Neuropsychologia xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Ipsilesional deficit of selective attention in left homonymous hemianopia and left unilateral spatial neglect

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ARTICLE INFO

Keywords:
Homonymous hemianopia
Unilateral spatial neglect
Sightblindness
Hemispheric specialization
Selective attention

ABSTRACT

Aims: Patients with homonymous hemianopia may present a subtle ipsilesional deficit, recently referred to as 'sightblindness' in addition to the contralesional visual field defect. We recently demonstrated that this deficit could be worse in right brain-damaged patients with left hemianopia than in left brain-damaged patients with right hemianopia, confirming right hemisphere dominance for visuo-spatial and attentional capacities. In the present study we investigate whether this ipsilesional deficit could be attentional in nature and to what extent it is comparable in right brain-damaged (RBD) patients with left hemianopia and in RBD patients with left neglect. The study was also conducted in RBD patients with neither left hemianopia nor left neglect signs in order to test if a right hemisphere lesion per se could be responsible for subtle ipsilesional attentional deficit. To reach this aim, we tested selective attentional capacities in both visual fields of 10 right brain-damaged patients with left neglect (LN), 8 right brain-damaged patients with left homonymous hemianopia (LHH), 8 right brain-damaged patients with no signs of left neglect or left hemianopia (RBD controls), and 17 healthy age-matched participants (Normal controls).

Method: A lateralized letter-detection task was used to test if right-brain damaged patients with LN or LH may present a deficit of selective attention in their right, ipsilesional visual field, in comparison to Normal and RBD controls. Participants were asked to detect a target letter in either a single large stimulus (low attentional load) or a small stimulus surrounded by flankers (high attentional load). Stimuli were displayed either in the left or in the right visual field. Accuracy and reaction times were recorded.

Results: Results on accuracy showed that both LN and LH patients exhibited lower correct responses than Normal controls in their ipsilesional right visual field, suggesting an attentional deficit in their ipsilesional, supposed healthy visual field. More specifically, LH patients exhibited a specific deficit for processing single large stimuli, but not for processing flanked stimuli, relative to normal controls. LN patients exhibited lower correct responses for processing all types of stimulus than normal controls, but also than right brain damaged controls, in both visual fields suggesting a non-lateralized deficit not only due to the right hemisphere lesion. Furthermore, this deficit is more pronounced for flanked small stimuli, requiring higher attentional load.

Conclusions: The present results bring further evidence that patients with left homonymous hemianopia or left unilateral neglect both present a weaker but significant ipsilesional deficit in addition to their well-known massive contralesional deficit. The presence of a specific attentional deficit in the right ipsilesional visual field of left hemianopic and left neglect patients is discussed regarding the hypothesis of hemispheric specialization for selective spatial attention and may have clinical implications for both conditions.

1. Introduction

Participants suffering from left unilateral neglect are usually described as being impaired in responding to stimulation in the hemispace controlateral to the brain lesion (Heilman and Valenstein, 1979; for a review, see Bartolomeo and Chokron, 2000). In addition, it has been repeatedly demonstrated that patients do not simply neglect left objects but are also attracted by right ones (Mark et al., 1988; Marshall and Halligan, 1989). This behavior has been interpreted as a 'rightward attentional capture' and indeed several experiments have demonstrated that reducing visual salience in the right hemispace may decrease left neglect signs (Mark et al., 1988; Marshall and Halligan, 1993; Chokron

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https://doi.org/10.1016/j.neuropsychologia.2018.03.013
Received 26 June 2017; Received in revised form 6 March 2018; Accepted 8 March 2018

et al., 2004). The hypothesis of a rightward attraction of attention increasing left neglect behavior raises an important question: does the rightward bias reflect enhanced attention to the right hemispace? This assumption would fit several attentional models such as Kinsbourne (1970) predicting that there is a bias towards orienting attention in the rightward, ipsilesional hemispace of left neglect patients due to the release of left hemisphere from right hemisphere inhibition (see for discussion, Bartolomeo and Chokron, 2002). Along those lines, Làdavas et al. (1990), and subsequently Natale et al. (2007), found that right brain-damaged patients with left neglect may respond faster to ipsilesional targets than right brain-damaged patients without neglect or may even outperform healthy participants (in the latter study). More recently, Vossel and Fink (2016) found that in right brain-damaged patients, the presence of a distractor in the contralesional hemifield expedited ipsilesional (i.e., right) target detection. This effect was significantly related to lesions in the anterior middle temporal and temporoparietal cortex, external and internal capsule, as well as the superior longitudinal fascicle (SLF). The authors thus suggested that damage to the temporal and temporoparietal cortex and white matter tracts may transform contralesional stimulation into an unspecific saliency signal contributing to facilitating information processing in ipsilesional space. However, rather than being interpreted in terms of facilitation, the rightward orientation of attention could be seen as a deficit in neglect patients. Indeed, according to Viken et al. (2014), the ipsilesional capture of attention in left neglect patients could be a predictor of chronic deficit. Indeed, these authors demonstrated that the most important predictors assessed early after stroke were presence of ipsilesional bias for dependency at 3 months and visual processing speed for dependency at 2 years after stroke. In this manner, the increase in rightward orientation of attention could be seen as a core deficit of unilateral spatial neglect.

