person who is moving towards one of the two landmarks. The positions of the landmarks and the person were signaled by different sounds as will be specified more in detail below (see Procedure section).

We predicted that the presence of another person captured through auditory inputs could trigger spontaneous SPT in blind and blindfolded sighted participants. Additionally, according to the fact that the perception of an acting person enhances the phenomenon (Tversky & Hard, 2009), we hypothesized that the presence of a moving person would further facilitate spontaneous SPT. Finally, given the blind people's difficulties in processing allocentric representations, we expected to observe a lower presence of spontaneous SPT in the blind than in the sighted participants.

Method

Participants

The study involved 30 participants, divided in two groups. The first included 15 early and totally blind adults (8 women) recruited with the help of the Turin UICI (Unione Italiana Ciechi e Ipovedenti). We considered people to be totally blind when they were not able to perceive objects' shapes and positions, and early blind when the visual deficit was present at birth or appeared in the first three years of life (Thinus-Blanc & Gaunet, 1997). Fourteen blind participants had been blind since birth and one became blind at the age of two years. Their blindness was due to various aetiologies: optic nerve damage (6 participants), retrolental fibroplasia (3), trauma (2), congenital glaucoma (2), and oxygen therapy (2). The participants' age ranged from 27 to 68 years (*M* = 49.9, *SD* = 13.9). They presented no other sensory, physical or cognitive deficits.

We also tested a group of 15 blindfolded sighted participants matched for gender (8 women), age (*M* = 49.7, *SD* = 13.4), and highest level of education (*n* = 3: junior high school, *n* = 8: high school, *n* = 4: university degree).

Materials

A tridimensional tactile map of the inner city of Turin (Italy) was used (96cm x 132cm, scale l:1000). The map represents in a realistic way buildings, streets, squares, and monuments of the city center (Figure 1).

---Figure 1 about here---

Procedure

Participants were examined individually in a quiet room and sighted ones were blindfolded before entering the room. The procedure entailed 6 phases (see a schema of the procedure in the supplementary material). First participants were guided through a predetermined itinerary of the tactile map and they explored the streets, houses and monuments being part of the itinerary. During this exploration, the experimenter pointed out 16 landmarks, such as the train station Porta Nuova, the Mole Antonelliana and the bell tower of the Cathedral (Figure 2).

---Figure 2 about here---

Once participants completed the exploration phase, the following three sounds were presented: (a) a ringing bell originating from the bell tower of the Cathedral (positioned on the participants' left) introduced by the experimenter as follows: "Here is the bell tower of the Cathedral"; (b) the sound of a train whistle originating from the train station (positioned on the participants' right) introduced as follows: "Here is the train station Porta Nuova"; and (c) the sound theme of a famous film production company originating from the Mole Antonelliana (positioned in front of the participants), accompanied by the following sentence: "Here is the Mole Antonelliana, location of the Film Museum". After the presentation of these three sounds, the experimenter asked participants to answer as quickly as possible the following question: "In relation to the Cathedral, where is the train station Porta Nuova?" (First condition: No person). Participants had to answer by choosing between "right" or "left".

Afterwards, for 15 minutes, participants had to answer distracting questions about the localization of other buildings without hearing any sound. Then, the experimenter informed participants that they will hear the voice of a person at a specific landmark. The experimenter anticipated the sound and said: "A person is at the exit of the Mole Antonelliana and comments the visit at the Film Museum by exclaiming…", and participants heard: "Che bello!" which means 'How beautiful!' (Second condition: Voice of a static person). Following this exclamation, participants were again asked to indicate the localization of Porta Nuova with respect to the Cathedral.

Then, the experimenter again asked unrelated questions about the landmarks explored, and, about 15 minutes later, he said: “Now you will hear the steps of a person who leaves the Mole Antonelliana and moves towards the train station Porta Nuova”. After having heard the footsteps (Third condition: Moving person), participants had to indicate the localization of Porta Nuova in relation to the Cathedral once again.

The whole experiment lasted about 50 minutes. The second and third conditions were presented in counterbalanced order. Half of the participants heard first the voice of a static person and then the footsteps of a moving person, half of them heard the same sounds in the opposite order.

