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Research Report

Improving residual vision by attentional cueing in patients with brain lesions

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ARTICLE INFO

Article history:
Accepted 3 April 2006
Available online 14 June 2006

Keywords:
Visual field defect
Attention focus
Conscious perception
Detection threshold
Functional recovery
Vision restoration

Abbreviations:
ARV, area of residual vision
HRP, high-resolution perimetry

ABSTRACT

Visual attention is crucial for almost all processes of visual perception, particularly when perception is difficult. We were interested in the effects of cueing spatial attention in patients with cerebral lesions who face difficulties in visual perception in areas of residual vision at the border of visual field defects. In 23 patients with visual field loss due to post-geniculate brain lesions, stimulus detection performance and reaction times were mapped with high-resolution computer-based perimetry. A cueing procedure using Gestalt completion to attract attention to areas of residual vision was implemented in this test and performance compared in attended and unattended conditions. Stimulus detection and reaction times in areas of residual vision improved significantly under attended conditions. The extent of this effect depended on the size of areas of residual vision within the cued field. Unexpectedly, facilitation was also observed, though to a lesser extent, in invalid cueing conditions, suggesting an unspecific increase of alertness in unattended areas. Our findings show that top-down influences are relevant for visual field testing. Visuo-spatial attention may change patterns of neural activation and induce short-term plasticity not only in the intact visual system but also in the presence of visual field loss after brain lesions. Attentional cueing induces a co-activation of the lesioned visual system and (intact) attentional networks in the brain inducing immediate facilitation of visual perception. This effect may be relevant for designing new strategies to permanently improve vision during neuropsychological rehabilitation.

1. Introduction

Patients with post-geniculate lesions of the visual system typically suffer from blindness in circumscribed homonymous regions of the visual field of both eyes. In perimetric tests, they often show areas of residual vision (ARVs) at the visual field border (Zihl and von Cramon, 1979; Kasten et al., 1999). Thresholds of light perception are elevated in ARVs, indicated by a reduced probability of detecting supra-threshold stimuli

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0006-8993/$ – see front matter © 2006 Published by Elsevier B.V.
doi:10.1016/j.brainres.2006.04.011

(Fig. 1a), prolonged reaction times (Fig. 1b), and a lower subjective quality of perception compared to stimuli in intact areas (Kasten et al., 1999; Poggel, 2002).

In normally sighted subjects, visuo-spatial cueing of attention enhances performance at the attended location in the visual field by reducing perceptual thresholds. Focusing attention at a specific position improves detection and decreases reaction times in that region (Posner, 1980) and enhances neuronal activity in visual brain areas (Moran and Desimone, 1985; Heinze and Mangun, 1995; Gandhi et al., 1999). The facilitating effects are most prominent under conditions of difficult or ambiguous perception (Poggel, 2002).

Patients with visual field defects face such difficult perceptual situations in ARVs as a result of the brain lesion. We therefore wanted to determine whether focusing visuo-spatial attention at the visual field border would improve their visual performance in partially defective regions. Since most patients do not have an exact topographical representation of their ARVs, a simple verbal instruction cannot reliably induce a precise shift of the attention focus to those locations. Therefore, we adapted a conventional design of attentional cueing (Posner, 1980) to help patients attend to areas at the visual field border. Visuo-spatial attention has been successfully manipulated in normally sighted subjects using direct and symbolic cueing (Posner, 1980, 1995). A direct cue appears at the location where the target is to be presented after some delay. This type of cue induces a topographically precise shift of attention to the target location. However a partially blind patient may not perceive the cue when it is presented in regions of the visual field which have a reduced stimulus detection probability and might thus be unable to shift attention in response to the cue. Symbolic cues, e.g. an arrow pointing towards the left or right, are commonly presented in the center of the visual field and would thus be easily perceptible for hemianopic patients. However, those cues are designed to induce an attention shift to a whole quadrant or hemifield so that the spatial accuracy is not sufficient for moving the focus of attention specifically to the ARVs. With these problems in mind, we designed a cue with both direct and symbolic characteristics that would allow the patient to shift attention reliably and precisely. We used a large square frame positioned over the visual field border which attracted the patient's attention precisely towards the ARVs and blind areas by means of Gestalt-completion into the blind field (Fig. 2).

2. Results

In 23 patients with visual field defects after post-geniculate brain lesions, repeated performance in computer-based visual

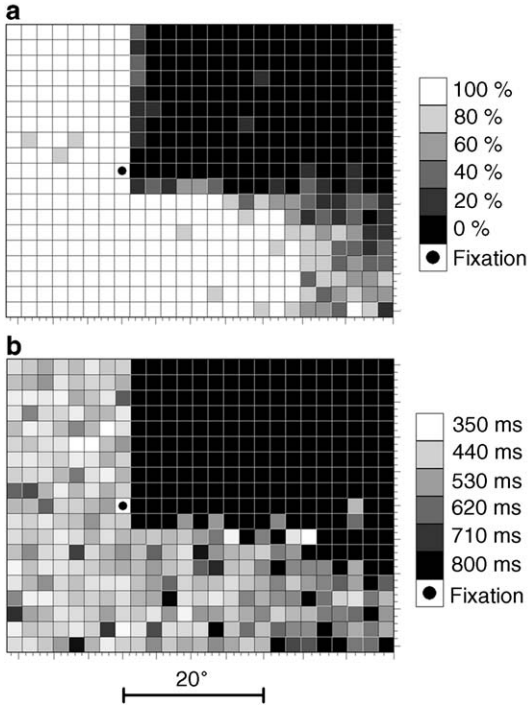

Fig. 1 – Stimulus detection probability and reaction times in areas of residual vision (ARVs). *1a (above):* Stimulus detection performance in five successive superimposed HRP tests in a patient with incomplete right hemianopia. In the upper visual field, there is an abrupt transition between intact and blind areas. In contrast, the visual field border is diffuse with a large ARV in the lower right part of the visual field. White = intact (stimulus detected in all five trials); black = blind (no detection in five trials); grey = ARV (20%–80% detection). *1b (below):* Reaction times of the same patient, measured in one HRP test. The response times were almost equally distributed in the left (intact) field. However, in the ARV in the lower right visual field, reaction times were markedly slower than in the corresponding region in the intact field. Shades of gray reflect reaction times.