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Research report

Specific impairments in visual processing following lesion side in hemianopic patients

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ABSTRACT

Introduction: Following unilateral damage of the primary visual cortex one of the most common visual field defects observed is Homonymous Hemianopia (HH), a loss of vision of the contralesional hemifield in each eye. The ipsilesional ("intact") part of the central visual field is often used to compensate for difficulties encountered in the peripheral hemianopic visual field. However, the quality of vision within the central visual field is not well-known.

Methods: To better describe and understand visual processing in hemianopia, two tasks were conducted with 25 healthy controls, six left hemianopes, and five right hemianopes. Filtered (in high, above 6 cycles/degree, or low, below 4 cycles/degree, spatial frequencies – HSF and LSF, respectively) and unfiltered natural scene images (5° of visual angle) were briefly presented (100 msec) centrally on a computer screen. Participants were required either to respond when a natural scene was presented (yes/no detection task) or to indicate if the stimulus was a city or a highway (categorization task).

Results: The three groups showed similar accuracy levels but significant differences were observed in response times. More precisely, left hemianopes were impaired both in the detection and in the categorization tasks whereas right hemianopes were only impaired in the categorization task. However, the three groups had similar responses to spatial frequencies: HSF were processed more slowly than LSF.

Conclusions: Overall these results suggest that central vision is not intact in hemianopia. Lesion side selectively affects reaction times (RTs) in the detection and the categorization tasks, but does not seem to determine a specific deficit in spatial frequency processing.

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1. Introduction

Visual analysis starts with an extraction of elementary information at different spatial scales/frequencies (for review, Basole et al., 2006), usually segregated as Low and High Spatial Frequencies (LSF and HSF, respectively). Experimental data from psychophysics (Ginsburg, 1986), functional neuroanatomy of magnocellular and parvocellular pathways (Van Essen and DeYoe, 1995) and ultra rapid categorization in humans and monkeys (Fabre-Thorpe et al., 1998) confirm the idea that visual analysis starts with a parallel extraction of different elementary visual attributes at different spatial scales or frequencies, with a coarse-to-fine processing design (Schyns and Oliva, 1994). According to this design, a rapid extraction of LSF should provide a global outlook of a stimulus structure, thus allowing an initial perceptual categorization. This perceptual categorization should be refined, confirmed or infirmed by the information conveyed by HSF whose extraction takes place later (Ginsburg, 1986; Hughes et al., 1996; Schyns and Oliva, 1994). Coherent with this hypothesis some authors have proposed that LSF conveyed by the magnocellular pathway reach higher order cortical areas (parietal and temporal cortices) more rapidly than HSF conveyed by the parvocellular pathway (for further details, see Bullier, 2001). Moreover, numerous behavioural and functional imagery studies using lateralized presentation of altered visual stimuli among healthy individuals as well as brain-damaged patients indicated that there could be a hemispheric asymmetry for LSF and HSF processing (Fink et al., 1996, 1997, 2000; Heinze et al., 1998; Robertson et al., 1988; Sergent, 1982; Wilkinson et al., 2001; Yamaguchi et al., 2000). These data revealed a left visual field/right hemisphere advantage for LSF yet a right visual field/left hemisphere advantage for HSF. This asymmetry takes the form of shorter response times (RTs, of about 30 msec) when detecting LSF in the left than in the right visual field as well as HSF in the right than in the left visual field (see for example, Peyrin et al., 2003). This asymmetry has been reported both for gratings of different spatial frequencies (Jonsson and Helige, 1986) and for filtered images of natural scenes (Peyrin et al., 2003, 2004). However, it seems sensitive to a wide range of factors, including task instructions (Oliva and Schyns, 1997) or time presentation (Peyrin et al., 2006a). In addition, some studies also report a general left visual field (right hemispheric dominance) advantage for visual processing whatever the spatial frequencies of the stimulus (e.g., Kitterle et al., 1990; Peyrin et al., 2006b) suggesting that although both hemispheres do not use exactly the same type of visual information, the right hemisphere may be more sensitive to all spatial frequencies (Rebaï et al., 1998).

Visual processing has been extensively studied regarding hemispheric asymmetries for spatial frequencies in associative cortices and less research has focused on asymmetries regarding the occipital cortex, notably in cerebral stroke patients. Yet, as underlined by Peyrin et al. (2006b), a population of choice to evaluate the implication of the each occipital lobe in visual processing is the one of patients suffering from a Homonymous Hemianopia (HH) following unilateral occipital damage (or a post-chiasmatic lesion). This disorder, in which patients are blind to the contralesional visual field, is particularly disabling regarding visual memory (e.g., Kerkhoff, 2000) but also results in significant deficits in activities of daily living. For example, impairments in visual exploration often result in the discontinuation of driving (Tant et al., 2002). Reading has also been found to be affected in these patients. These hemianopic patients show slowed reading, make several errors, or can even suffer from alexia (e.g., Leff et al., 2006). Given that reading relies largely on the central, detailed vision, it is likely that hemianopic patients experience impairments not only in their contralesional visual field but in their central visual field as well. Yet it is the central and the ipsilesional visual fields of these patients that are usually used in clinical practice and rehabilitation to compensate for their contralesional deficit (see for discussion Chokron et al., 2008). In spite of the classic assumption that these visual fields are perceptually unaffected in hemianopic patients, vision may not be fully intact. For example, it has recently been shown that hemianopic patients are impaired in detecting figures presented in their "intact" visual field (Paramei and Sabel, 2008). Regarding the asymmetry for spatial frequency processing, and thus for the nature of the underlying information, the Paramei et al. study also raises the question of the quality of global and local information processing in the central visual field.

The goals of the present study were three-fold. First we wanted to evaluate the quality of central vision in hemianopia. The scarce reports in the existing literature lead to suggest that there are some anomalies in the central visual field. Moreover, due to the right hemisphere superiority in visual processing (including the occipital lobe), impairments are expected to be greater in left hemianopic/right cerebral stroke patients. Second, we aimed to assess the effect of a lateralized occipital injury on cerebral asymmetry for spatial frequency processing. We expected to observe an LSF processing deficit in left hemianopic patients (with a right occipital lesion), but an HSF processing deficit in right hemianopic patients (with a left occipital lesion) in regard to the occipital asymmetry reported in imaging studies (e.g., Peyrin et al., 2004). Given the fact that at a behavioural level, such asymmetry can be observed when stimuli are presented in lateral visual fields (e.g., Peyrin et al., 2003) and because our study used central presentation, this asymmetry for spatial frequency processing could be attenuated. Finally, the task constraint effects were also evaluated using two tests: detection and categorization tasks of natural scenes images. Detection is the process of finding out the existence of a body or a hidden phenomenon; experimentally, it requires deciding on the presence of an object. Categorization is the ability to discretize physical reality by creating classes containing objects of similar nature; experimentally, it asks to assign exemplars to its corresponding category. According to Kitterle et al. (1990), hemispheric differences are more often found in the identification, but not the detection, of LSF versus HSF. Due to the right hemisphere superiority for visuospatial processing (e.g., Benton and Tranel, 1993), we expected left hemianopic/right cerebral stroke patients to be impaired in both tasks and to a larger extent in the detection task (Peyrin et al., 2006b). However, due to the supposed specialization of the left hemisphere for categorization (Kitterle et al., 1990) we