Since the Mole Antonelliana is located in front of the participants (Figure 2), we assumed the adoption of spontaneous SPT if they answered “left” to the question asked in the second and third condition, and the use of an egocentric representation when they responded “right”. The answers given in the first condition with no person in the scene, served as a control condition.

Results

Scored answers were converted in a binary variable: if the participant’s answer reflected an egocentric representation, the variable was coded 0, if it reflected the perspective of the other person present in the scene, the variable was coded 1. Data were analyzed by using SPSS version 24.

The percentages of answers reflecting spontaneous SPT and the ones reflecting the maintenance of the own perspective are reported in Figure 3. As predicted, when no person was present in the scene, most of the sighted (93.3%, n = 14) as well as the blind (86.7%, n =

13) participants maintained the egocentric perspective. About a quarter of the sighted participants (26.7%, $n = 4$) shifted perspective after hearing the voice of a static person, and more than half of the blind persons (53.3%, $n = 8$) did the same. A majority of the sighted (66.7%, $n = 10$) and one third of the blind (33.3%, $n = 5$) participants adopted the perspective of the moving person after hearing his/her footsteps.

---- Insert Figure 3 about here ----

To assess the statistical significance of the possible effects of condition and the possible differences between the two groups, GEEs (Generalized Estimating Equations) were computed on the binary variable indicating the presence or absence of spontaneous SPT. It is worth noticing that GEE models allow to analyze correlated data, particularly binary ones (Hanley, Negassa, Edwardes, & Forrester, 2003). In a first GEE analysis we computed a model with a logit link function and a binomial distribution by considering the presence of spontaneous SPT as dependent variable and by defining Group (blind vs sighted) as between-subject factor and Condition (no person, voice, movement) as within-subject factor. Cohen's *ds* are reported to indicate the effect sizes.

Results showed no effect of group, $X^2(1, N = 90) = 0.66$, $p = .797$, whereas an effect of condition, $X^2(2, N = 90) = 13.14$, $p < .01$, $d = 0.83$, and an interaction group by condition, $X^2(2, N = 90) = 6.75$, $p < .05$, $d = 0.57$, were observed.

To analyze these significant effects more in depth, three further GEEs were computed. First, by considering the overall sample, the three conditions were compared by setting the 'no person' condition as reference category. As shown in Table 1, participants adopted SPT more frequently in the voice, Exp$(B) = 6.0$, $p < .01$, $d = 0.99$, and in the movement, Exp$(B) = 9.0$, $p < .001$, $d = 1.21$, conditions, than in the no person condition.

To analyze the interaction group by condition more in depth, two separate GEEs were computed, the first by considering only the blind, the second by considering only the sighted participants. Results showed that blind participants manifested spontaneous SPT more in the voice, Exp*(B)* = 7.43, $p < .05$, $d = 1.11$, than in the no person condition, no significant difference being observed between the movement and the no person condition (Table 1).

Sighted participants for their part, showed spontaneous SPT more in the movement, Exp*(B)* = 28.00, $p < .01$, $d = 1.84$, than in the no person condition, no significant difference being observed between the voice and the no person condition (Table 1).

Table 1. Differences between conditions

Participants	Condition	Regression coefficient (SE)	Exp*(B)*	*p*	95% P.I.	
					Lower limit	Upper limit
All participants						
	No person	0	1	-	-	-
	Voice	1.79 (.65)	6.00	.006	1.67	21.59
	Movement	2.20 (.60)	9.00	.001	2.80	28.96
Blind						
	No person	0	1	-	-	-
	Voice	2.01 (.93)	7.43	.031	1.20	46.00
	Movement	1.18 (.64)	3.25	.067	0.92	11.49
Sighted						
	No person	0	1	-	-	-
	Voice	1.63 (.94)	5.10	.082	.81	31.90
	Movement	3.33 (1.1)	28	.002	3.40	230.57

Conclusion

This study aimed to investigate whether spontaneous SPT can be observed when the environment is perceived by auditory inputs, whether it can also be observed in blind people, and whether the auditory perception of the other's movement, compared to the perception of his/her mere presence, can further enhance spontaneous SPT. By adapting a task developed by Tversky and Hard (2009), in our study, blind and blindfolded participants had to explore a tactile map with different landmarks and then had to indicate the relative positions of two landmarks in three conditions created by the use of auditory stimuli: no person present in the scene, presence of a static person perceived by a voice, and presence of a moving person, perceived by footsteps.

