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Research report

Dynamic attentional modulation of vision across space and time after right hemisphere stroke and in ageing

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ABSTRACT

Introduction: Attention modulates the availability of sensory information to conscious perception. In particular, there is evidence of pathological, spatial constriction of the effective field of vision in patients with right hemisphere damage when a central task exhausts available attentional capacity. In the current study we first examined whether this constriction might be modulated across both space and time in right hemisphere stroke patients without neglect. Then we tested healthy elderly people to determine whether non-pathological ageing also leads to spatiotemporal impairments of vision under conditions of high attention load.

Methods: Right hemisphere stroke patients completed a task at fixation while attempting to discriminate letters appearing in the periphery. Attentional load of the central task was modulated by increasing task difficulty. Peripheral letters appeared simultaneously with the central task or at different times (stimulus onset asynchronies, SOAs) after it. In a second study healthy elderly volunteers were tested with a modified version of this paradigm.

Results: Under conditions of high attention load right hemisphere stroke patients have a reduced effective visual field, over a significantly extended 'attentional blink', worse for items presented to their left. In the second study, older participants were unable to discriminate otherwise salient items across the visual field (left or right) when their attention capacity was loaded on the central task. This deficit extended temporally, with peripheral discrimination ability not returning to normal for up to 450 msec.

Conclusions: Dynamically tying up attention resources on a task at fixation can have profound effects in patient populations and in normal ageing. These results demonstrate that items can escape conscious detection across space and time, and can thereby impact significantly on visual perception in these groups.

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1. Introduction

Our eyes are bombarded with a vast amount of information from across the visual field. Visual acuity for this information can be mapped by standard perimetry. However, what is available to conscious perception is affected by factors other than low-level visual processes. Availability of attentional resources appears to be critical for awareness (e.g., see, Lavie, 2005; Rees et al., 1997, 1999; Schwartz et al., 2005; Vanni and Uutela, 2000). If the amount of attention required for a task at fixation is high, there is an effective constriction of the available visual fields and failure to perceive otherwise salient onsets in healthy people (Russell et al., 2004). The dynamic loss of vision for peripheral targets when attentional resources are occupied can be seen by the decrease in neural activity for peripheral checkerboard patterns even in early visual cortex when task demands at fixation are high (Schwartz et al., 2005 see also, Rees et al., 1997).

Recently O'Connell et al. (2011) examined the effect of central attentional load on spatial orienting towards peripheral events, measuring event-related potentials to assess timing of the modulation. The early N1 signal (previously shown to indicate enhanced attentional processing) was attenuated, particularly over the right hemisphere, for expected peripheral targets when participants completed a high load task at fixation. Modulation of N1 is consistent with evidence linking this signal to the right temporo-parietal cortex. The key role of these regions in directing attention is well documented (e.g., Corbetta and Shulman, 2002; Friedrich et al., 1998). Indeed fMRI has revealed modulation by load in these regions, particularly right intra-parietal sulcus, suggesting an important contribution to non-spatial attentional capacity (e.g., Culham et al., 2001).

Compatible with studies on healthy participants, damage to the right hemisphere leads to impairments in attention. Visuospatial neglect, frequently occurring after damage to right parietal cortex (e.g., see, Driver and Mattingley, 1998; Mort et al., 2003; Vallar, 2001), is characterized by a loss of awareness for items in the visual field contralateral to the lesion. Although the most salient features of neglect involve spatial attention, as deficits are strongly lateralized, there is evidence that non-spatial components of attention are affected (see Husain and Rorden, 2003; Robertson, 2001). These patients have problems in sustaining attention over minutes (e.g., Malhotra et al., 2009: Robertson et al., 1997) and increasing alertness ameliorates the lateralized symptoms (e.g., Chica et al., 2012; Degutis and Van Vleet, 2010; Thimm et al., 2006; Robertson et al., 1998). Further, non-spatial attention capacity deficits in these patients affect conscious awareness for items across the visual field. Vuilleumier et al. (2008) examined responses to background checkerboards in early visual cortex of neglect patients completing a task at fixation. When central task load was low, early visual cortex responded to the checkerboards on both sides. However, when central load was increased, responses to checkerboards presented to the left visual field were reduced or abolished (see also, Bonato et al. (2010); Peers et al., 2006; Sarri et al., 2009). Russell et al. (2004) revealed that patients with damage to right parietal cortex, even without neglect, missed peripheral targets when they were required to complete a difficult task at fixation. Performance was particularly poor on the contralesional side but there was even loss of ipsilesional vision when central task demand was sufficiently high.

In addition to spatial impairments in conscious awareness under high load, observers can suffer detection deficits over *time*. The 'Attentional Blink' (AB) paradigm is used to delineate temporal capacity limits to perception (Raymond et al., 1992; Shapiro et al., 1994). Participants are presented with two targets embedded in a stream of rapidly presented items at fixation. Healthy young participants often fail to detect the second target if it is presented within a short lag of the first (under ~500 msec). The time taken to process the first target occupies capacity, rendering it briefly difficult to identify another target; indeed task load manipulations within the AB paradigm indicate that perception of the second target reflects current availability of attentional resources (e.g., Elliott and Giesbrecht, 2010). Patients with visuospatial neglect have shown an extended 'AB', with a failure to report second targets over a much longer lag period (e.g., up to 1300 msec) (see Husain et al., 1997; Hillstrom et al., 2004; Rizzo et al., 2001). However, it is unclear whether such deficits can also be protracted spatially, particularly to the contralesional side, as previous studies have used centrally presented targets. Our first study aims to assess whether the spatial contralesional deficit for discriminating stimuli when performing a demanding central task extends temporally and impairs perception for a longer period.

This potential attention-modulated loss of available visual field – over space and time – is also relevant to healthy ageing and our understanding of the impact of age-related decline on daily function. Investigators have developed tests of the Useful Field of View (UFOV) and correlated performance with driving ability (e.g., Clay et al., 2005; Owsley et al., 1995). UFOV tests typically involve making judgements on a central item whilst attempting to discriminate peripheral items, often with concurrent distractors. Older adults who, despite having intact visual fields, are poor at this test are more dangerous drivers as indexed by measures including road accidents and driver simulator performance (Clay et al., 2005). Crucially, these studies have not modulated the amount of attention required in the central task in order to examine how this impacts on deployment of attention to peripheral items. Some investigations have also reported that older participants might suffer from an AB that is longer and of greater magnitude (e.g., Georgiou-Karistianis et al., 2007; Maciokas and Crognale, 2003), but no studies have examined perception across the visual field in these paradigms. In our second experiment, we used our paradigm to probe deployment of attention over space and time within healthy ageing when participants perform a demanding task at fixation.

2. Experiment 1

2.1. Method

2.1.1. Participants

Five patients with right hemisphere stroke participated in the study. Patients were aged from 55 to 75 (mean 66 years). All