Contrasting with the idea of a rightward facilitation, Bartolomeo and Chokron (1999), as well as Bartolomeo et al. (1999), found that left neglect patients were slower than normal controls when responding to left, but also to right, ipsilesional stimuli. This finding can be interpreted based on Heilman and Van den Abell's (1980) hypothesis that the left hemisphere attends only to contralateral space whereas the right attends to both contralateral and ipsilateral hemispaces. Thus, left hemispheric damage could be compensated for by right hemispheric attentional mechanisms, thereby only rarely provoking right neglect. Conversely, right cerebral damage would cause left neglect because the left hemisphere is unable to attend to the left hemispace. An essential corollary of this hypothesis is that right hemisphere lesions should determine a severe deficit in attention for the contralateral hemispace, but also a milder ipsilesional deficit, because fewer attentional resources could now be deployed in the right hemispace. Consistently, Bartolomeo and Chokron (1999) and Bartolomeo et al. (1999), found that left neglect patients were also impaired in their right hemispace. In addition, the authors demonstrated that this ipsilesional slowing of reaction times does not simply reflect a non-specific arousal deficit, but is strictly related to the severity of left neglect. In addition, they demonstrated that the capacity to inhibit successive responses to right-sided events could predict performance on the left side of paper and pencil neglect tests (Bartolomeo et al., 1999). The rightward attentional bias in left neglect patients can thus take the form of a facilitation for simple detection as mentioned above or a deficit in more complex attentional tasks. Therefore, it seems to be one of defective, and not enhanced, attention, but the nature of this deficit is still unclear.

On the one hand, according to Robertson (1993, 2001), unilateral neglect would be very strongly associated with a fundamental loss of attentional capacity that may not be confined to one region of space, but could also involve the right ipsilesional space, meaning a non-lateralized attentional deficit. In this view, neglect patients suffer from a spatially nonselective component of attentional deficit that may be some form of basic arousal dysfunction. On the other hand, the attentional deficit in the ipsilesional field of left neglect patients could merely involve selective attention such as filtering processing. Indeed, using a 'flanker task' (e.g., the identification of a central stimulus flanked on both sides by task-irrelevant flankers), Snow and Mattingley (2006) clearly demonstrated that right brain-damaged patients with left unilateral neglect or extinction have a specific impairment in the ability to selectively inhibit task-irrelevant information within the ipsilesional visual field (IVF). Thus, according to these authors, in addition to the deficit of spatial orientation of attention present in left neglect patients, selective attention in IVF might more accurately be viewed as 'dysfunctional' rather than 'intact', as previously thought (for review, see Snow and Mattingley, 2006). Indeed, it has to be noted that although the orientation of attention in space has been extensively studied in left neglect patients (for review, see Bartolomeo and Chokron, 2002), relatively few studies have focused on selective attention. When they did, these studies mainly focused on the deficit in the left, contralesional hemispace (see for example, Rapcsak et al., 1989 and Lavie and Robertson, 2001), but not on the behavior in the right, ipsilesional space. Interestingly, regarding visual field defects consecutive to retrochiasmatic unilateral damage (V1), the same conclusion can be drawn.

Indeed, most studies focused on the contralesional visual field, either on the deficit per se or on the residual, implicit capacities, referred to as *'blindsight'* (Weiskrantz, 2004). However, contrary to the case of blindsight, which has been extensively studied in hemianopic patients, vision quality in the central visual field and in the IVF of these patients has scarcely been assessed, and moreover, has traditionally been assumed to be fully preserved. Yet, regarding visuo-attentional capacities in the IVF of hemianopic patients, Hess and Pointer (1989) proposed that spatial and temporal sensitivities were lower than in control subjects. Rizzo and Robin (1996), followed by Poggel et al. (2011), confirmed that hemianopic patients can exhibit lower sensitivity to signals, compromised processing of temporal information and longer reaction times in both contralesional and ipsilesional visual fields, as compared to control participants. By studying a patient one week before and six months after a surgical intervention (embolization of an arteriovenous malformation in the right occipital lobe), we directly addressed the role of the right visual cortex on local analysis (based on the high spatial frequency content of scene stimuli) and global analysis (based on the low spatial frequency content) of visual information in scenes (Peyrin et al., 2006b). Results confirmed that damage to the right primary visual cortex (V1) induces a decrease in performance in the right IVF. In fact, the patient was found even before surgery to perform with lesser accuracy and higher reaction times in the right IVF for all types of scenes compared to performance in healthy controls and presented an additional deficit for global analysis (based on low spatial frequencies) in her right IVF after surgery. This study led us to hypothesize that the right occipital lobe could be involved in the processing of the global aspects of a visual scene (low spatial frequencies) in both visual fields. The right temporo-parietal junction has already been hypothesized to be involved in global processing (Fink et al., 1997, 1999).

Regarding visual detection and analysis, Paramei and Sabel (2008) reported that hemianopic patients exhibited diminished ability to detect fragmented targets among a noisy background in the IVF, whereas Schadow et al. (2009) found deficits in the early and late visual processing of Gestalt patterns in the IVF. More recently, Bola et al. (2013a) confirmed these findings and reported processing-speed deficits in a simple detection task in the IVF. The authors termed this phenomenon *sightblindness*, as the reverse situation of *blindsight* (Bola et al., 2013b): the former refers to visuo-attentional deficits in the IVF, whereas the latter refers to residual (although implicit) visual abilities in the contralateral visual field (CVF) that are highlighted in forced-choice tasks (e.g., Weiskrantz et al., 1974; Leopold, 2012). Along those lines, and as recently suggested, neither the central visual field (Cavézian et al., 2010, 2015; Perez et al., 2013) nor the IVF of hemianopic patients (Bola et al., 2013a, 2013b; Sanchez-Lopez et al., in press) actually appear to be fully intact or functional. In line of these findings, it was also