Results showed that the mere presence of a person, who perceives the environment from a frontal viewpoint with respect to the observer, or moves from a specific place to another from a frontal position, induced numerous participants, both sighted and blind, to take this person's perspective. Specifically, when the sound coming from the frontal landmark suggested the presence of a speaking or moving person, several blind (voice: 53.3%, movement: 33.3%) and sighted (voice: 26.7%, movement: 66.7%) participants adopted this person's perspective when asked to indicate the reciprocal position of two lateral landmarks. In addition, in the voice condition spontaneous SPT was adopted more by the blind than the sighted participants, while in the movement condition the reverse was true, an interesting interaction that will be commented in more detail below.

Overall, these findings suggest that the perception of the presence of another person through senses different than sight, in this case audition, can spontaneously induce SPT, and that also blind people spontaneously adopt the viewpoint of another person, as sighted participants do. In addition, these findings sustain the hypothesis that "[…] spatial imagery exceeds the input from different input modalities to form an abstract mental representation

[…].” (Struiksma et al., 2009, p. 145), i.e., the hypothesis of the existence of a supramodal spatial representation system that can be activated also in the absence of vision.

In more detail, integrating the supramodal spatial imagery hypothesis (Struiksma et al., 2009) with the embodied cognition theory (Barsalou, 2008; Wilson, 2002), the results obtained in the movement condition could be explained by hypothesizing that the noise of the footsteps could have enhanced the formation of an image of the moving other in the supramodal spatial representation system. In parallel, according to the embodied cognition theory, the perception of another’s movement, and especially when this movement evokes an intention towards an object, activates the observer’s motor representation system (Buccino et al., 2001; Kohler et al., 2002). This phenomenon, also known as “motor resonance” (Zwaan & Taylor, 2006), relies on the activation of mirror neurons (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996) that simulate the movement and, simultaneously, could enhance the tendency to “view” the target from the perspective of the acting other.

To sum up, the finding that in the movement condition both the blindfolded sighted as well as the blind participants manifested spontaneous SPT more frequently than in the no person condition, sustains the supramodal spatial imagery model (Struiksma et al.,2009) and confirms data showing that the mirror system is not only dependent from vision (Kohler et al., 2002). Nevertheless, the observation that we found a higher percentage of spontaneous SPT in the sighted compared to the blind participants in the movement condition, suggests that the above mentioned “motor resonance” mechanism is probably more easily activated by visual images of the moving other. In particular, with respect to our experiment, we could hypothesize that in the sighted, the noise of the footsteps could have created both an auditory as well as a visual image of the moving other, thus strengthening the motor resonance mechanism and enhancing the spontaneous SPT, while we speculate that in the blind the noise of the footsteps only created an auditory image of the moving other. This explanation would be coherent with the hypothesis of Struiksma et al. (2009), that the supramodal spatial image of blind people might be different from that of sighted people since the visual image is lacking and some other sensory images, especially the auditory and tactile ones, might have higher weights. In particular, in the movement condition of our experiment, the image of the moving other formed through auditory inputs could have had more weight in the blind compared to the sighted participants, but not enough to even out the effects of the sum of the visual and auditory images - probably present in the sighted participants - on the motor resonance mechanism and, thus, on spontaneous SPT.

The hypothesis of different weights of various sensory inputs in blind and sighted people in the supramodal spatial representation system, could also explain the finding that we observed more spontaneous SPT in blind than in sighted people in the voice condition. Actually, in this case it is plausible to assume that the auditory image related to the voice stimuli could have had a higher weight in the creation of a supramodal spatial image in the blind than in the sighted participants. In fact, voice is not only the blind people's principal communication channel but also their principal mode of perception of the others in the environment (Chen, Zhang, & Zhou, 2006; Velten et al., 2016). In addition, the adoption of spontaneous SPT in this condition could have been enhanced by hearing the other exclaiming "Che bello!" (How beautiful!), which suggests that the person in front just lived a positive experience. We speculate that the emotional valence of the exclamation could have fostered also an empathic perspective taking (Erle & Topolinski, 2015). This explanation would be consistent with studies around the mechanisms of communicative interaction and empathy in blind people. Klinge, Röder, and Büchel (2010), for instance, found that blind compared to sighted people, have a higher amygdala response to emotional auditory stimuli and that voices are their privileged channel to understand others' feelings.

