

# A dissociation between visual and auditory hemi-inattention: Evidence from temporal order judgements

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## Abstract

Patients with right hemisphere brain lesions often suffer from deficits in spatial attention that can be manifested in different sensory modalities. It has recently been claimed that a relationship (i.e., association) could exist between symptoms of hemi-inattention in different modalities, based on correlations between the results of visual and auditory clinical tests of neglect or extinction. However, it should be noted that the visual and auditory tasks varied greatly both in response type and level of sensitivity. Here, we have examined cross-modal associations in spatial attention deficits using a temporal order judgment task (TOJ) in which patients were required to identify which of two visual or auditory objects had appeared first. When compared to age and education matched control participants, the patients needed, on average, the contralesional stimulus to lead the ipsilesional stimulus to achieve the point of subjective simultaneity (PSS). No association between the degree of visual and auditory hemi-inattention was observed amongst the patients, suggesting that there is a certain degree of independence between the mechanisms subserving spatial attention across sensory modalities.

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## 1. Introduction

Neurological patients with lesions affecting the temporoparietal (TPL) region of the right hemisphere often suffer deficits in spatial attention. Typically, these patients can fail to detect, or to be consciously aware of objects, or parts of objects, presented in the contralesional side of space (i.e., the side opposite of the lesion), a syndrome commonly referred to as spatial hemineglect. One manifestation of this neurological syndrome, that can be present in the absence of other symptoms of neglect, is extinction. In extinction, contralesional stimuli presented in isolation can usually be detected; but when presented concurrently with a competing ipsilesional stimulus, the patient often

fails to consciously perceive the contralesional target. That is, orienting attention to the ipsilesional stimulus causes the contralesional stimulus, which would normally be perceived, to be extinguished from awareness. This deficit appears to be based on a failure at the level of attentional mechanisms; that is, the deficits seen in spatial processing can occur in the absence of primary sensory difficulties (i.e., hemianopsia), and are modulated with manipulations of attention (Posner, Walker, Friedrich & Rafal, 1984). The attentional and perceptual deficits observed following TPL lesions have been reported in several sensory modalities (i.e., vision, somatosensation, and audition; see Di Pellegrino, Basso, & Frassinetti, 1997; Guerrini, Berlucchi, Bricolo, & Aglioti, 2003; Pavani, Ládavas, & Driver, 2003 for examples), thereby offering researchers an opportunity to investigate the mechanisms of crossmodal attention. Indeed, crossmodal extinction has been observed in some of these patients when a stimulus in one sensory modality (i.e., a visual stimulus on the right) has the effect of extinguishing the perception of a stimulus in a separate modality (i.e., a

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touch on the left; see for example, Di Pellegrino, Làdavas, & Farnè, 1997; Làdavas, Pavani & Farnè, 2001; Maravita, Spence, Clarke, Husain & Driver, 2000; Làdavas et al., 2004).

The current investigation examines the extent to which symptoms of auditory and visual hemi-inattention are associated in individual patients. This issue has important implications when considering multisensory spatial processing. An association could indicate that the deficits of hemi-inattention affect a general sensory processing system (i.e., multimodal spatial map). That is, if symptoms of visual and auditory hemi-inattention were associated, this would suggest that individual sensory modalities share, to some extent, attentional resources for spatial processing (see Driver & Spence, 2004 for a related example). However, dissociation would suggest a certain degree of independence in the spatial representation of different sensory modalities. This would converge with the idea that different sensory modalities are able to draw from separate reservoirs of attentional resources (see Wickens, 1984; Treisman & Davies, 1973; Duncan, Martens & Ward, 1997; Soto-Faraco & Spence, 2002; Sinnott, Costa & Soto-Faraco, in press), or that spatial attention mechanisms in different sensory modalities can be somewhat decoupled (see Eimer & Driver, 2000; Eimer & Van Velzen, 2002; Soto-Faraco, Morein-Zamir & Kingstone, 2005). The attentional disturbances seen in neglect patients offer an opportunity to further investigate any possible segregation between sensory modalities.

