Virtual-grasping influences visual exploration in hemispatial neglect: a preliminary eye-tracking study

Davide Crivelli[1,2] **- Matteo Sozzi**[3] **- Michela Balconi**[1,2]

[1] *Research Unit in Affective and Social Neuroscience, Catholic University of the Sacred Heart, Milan, Italy*

[2] *Department of Psychology, Catholic University of the Sacred Heart, Milan, Italy*

[3] *Department of Neurorehabilitation Sciences, Casa di Cura del Policlinico, Milan, Italy*

doi: 10.7358/neur-2014-015-criv davide.crivelli@unicatt.it

Abstract

The present study aims at investigating dissociations between vision-for-action and vision-for-perception in hemispatial neglect patients through eye-tracking. Three patients and ten controls completed two gap-bisection tasks. While patients showed a rightward bias during the perceptual task, in the virtual-grasping task we have not found evidences for a similar deviation.

Keywords: Hemispatial neglect; Eye-tracking; Vision-for-perception; Vision-for-action; Motor imagery

1. Introduction

Hemispatial neglect is a neurological syndrome where patients typically show attention, movement, visual exploration and information-processing impairments with respect to the contralesional perceptual hemifield as a consequence of a lateralized brain damage. The syndrome is typically associated to lesions of the right inferior parietal lobule, but may results also from superior temporal gyrus, premotor cortex, thalamus and basal ganglia lesions (Karnath, Fruhmann Berger, Küker & Rorden, 2004; Vallar & Perani, 1986). Symptoms may affect the visual, auditory, somatosensory and motor domains, and it is possible to dissociate clinical pictures with respect to personal, peripersonal, extrapersonal, and representational space (Bisiach & Luzzatti, 1978; Halligan & Marshall, 1991).

The heterogeneity of hemispatial neglect symptoms, however, suggests that the syndrome might be characterized by a complex pattern of strengths and weaknesses. Clinical and experimental evidences, for example, proved that visual processing abilities for action and perception are supported by different neural networks (respectively, a dorsal or a ventral pathway; Milner & Goodale, 1995; 2008) and that action-related mechanisms – or, at least, a subset of them, operating independently of perceptual awareness – might be preserved in neglect syndrome (Rizzolatti & Matelli, 2003). Thus, the present study aims at investigating potential dissociations between vision-for-action and vision-for-perception in such patients by using eye-movement measures, a powerful tool to track attention orientation and focus. Given well-known behavioural findings, we hypothesise that patients' visual behaviour will present some form of rightward bias and that, if one of two visual streams is preserved, their visual behaviour will be only partially pathological.

2. Methods

2.1. Participants

Three patients (three males) showing left hemispatial neglect (see Table 1) and ten control subjects (four females, six males) took part to the study. Clinical cases have been selected on the basis of a complete in depth neurological and neuropsychological assessment while in post-acute phase.

Table 1. Clinical details of hemispatial neglect patients

Patient	Age	Education	Time interval	Etiology	Lesion site	B.I.T.
A	72	15	8 w.	Ischemic	Cortical-subcortical, TP Dx	120
B	68	13	12 w.	Ischemic	Cortical-subcortical, P Dx	113
C	71	13	10 w.	Ischemic	Cortical-subcortical, P Dx	122

All patients included in the study (M_{age} = 70.34, SD_{age} = 1.70; M_{edu} =13.67, SD_{edu} = .94) showed left hemispatial neglect symptomatology as a consequence of posterior right-sided lesions. History of dementia, psychiatric and neurodegenerative disorders and co-occurring severe cognitive deficits was an exclusion criterion. Control subjects were matched by handedness, age and education (M_{age} = 68.81, SD_{age} = 3.4; M_{edu} = 13.60, SD_{edu} = .81; Mann-Whitney and χ^2 = *n.s.*) with patients and none reported history of sensory neurological or psychiatric disorders. All participants gave their written consent to participate and the study was approved by the local Ethical Committee.