In summary, our results suggest that blind people are able to take spontaneously another person's viewpoint, such as sighted participants do. The total percentage of spontaneous SPT observed in the two groups is comparable, so visual experience seems not necessary for this ability. These data suggest that the perception of a person in the scene is an effective and appropriate condition to induce people to modify their mental spatial representation and to take the perspective of this person, independently from the sensory modality that captures his/her presence. Given the importance of the complex cognitive processes implied in spontaneous SPT, this is a very relevant finding. In fact, spontaneous SPT enhances social interactions, facilitates communication and the comprehension of what another person is telling us, as well as the prediction of his/her actions and intents (Frith & Frith, 2010). An unexpected, interesting finding, which opens the way for future research, is that spontaneous SPT seems to be influenced by the interaction between the different characteristics of the stimulus, in this case an emotionally loaded vocal expression vs the footsteps of another person, and the different characteristics of the participants, in this case blind vs sighted.

In future research it would be worthwhile to address some of the limitations of the present study. A first limitation regards the rather small sample size, although the exiguous number of participants is mainly due to the difficulty to recruit a large group of early and totally blind people. Another possible limitation of this study could be that in the voice condition we used an emotional exclamation. In further studies it would be interesting to propose emotional as well as neutral sentences to analyze more in depth the possible effects of the empathetic SPT. Finally, another variable worth of investigation in future studies is the material employed for the encoding of spatial information. In this study, we used a complex tactile map. Future studies should investigate whether the same results as the one obtained in the present study can be observed also with more simple tactile maps or, more in general, with tasks that do not require the previous learning of complex spatial environmental configurations (e.g., Koustriava & Papadopoulos, 2012).

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Figure 1. Detail of the map.

