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In your place: neuropsychological evidence for altercentric remapping in embodied perspective taking

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Humans are able to mentally adopt the spatial perspective of others and represent the visual world from their point of view. Here, we present neuropsychological evidence that information inaccessible from an egocentric perspective can be accessed from the perspective of another person. Patients affected by left neglect were asked to describe arrays of objects from their own egocentric perspective, from an opposite perspective (disembodied perspective taking), and from the point of view of another person actually seated in front of them (embodied perspective taking). Although disembodied perspective-taking ameliorated neglect severity, there was an even stronger positive effect of embodied perspective-taking: items presented on the left and neglected when reported from the egocentric perspective were instead recovered when patients assumed the perspective of the other. These findings suggest that perspective-taking entails an altercentric remapping of space, i.e. remapping of objects and locations coded with reference to the other person's body.

Keywords: perspective taking; unilateral neglect; space representation; social space; altercentric remapping

INTRODUCTION

Spatial perspective-taking is essentially bound to the presence of others. Although mental transformations required for taking a different point of view can be performed in absence of other persons (e.g. imagining what one would see if he/she was seated on the opposite side of the table), it is uncommon for people to take a different spatial perspective when alone. However, when the scene includes others, people may spontaneously take their perspective and judge/describe what they perceive from their position in space (Mainwaring *et al.*, 2003; Tversky and Hard, 2009; Frith and Frith, 2010; Samson *et al.*, 2010). When a person asks to another where an object is located, for instance, people typically favor the other's perspective over their own and tend to answer from his/her viewpoint (e.g. 'on your left') (Mainwaring *et al.*, 2003). Even in absence of communication, the mere presence of another person in the position to act on the objects has been shown to induce a good proportion of respondents to describe spatial relations from that person's point of view (Tversky and Hard, 2009).

These results show that people can overcome their own position in space in presence of others. But do people actually disengage from an egocentric frame of reference when they represent the scene from the perspective of another person? In an egocentric frame of reference, objects and locations are encoded with respect to one's own body (Klatzky, 1998; Halligan *et al.*, 2003; Vogeley and Fink, 2003). Does taking the perspective of another person entail an altercentric remapping of space, i.e. a remapping of objects and locations with reference to the other person's body (Braten, 2007). We explored this possibility in a group of patients affected by left neglect, namely a failure in attending and reporting stimuli on the left side of the perceived and/or internally generated egocentric space (Bartolomeo *et al.*, 2007). We reasoned that, if distinct neural representations underlie egocentric and altercentric space coding, then neglect of left egocentric space might occur without neglect of left altercentric space. As a result, taking a third-person perspective (i.e. the perspective of another person) might allow patients with neglect to represent stimuli inaccessible from a first-person perspective.

Evidence that the performance of neglect patients may be influenced by perspective was first provided by Bisiach and Luzzati (Bisiach and Luzzatti, 1978). These authors reported on two patients who failed to mention left-sided details of familiar surroundings from memory. Critically, left-sided

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details omitted when patients imagined facing the scene from a particular vantage point could be retrieved from memory when they imagined themselves assuming the opposite vantage point. A similar effect was demonstrated by Della Sala and colleagues (Della Sala *et al.*, 2004; Logie *et al.*, 2005) for novel visual arrays of objects. Left omitted items in a first-person perspective could be recalled assuming the opposite perspective. In these studies, neglect patients were required to imagine the scene from a different egocentric point, i.e. as if they were occupying a different position in space.

The aim of this study was to investigate how patients with neglect would represent a spatial scene from the perspective of another person. Since visual and representational neglect are double dissociated (Bartolomeo *et al.*, 1994), we investigated the effects of spatial perspective taking at both perceptual and imaginative level. In the perceptual condition, patients were presented with an array of objects placed on a table in front of them. They were asked to describe the scene from their own perspective (first-person perspective, 1PP), if sitting at the opposite side of the table (third-person disembodied perspective, 3PPD), and as seen by another person actually sitting at the opposite side of the table (third-person embodied perspective, 3PPE). In the imaginative condition, patients were requested to perform the same task after the array had been removed from view. We predicted that items omitted when report was required from ea first-person perspective, would be recovered when the scene was represented from the perspective of another person. Furthermore, because disengagement from an egocentric frame of reference might be easier in presence of another person, we predicted that the effect of perspective taking should be more pronounced for embodied perspective taking (3PPE) compared to disembodied perspective taking (3PPD).