2.2. Procedure and materials

The experimental design included two gap-bisection tasks, which differ from classic line-bisection tasks in that the stimulus is constituted by a pair of endpoints and subjects have to mark the perceived midpoint of the gap between them (see McIntosh, Schindler, Birchall & Milner, 2005 for a discussion of the approach and its advantages). In a first perceptual task, participants were asked to estimate the distance between two endpoints presented on a screen and to mark the midpoint of the gap. In a further virtual-movement task, participants were asked to imagine grasping an object between the two endpoints and, then, to mark the midpoint of the gap. Each stimulus included two red spheres (Ø = 20 mm, 1.64°) on a white background (duration = 5000 ms), and was followed by a blank screen (duration = 5000 ms). The sphere were presented symmetrically with respect to the centre of the screen, and the actual distance between them varied systematically across trials (six gap widths: I: 20 mm – 1.64°; II: 40 mm – 3.27°; III: 80 mm – 6.55°; IV: 120 mm – 9.82°; V: 160 mm – 13.10°; VI: 240 mm – 19.64°). Stimuli were replicated and randomly presented (E-Prime 1.2, Psychology Software Tools), and the order of experimental tasks has been counterbalanced across subjects. In order not to induce perseverations or invariant response position, participants were asked to move their hand from the mouse after each bisection response.

During experimental tasks, participants were seated in front of a 16'' PC screen (distance = 70 cm) subtending a visual angle of approximately 27°. An infrared eye-tracking system (Tobii X120, Tobii Technology) was used to record eyes movements with a sampling rate of 120 Hz and to identify visual fixations (minimal fixation-radius = 50 pixel; minimal fixation-duration = 100 ms) – i.e. the brief time intervals between two saccades when the eyes hold a stable position and acquire new information.

3. Results

After determining right vs. left Areas of Interest (AoI) with respect to the stimulus actual midline, raw data have been fed to a custom-made algorithm to extract AoI-specific fixations count and length indices. AoI-specific indices have then been used to compute asymmetry measures (AM = rightAOI-index - leftAOI-index) mirroring biases in participants' visual exploration and ocular behaviour due to right vs. left endpoint weight effect. Positive asymmetry values reflect rightward biases. Asymmetry measures for fixation-count and fixation-length deriving from the perceptual and virtual-grasping tasks have been statistically analyzed by distinct repeated-measures ANOVA models using gap widths (level I to VI) as within-subject factor and group (clinical vs. control) as between-subject factor. Type-I Errors due to dishomogeneity of variances have been controlled by applying Greenhouse-Geisser corrections to degrees of freedom.

As for the perceptual task, statistical analysis of fixation count asymmetries yielded a significant main effect for group ($F[1, 11] = 7.78$, $p \leq .001$, $\eta^2 = .29$) and a significant group by gap width interaction ($F[5, 11] = 9.76$, $p \leq .001$, $\eta^2 = .37$). Patients showed a clear rightward fixation-count bias when compared to controls, in particular for the two widest gap stimuli (I-IV: *n.s.*; V: $F[1, 11] = 10.02$, $p \leq .001$, $\eta^2 = .38$; VI: $F[1, 11] = 8.63$, $p \leq .001$, $\eta^2 = .31$). Similarly, the ANOVA model applied to fixation-length asymmetries highlighted significant group differences ($F[1, 11] = 12.45$, $p \leq .001$, $\eta^2 = .38$), and a significant group by gap width interaction ($F[5, 11] = 9.13$, $p \leq .001$, $\eta^2 = .31$). Again, patients tended to produce longer-lasting fixations in the right portion of the stimuli than controls, but the effect was mainly driven by their visual behaviour in response to the two widest gap stimuli (I-IV: *n.s.*; V: $F[1, 11] = 12.60$, $p \leq .001$, $\eta^2 = .37$; VI: $F[1, 11] = 10.12$, $p \leq .001$, $\eta^2 = .32$).

As for the virtual-grasping task, none of the ANOVA models yielded statistically significant differences between groups or stimuli conditions, suggesting that patients and controls visual behaviour was, in a sense, similar. Figure 1 (a-b) depicts patients' and control subjects' asymmetry measures regarding, respectively, the perceptual and virtual-grasping task.