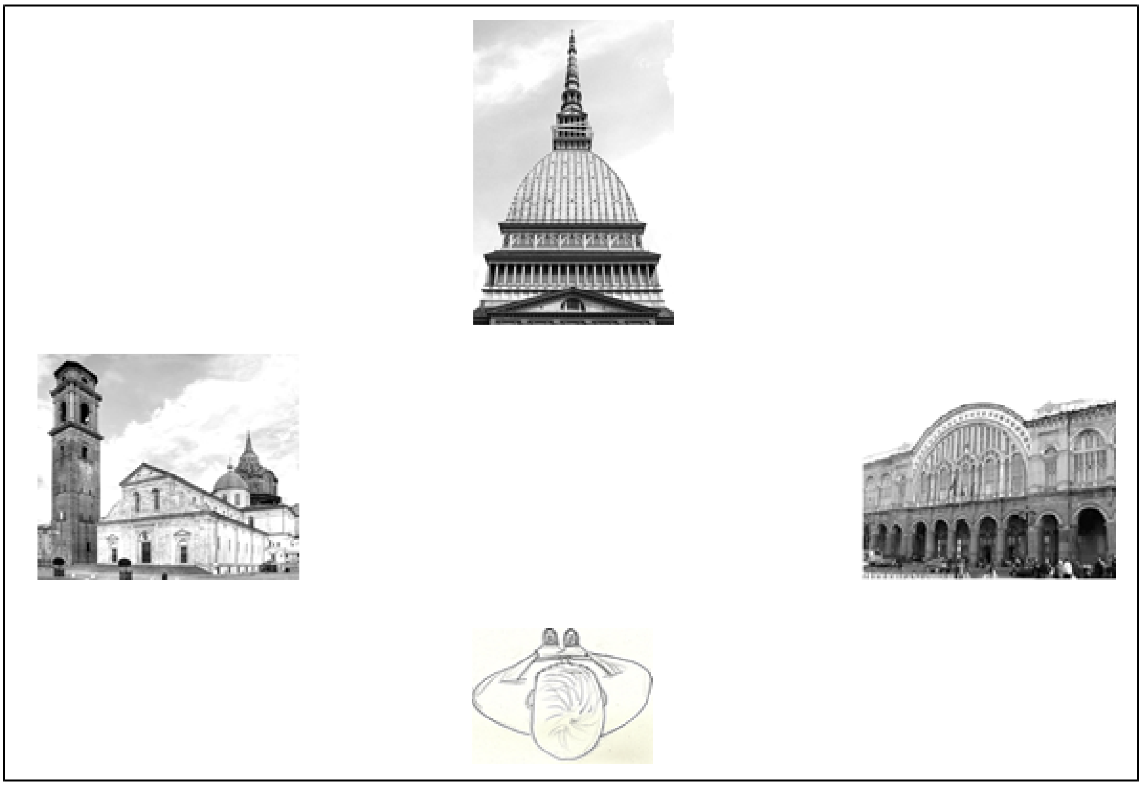

Figure 2. Position of the participant and the three landmarks.

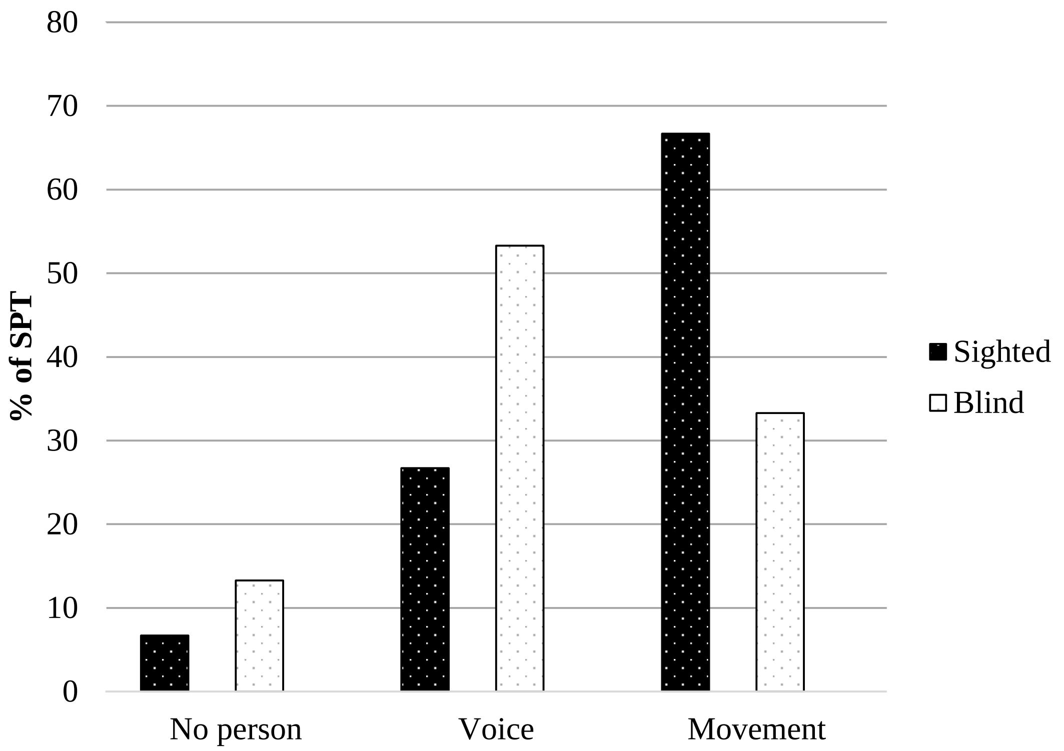

Figure 3. Percentages of spontaneous SPT in sighted and blind participants in the three conditions.

Supplementary Material

Scheme of the procedure.

Phases	Duration	Description
Phase 1	15’	Exploration of the tactile map.
Phase 2	3’	No person condition: - sounds of three landmarks: ringing bell of the Cathedral, sound of a train whistle at the station Porta Nuova, sound theme of a film company at the Mole Antonelliana Question: “In relation to the Cathedral, where is the train station of Porta Nuova?”
Phase 3	15’	Unrelated questions
Phase 4	1’	Voice condition: - exclamation “Che bello!” originating from the Mole Antonelliana Question: “In relation to the Cathedral, where is the train station of Porta Nuova?”
Phase 5	15’	Unrelated questions
Phase 6	2’	Movement condition: - sound of the steps of a person moving from the Mole Antonelliana towards the train station Porta Nuova. Question: “In relation to the Cathedral, where is the train station of Porta Nuova?”

Note. Phase 4 and phase 6 were counterbalanced among participants.