MATERIALS AND METHODS

Participants

Sixteen right-handed patients (eight with neglect N+ and eight without neglect N−) with right-hemisphere damage participated in the study, after giving written informed consent according to the Declaration of Helsinki. The experiment was approved by the local ethical committee. Age and educational level did not differ between the two groups [age: $t(14) = -0.076$, $P = 0.940$; education: $t(14) = -0.118$, $P = 0.908$]. The presence of a single right-hemisphere lesion was confirmed by CT or MRI scans. Patients were initially screened with the Mini Mental State Examination (Measso *et al.* 1993) to exclude the presence of diffuse cognitive impairment (cut-off score = 20). Hemispatial neglect was assessed with the Behavioral Inattention Test (BIT) battery; scores on the Conventional (BIT-C) and Behavioral (BIT-B) scales were averaged to form a single score (range: 0–114). The criteria for inclusion in the N+ group were (i) a BIT score below a cutoff of 97 and (ii) a positive asymmetry score for the 1PP (see below). Demographic and clinical data are reported in Table 1.

Apparatus and procedure

Thirty-six daily life objects belonging to six different categories (i.e. desktop, kitchen, bathroom items, personal

Table 1 Patients' demographic and clinical data

Patient	Group	Age	Sex	Education (years)	Illness onset (months)	Lesion site	MMSE	BIT	Asymmetry (1PP)	
									Perceptual condition	Imaginative condition
1	N+	67	M	5	16	F, P, Wm, Bg, Ic,	24.4	12.5	+	+
2	N+	71	M	8	9	F,T,P, Wm, I	24.4	36	−	+
3	N+	56	F	13	13	T, P, Wm	26	9	+	−
4	N+	82	F	5	3	T, P, F, Wm	25	93	+	−
5	N+	70	F	18	3	Th, Wm	25.7	96	+	+
6	N+	57	M	11	2	P, Wm	27	87.5	+	+
7	N+	74	F	5	4	F, T, P, Wm	28.03	96.5	−	+
8	N+	74	F	8	16	T, P, Wm	26.4	52	−	+
9	N−	77	M	5	4	T, Wm	25	113	−	−
10	N−	51	M	8	3	Bg	27	113.5	−	−
11	N−	70	F	8	4	Ic	28.4	113.5	−	−
12	N−	61	M	8	2	Ln	24.2	112	−	−
13	N−	80	M	8	2	F, Wm	24.7	111	−	−
14	N−	79	F	8	3	Pons	26	108.5	−	−
15	N−	44	M	13	2	Ic, Th	26.2	106.5	−	−
16	N−	93	M	17	5	Bg	23.3	108.5	−	−

Lesion: F, frontal; O, occipital; T, temporal; P, Parietal; Bg, basal ganglia; Ic, Internal capsule; Ln, Lenticular nucleus; Th, Thalamus; Wm, White matter; P, Pons; I, Insula; MMSE, corrected score at the Mini Mental State Examination (cutoff = 24); BIT (average of the Conventional and Behavioral scales; cutoff = 97); Asymmetry (1PP), the '+' sign indicates a positive asymmetry score in the first-person perspective (i.e. the number of omissions on the left-side was larger than the number of omissions on the right-side).

objects, fruit and vegetables; see Supplementary Table S1) were employed.