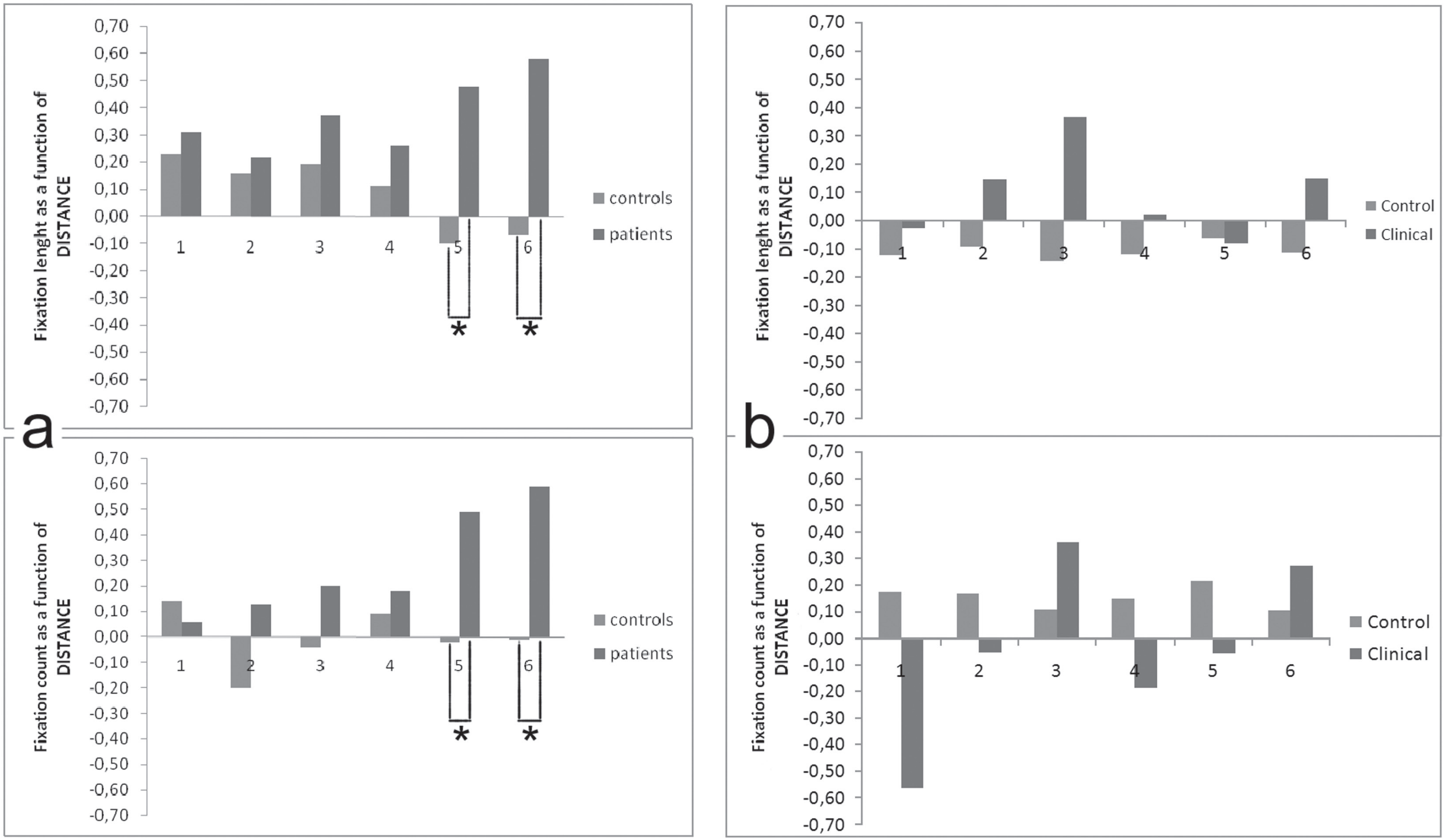

Figure 1. Patients' and controls' asymmetry measures with respect to increasing gap widths
(a) Perceptual gap-bisection task
(b) Virtual-grasping gap-bisection task
Stars mark statistically significant differences ($p < .001$)