A few earlier studies have investigated the levels of association between visual and auditory neglect with mixed results. Bisiach, Cornacchia, Sterzi and Vallar (1984) studied 107 right and left brain lesioned patients (in addition to healthy participants) in an auditory task that required participants to manually point to the perceived direction of a sound delivered via headphones.<sup>1</sup> The patients were divided into four different groups (left versus right hemisphere lesioned patients, and then by the absence or presence of visual defects based on confrontation tasks). The right brain damaged patients showing signs of visual defects ( $n=25$ ) had the poorest performance on the sound localization task, misperceiving the origin of the sound further in space ipsilesionally (to the right) than any of the other groups. Of interest, 15 of the patients in this group (right brain damaged patients with visual defects) exhibited visual hemineglect on cancellation tests. The auditory and visual scores of these 15 patients (right brain damaged patients exhibiting visual hemineglect) were analysed in order to determine if performance was correlated in the two modalities. The magnitude of the errors in the auditory task was generally larger when compared with patients not suffering from visual hemineglect, leading the authors to claim that the magnitude

of visual and auditory neglect was associated. However, it should be noted that the correlation failed to reach statistical significance even when restricting the analysis to the 15 patients who exhibited visual hemineglect based on cancellation tasks. That is, including the other 10 patients, who were originally part of the group of right brain damaged patients showing visual defects, would surely nullify any numerical trend indicating an association between auditory and visual hemi-inattention deficits, as the auditory localization scores for these patients were not biased to the right to the same extent as the 15 patients classified as exhibiting visual hemineglect.

Zimmer, Lewald and Karnath (2003) investigated the ability of hemineglect patients to lateralize sounds (i.e., to decide if a sound, presented via headphones, was positioned to the left or right of midline). Their patients were divided into two subgroups, one ( $n=7$ ) showing erratic lateralization judgements (i.e., spatial localization errors to the left and right of the original sound source) and the other ( $n=8$ ) consistently perceiving the sounds as slightly shifted to the right (i.e., into ipsilesional space). The authors concluded that the inability to localize sound (the former group) was associated with the strength of clinical visual neglect tests (i.e., they performed worse on classic clinical visual neglect tests). That is, the group that consistently perceived the sounds as shifted to the right failed to show an association between their results for visual and auditory testing. If spatial hemi-inattention deficits were based on a breakdown of some kind of multimodal map of space, one would expect the group who consistently misperceived sound location towards the right (a more 'classical' symptom of auditory hemineglect, see Pavani, Farnè, & Làdavas, 2003), to exhibit stronger symptoms of clinical neglect (i.e., letter cancellation and copying tests) when compared with the group who exhibited erratic auditory localization judgements. Thus, Zimmer et al.'s (2003) results seem more consistent with a dissociation between auditory and visual hemi-inattention symptoms.

Bellman, Meuli and Clarke (2001) suggested that two types of auditory neglect might exist based on how a group of patients ( $n=4$ ) performed in two different tests measuring deficits of auditory spatial attention. In the first task, pairs of words were presented to the left and right ears (via headphones) and the patients were required to repeat what they heard at both ears. The second task required patients to locate the perceived source of sounds (presented via headphones) occurring at five different locations, one central and four lateral (two in each hemisphere). Half of the patients were impaired when recalling the word presented to the left ear (i.e., extinction, test one as described above) while they did not show any spatial bias when localizing sound. The other half showed the reverse, that is, they were able to correctly repeat the words, but sound localization judgements were severely biased towards the right. The authors interpreted the results as evidence for two separate types of auditory hemineglect and explained the dissociation by the location of their respective lesions. The group who suffered from extinction-like symptoms in the word identification task, but was able to localize sound, had lesions affecting the basal ganglia, whereas, the group displaying a spatial bias in localization suffered from fronto-temporo-parietal lesions. These results suggest that the

<sup>1</sup> It should be noted that the manual pointing task in itself is not the most adequate task to measure amounts of auditory hemi-inattention, since it is possible that visual and motor biases could affect the manual responses. Indeed, it has been reported that healthy, neurobiologically intact participants achieve better auditory localization scores when blindfolded than when being allowed to see (Warren, 1970; Platt & Warren, 1972). This same trend has been seen with neglect patients with improved scores while blindfolded (Soroker, Calamaro, Glicksohn, & Myslobodsky, 1997; Pavani, Farnè, & Làdavas, 2003).

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