Participants sat in front of a table desk (70 × 80 cm) centered on their sagittal midline. An empty office chair ($h = 90$ cm; $w = 58$ cm) was placed on the opposite side of the table, in front of the participant. The experimenter, seated on the ipsilesional (healthy) side, delivered to the participant the six objects belonging to one category, one at a time. He/she was asked to name each object and briefly describe its use. After that, the object was randomly placed on the desk in one out of six preset locations (three rows by two columns on each side respect to the midline) within a 50 × 60 cm array. This procedure was repeated for each object from the given category so that six objects were displayed on the table desk. Participants were asked to report the objects in each row by means of three different questions: 'What objects are in front?', 'What objects are in the middle?' and 'What objects are on the back?' For each object set, the report was required from three different perspectives: the participant's own perspective (1PP), the opposite perspective (3PPD) and the perspective of a co-experimenter seated in front of the participant (3PPE). The co-experimenter was only seating at the table when 3PPE questions were being asked. In the perceptual condition, the objects remained on the table when participants were asked to give their report. In the imaginative condition, objects were removed after 90 s, and participants answered the questions from memory.

For each condition (perceptual and imaginative), participants provided nine reports: three 1PP reports, three 3PPD reports and three 3PPE reports. Half of the participants performed the perceptual condition first and half performed the imaginative condition first. The order of the questions (front, middle, back) as well as the order of perspectives (1PP, 3PPD, 3PPD) was randomized across participants.

As an index of neglect severity, we calculated an asymmetry score for each of the three perspective conditions, by subtracting the number of omissions (i.e. unreported objects) on the right-side from the number of omissions on the left-side and dividing the result by the number of trials. Position errors (i.e. the object was reported as being placed in a different row; less than one object per participant) were not treated as omissions. Five N+ patients out eight (#1, #3, #4, #5 and #6) were included in the analysis for the perceptual condition, whereas six N+ out of eight (#1, #2, #5, #6, #7 and #8) were included in the analysis for the imaginative condition. To control for task difficulty and effects related to the report of specific objects, eight N− patients with a bit score below the cutoff and no positive asymmetry scores for 1PP were tested in both conditions.

RESULTS

Effect of perspective on the perception of a visual scene

Figure 1a shows the percentage of left-and right-sided omissions for the different perspectives. A repeated-measures analyses of variance (ANOVA) on asymmetry scores with perspective (1PP, 3PPD, 3PPE) as the within-subjects factor yielded a significant linear effect of perspective [$F(1,4) = 12.480$, $P = 0.024$]. Repeated measures tests maximize power for small *N*s, such as in the present sample. The sphericity assumption was satisfied ($P = 0.777$). Asymmetry scores were highest in the first-person perspective (1PP; $M = 0.67$), lower in the third-person disembodied perspective (3PPD; $M = 0.47$) and lowest in the third-person embodied perspective (3PPE; $M = 0.00$). In order to exclude that the aforementioned effect was simply driven by a linear increase of right-sided omissions rather than to a decrease of left-sided omissions, we performed two separate ANOVA on omissions from each side (left and right) with perspective as