4. Discussion

Present findings suggest two main points. Firstly, the experimental manipulation of gap width showed consistent differences between controls and patients, at least in the perceptual task, in particular for the widest gaps. It has been shown that left neglect patients tend to exhibit a primary rightward orientation bias in attention that may account for behavioural pathological manifestations (Kinsbourne, 1993) – e.g. bisection errors, right-side exploration preference. Accordingly, it has been suggested that hemispatial neglect patients exhibit progressively increasing pathological responses moving from the centre of their perceptual field to its left periphery and progressively smaller difficulties moving toward the right periphery, thus showing a sort of continuous left-to-right "performance gradient". The peculiar pattern we found by analysing visual behaviour, though, seem to contrast with the hypothesis of a continuous gradient, and it suggests the existence of a "partial gradient". According to this alternative view, hemispatial neglect symptomatology tends to show primarily in response to eccentric cues and the decreasing performance gradient affects a limited contralesional portion of space, whose width depends on clinical severity. Secondly, the experimental manipulation of gap width affect patients' visual behaviour specifically in the perceptual task but not in the virtual-grasping task. Increases of directional error have been associated to a sort of attentional "reduced weighting" phenomenon concerning the left endpoint in a "perceptual" gap-bisection task (McIntosh et al., 2005). However, the visual analysis of the environment may be different if we process contextual information for situated acting or for object recognition, and – as pointed out by Milner and Goodale (1995; 2008) – it is mediated by different neural networks: contextual representations might be influenced by goals and sensorimotor intentions. Our results suggest that the mere mental simulation of grasping movements might lead to a reduction of visual exploration biases shown by hemispatial neglect patients in a bisection task. That finding may be explained by the task-specific role of different perception-oriented vs. action-oriented visual representations and, consequently, by the predominant mediation of ventral vs. dorsal visual system pathways and other structures involved in visual-motor processing unaffected by neglect-inducing lesions.

5. Conclusion

To conclude, our preliminary findings are consistent with the hypotheses of a partial gradient in clinical manifestations of neglect syndrome and a relative sparing of specific visual-exploration skills. In particular, task-related effects on visual behaviour suggest interesting hints for rehabilitation of spatial exploration. In fact, if vision-for-action networks are preserved in hemispatial neglect patients, the clinical practice should capitalize on that by including motor imagery in classic protocols. Moreover, it is worth noting that eye-tracking measures proved to be sensitive assessment indices and that eye-movements monitoring might lead to more complete and precise diagnoses, guiding future interventions (e.g. ocular bio-feedback systems to increase patients' awareness of disability).

References

Bisiach, E., & Luzzatti, C. (1978). Unilateral neglect of representational space. *Cortex*, 14, 129-133.

Halligan, P.W., & Marshall, J.C. (1991). Left neglect for near but not far space in man. *Nature*, 350 (6318), 498-500.

Karnath, H.-O., Fruhmann Berger, M., Küker, W., & Rorden, C. (2004). The anatomy of spatial neglect based on voxelwise statistical analysis: a study of 140 patients. *Cerebral Cortex*, 14 (10), 1164-1172.

Kinsbourne, M. (1993). Orientational bias model of unilateral neglect: evidence from attentional gradients within hemispace. In: Robertson, I.H., & Marshall, J.C. (eds.), *Unilateral neglect: clinical and experimental studies*. Hove: Lawrence Erlbaum Associates, pp. 63-86.

McIntosh, R.D., Schindler, I., Birchall, D., & Milner, A.D. (2005). Weights and measures: a new look at bisection behaviour in neglect. *Cognitive Brain Research*, 25 (3), 833-850.

Milner, A.D., & Goodale, M.A. (1995). *The visual brain in action*. Oxford, UK: Oxford University Press.

Milner, A.D., & Goodale, M.A. (2008). Two visual systems re-viewed. *Neuropsychologia*, 46 (3), 774-785.

Rizzolatti, G., & Matelli, M. (2003). Two different streams form the dorsal visual system: anatomy and functions. *Experimental Brain Research*, 153 (2), 146-157.

Vallar, G., & Perani, D. (1986). The anatomy of unilateral neglect after right-hemisphere stroke lesions. A clinical/CT-scan correlation study in man. *Neuropsychologia*, 24 (5), 609-622.