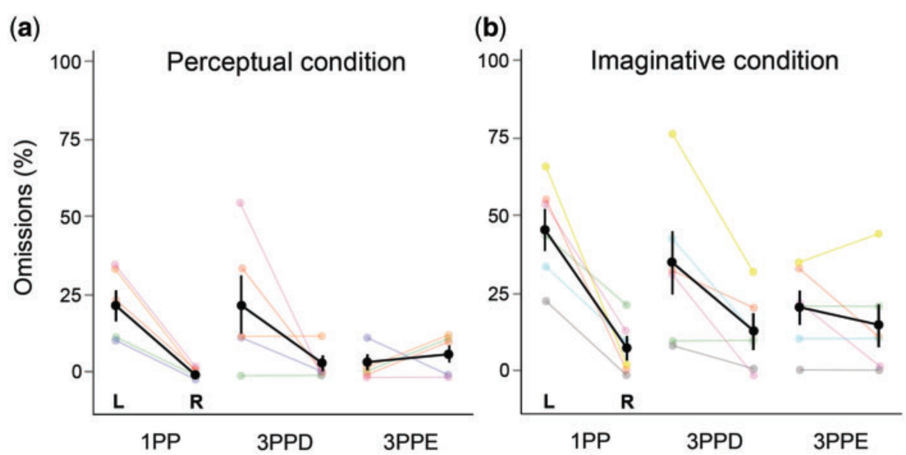

Fig. 1 Percentage of left- and right-side omissions in the perceptual (**a**) and imaginative (**b**) condition in left-neglect patients. Black circles and error bars represent group means and standard errors; the performance of individual patients is shown by colored circles (vertical jitter added to avoid overlap).

the within-subject factor. The ANOVA on left-side omissions yielded a significant effect of perspective [$F(1,4) = 9.529$, $P = 0.037$]. For right-side omissions; however, the effect of perspective did not reach statistical significance [$F(1,4) = 6.0$, $P = 0.070$]. Patients in the N− group performed at ceiling (0% omissions for 1PP, 3PPD and 3PPE).

Effect of perspective on the imagination of a visual scene

Figure 1b shows the percentage of left- and right-sided omissions for the different perspectives. A repeated-measures ANOVA with perspective (1PP, 3PPD, 3PPE) as the within-subjects factor yielded a significant linear effect of perspective [$F(1,5) = 13.567$, $P = 0.014$]. The sphericity assumption was satisfied ($P = 0.622$). As in the perceptual condition, asymmetry scores were highest in the first-person perspective ($M = 1.17$), lower in the third-person disembodied perspective ($M = 0.67$) and lowest in the third-person embodied perspective ($M = 0.17$). The ANOVA on left side omissions revealed a significant effect of perspective [$F(1,5) = 122.500$, $P < 0.001$]. No difference was found between right-sided omissions for the different perspectives [$F(1,5) = 0.870$, $P = 0.394$]. In the control group (N−), no difference was found between asymmetry scores in the first-person ($M = -0.17$), the third-person disembodied ($M = -0.04$) or third-person embodied perspective ($M = -0.07$) [$F(1,7) = 0.657$, $P = 0.444$].

DISCUSSION

As members of a highly social species, humans are skilled in the perception and representation of their conspecifics. This encompasses taking other people's perspective to judge what they perceive from their position in space (Tversky and Hard, 2009; Frith and Frith, 2010). In the present study, we examined the effects of perspective-taking in patients affected by left neglect. Results demonstrate that perspective taking significantly ameliorated neglect severity: items presented on the left side and omitted when report was required from the first-person perspective (1PP) could be reported when patients assumed a different spatial perspective (3PP). Critically, no left–right asymmetry was observed when report was required from the perspective of another person actually present in the scene (3PPE).

These findings suggest that severe neglect in the first-person perspective can coexist with minimal or no neglect in the third-person perspective. In the first-person perspective, neglect operates in egocentric coordinates. Thus, if taking the perspective of another person simply entailed translocating the origin of the egocentric coordinate system (Zacks and Michelon, 2005), the same left–right asymmetry observed in the first-person perspective should be observed in the third-person perspective, only referred to a different to origin. In contrast, we found no evidence of left–right asymmetry when patients represented the scene from the perspective of another person. This implies that perspective-taking influenced the patients' computation of space, so that, in presence of another person, objects were no longer coded with reference to one's own body (egocentric frame of reference), but with reference to the other person's body (altercentric remapping).

Evidence that the presence of humans (as opposed to non-human entities) changes the spatial coding of visual events is provided by recent studies investigating spontaneous perspective taking (Frischen *et al.*, 2009; Tversky and Hard, 2009; Zwickel, 2009; Samson *et al.*, 2010; Zwickel and Muller, 2010). For example, observers have been shown to be slower to make self-perspective judgments when the scene includes a human model looking at the scene from a different perspective. This altercentric interference effect only occurred in presence of a human model: when the human model was replaced by an inanimate object displaying no human features (i.e. a rectangular object of the same size), no interference in the participants' self-perspective was observed (Samson *et al.*, 2010).

These findings suggest that in presence of humans, the processing of direct cues to attention such as gaze direction, head and body orientation, leads observers to spontaneously compute what others see (see also Michelon and Zacks, 2006). The result of this computation is easily incorporated into the coding of visual events and might override egocentric spatial coding. In the present study, direct cues were available when report was required from the perspective of the co-experimenter (3PPE), but not when participants were asked to describe the scene from their own perspective (1PP) or if sitting at the opposite side of the table (3PPD). It is thus possible that the presence of human body oriented towards the object contributed to altercentric remapping in the embodied perspective task. Not that, if patients merely used the other person's body as landmark to organize spatial information (Mainwaring *et al.*, 2003), a similar effect would be obtained for 1PP and 3PPD, in which an empty chair was placed on the opposite side of the table (see 'Materials and Methods' section); this clearly wasn't the case in our results.

Future studies will be necessary to characterize the effect of embodied perspective in more detail and to determine the minimal requirements for altercentric remapping to occur in neglect: presence of human body, availability of direct cues to attention, attribution of agency, display of action or action cues. Using Frith-Happé animations, Zwickel (2009) demonstrated processes that invoked the attribution of agency also lead to spontaneous perspective taking when no visual features of humans are present. If agency attribution, rather than human body presence, mediates visual-perspective taking, then an effect of embodiment should also expected for inanimate objects displaying agency cues. On this view, the effect of embodied perspective found for 3PPE might depend on so much on the presence of a human body as on the presence of an agent in the position to act on objects. This interpretation is further supported by the finding that spontaneous perspective taking in presence of another person is stronger for 'reaching' scene than for 'looking' scenes and might be further increased by calling attention to the agent's action (Tversky and Hard, 2009).

Since the effects of the presence of another person were also apparent in the imaginative condition, this raises the question of how embodied perspective taking mechanisms influence representational space. Neglect in the representational domain has been interpreted as the result of a disorder in mental imagery processes operating in a body-centered system (Ortigue *et al.*, 2001; Rode *et al.*, 2004). Our findings support and extend this notion, suggesting that patients can escape the entrapment of representational neglect by taking the perspective of another person. When patients overcome their own embodied position in space to take the position of another person, imaginative neglect becomes much less severe, and can even disappear. This indicates that embodied perspective taking might contribute to altercentric remapping of both perceptual and representational space. Note that, in the imaginative condition, objects were removed from view and participants answered from memory. During the encoding of objects, no person was sitting at the opposite side of the table. This rules out any possible impact of the presence of the co-experimenter on the perceptual encoding of objects.

Our results demonstrate that items inaccessible from a first-person perspective can be accessed from the perspective of another person. A similar advantage for third-person *vs* first-person access has been observed in anosognosia for hemiplegia, i.e. the false belief of being able to move the paralyzed limb (Marcel, 2004). Motor awareness was reinstated when patients were asked to judge their ability from the experimenter's perspective. While some patients show this person difference occasionally, others show this effect consistently, suggesting that knowledge of the state of one's limb may be radically different depending on whether it is accessed from either a first- or third-person perspective. Our results extend this evidence to the representation of the external space ('out there'): items that were not accessible when encoded within an egocentric frame of reference, could be accessed when looking at the scene 'through the eyes' of another person.

Despite a plethora of knowledge of the mechanisms representing space around a single body, little is known about the neural mechanisms that encode social space, i.e. space in relation to other bodies (Lloyd, 2009). Our results expand this knowledge by providing evidence of altercentric remapping when perspective taking is required from the position of another person. These findings have direct implications for theories of spatial cognition as they contribute to elucidate the neuropsychological structure of social space. Future research will be necessary to explore the dissociation between egocentric and altercentric representations: to describe their computational characteristics and pinpoint the underpinning neurocognitive mechanism.

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

Conflict of Interest

None declared.

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