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Visual field asymmetries in selective attention: Evidence from a modified search paradigm

George A. Michael *, Nathalie Ojéda

Université Lumière – Lyon 2, Laboratoire d'Étude des Mécanismes Cognitifs, 5, Avenue Pierre Mendès-France, 69676 Bron, Cedex, France

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Abstract

The present study investigated visual field differences in selective attention. Five stimuli were briefly presented and subjects were asked to identify a predefined target. The target/distractor physical similarity varied systematically (low, medium or high) in order to encourage attentional resolving. Right/left hemifield differences were examined in Experiment 1, temporal/nasal hemifield differences in Experiment 2, and upper/lower hemifield differences in Experiment 3. Visual field differences were found only in Experiment 1 suggesting a left/right hemispheric asymmetry in selective attention. These asymmetries appear with increasing stimuli similarity, and suggest that each hemisphere gets involved when attentional selection cannot be carried out without the mode of information processing that characterizes that hemisphere. The absence of other hemifield asymmetries is not in favor of neither a subcortical, nor a specific superior occipito-parietal involvement in attentional resolving and selectivity.

Keywords: Visual selective attention; Stimuli similarity; Visual field asymmetries; Visual search; Hemispheric asymmetry; Temporal/nasal asymmetry; Upper/lower asymmetry

Our visual world is made of cluttered scenes where behaviorally relevant information (i.e., target) is intermixed with irrelevant stimuli (i.e., distractors). Attention is required in order to carry out selection, through processes such as resolving of information sources for identifying components of that cluster [14]. One way to investigate the neural bases of such processes is to examine visual field asymmetries. Three different visual field asymmetries have been reported in the literature.

Right/left hemifield asymmetries: The right field/left field (RVF/LVF) is the most frequently reported asymmetry, thought to reflect hemispheric differences. The major question is whether both hemispheres participate in selective attention and whether they function in the same way. In a visual search task, Luck et al. [17] found that bilateral displays were scanned at a faster rate by split-brain subjects, than by healthy controls. They suggested that there might exist independent hemispheric systems, each one being able to deploy the focus of attention over the contralateral hemifield. Arguin et al. [1] provided evidence that the mode and speed of search of each hemisphere does not differ. Nevertheless, several studies suggest that visual field differences in attention are observable only with increasing task demands [11], that the left hemisphere is less efficient than the right hemisphere in the analysis of degraded or blurred stimuli [21], and that the left hemisphere is involved in the processing of details, whereas the right hemisphere is specialized in the analysis of global aspects of the image. For instance, there is clinical evidence that right-hemisphere patients attend poorly to the global aspects of a compound stimulus (a big figure made of small figures), whilst left-hemisphere patients to the local aspects [6,16]. On the other hand, clinical and experimental data suggests that the right hemisphere controls attentional processing of the entire visual field, whilst the left hemisphere exerts only contralateral control [11,19]. When the right hemisphere's mechanisms are damaged, the left part of space remains without attentional control. This is manifested through the neglect syndrome [19]. In overall, the right hemisphere seems specialized in the analysis of large portions of

* Corresponding author. Tel.: +33 4 78 77 43 95; fax: +33 4 78 77 43 51.
E-mail address: George.Michael@univ-lyon2.fr (G.A. Michael).

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the visual field [11,19] and, may be because of this specificity, it is also specialized in the analysis of global configurations [16]. We may thus hypothesize that RVF/LVF asymmetries would appear with increasing task demands, and the specific pattern of results within each visual hemifield would reflect the abilities of each hemisphere to analyze preferentially local or global aspects of the display.

Temporal/nasal visual hemifield asymmetries: The temporal field/nasal field (TVF/NVF) asymmetry may be observed under monocular viewing conditions. Several studies found a dominance of the temporal hemifield in tasks of attention, thought to occur because of the dominant numerical representation of the temporal hemifield in subcortical relays of visual information, such as the superior colliculus and the pulvinar [13]. This asymmetrical representation is also attested by the abolishment of the temporal dominance following lesions of the pulvinar [27]. Such TVF/NVF asymmetries were frequently investigated in studies involving spatial orienting, but not attentional resolving. According to some theoretical accounts [14,15], the subcortical mechanisms need time to perform resolution operations on components of a stimulus cluster. Yet, these mechanisms cannot function correctly when clusters are briefly presented (as the one used here), and enhancement therefore concerns both target and non-target information. We may thus hypothesize that since the temporal field dominance reflects asymmetrical subcortical innervation [13,27]; since stimuli similarity increases attentional demands and the need for resolving [8,14]; and since subcortical mechanisms – being unable to correctly operate resolving on brief displays – enhance the whole cluster, then, with increasing need for attentional resolving, decrement in performance will be sharper for temporal than nasal displays. Not all neuropsychological evidence favors this hypothesis, since no deficits of this process were found following lesions of the pulvinar [5,20]. Experiment 2 may thus offer some interesting data on this issue.

Upper/lower visual hemifield asymmetries: Some visual attributes, such as orientation and size, are processed more finely in the lower visual field (LwVF) [24]. This asymmetry seems to concern attentional processing too, since it was suggested that attentional resolution is not uniform in the visual field, but finer in the LwVF [12]. Such differences were found in tasks requiring serial visual search for conjunction, and only when the stimulus display was restricted to the LwVF [10,12]. The LwVF advantage in attentional resolution may be due, at least partly, to the fact that the LwVF is represented in the upper part of the primary visual cortex, which projects more heavily into the posterior parietal cortex [18] that is often linked to spatial attention. Such neuroanatomical arrangements may play a critical role in attention, since impairments of the selective allocation of attentional resources to the lower part of the visual space, giving rise to altitudinal neglect, were reported after bilateral posterior parietal lesions [25]. Thus, if neurons in the superior portion of the posterior parietal cortices have a finer attentional resolution, then one might expect that UVF/LwVF differences increase with increasing task demands, with performance decreasing less sharply in the LwVF because of its fine attentional resolution [12].

In light of this evidence, visual hemifield asymmetries may be expected in a task of visual selective attention. The goal of the present study was to investigate RVF/LVF asymmetries (Experiment 1), TVF/NVF asymmetries (Experiment 2), and UVF/LwVF asymmetries (Experiment 3), respectively, using the same modified visual search task. Subjects were asked to identify a briefly presented target embedded among distractors. Since “one important requirement (for attentional resolving) is that the distractor be similar to the target” ([14]; p. 156), the critical manipulation was the target-distractors physical similarity, known to influence attentional demands [8]. Performance is expected to decrease with increasing task demands [8], and visual field differences are expected to be more pronounced in high attentional demanding conditions, at least as far as RVF/LVF differences [11] and TVF/NVF differences [15] are concerned.

Subjects: A total of 54 healthy volunteers participated in the present study: 14 (10 female and 4 male; mean age 20.8 ± 2.1 years) in Experiment 1, 24 in Experiment 2 (20 female and 4 male; mean age was 21 ± 2.7 years), and 16 in Experiment 3 (14 female and 2 male; mean age 21.8 ± 3.7 years). All subjects were right-handers, as assessed with the Edimburg inventory [23], and all had normal or corrected-to-normal vision.

Stimuli and apparatus: Stimuli were symbols made of a vertical and a horizontal, deep gray lines (5.04 cd/m^2) arranged perpendicularly. At a viewing distance of 54 cm, each stimulus subtended $0.53^\circ \times 0.53^\circ$ of visual angle. The distance between the fixation sign and each stimulus was 2.3° of visual angle, and the distance between two adjacent items was 1.6°. The distance of 2.3° was chosen because, during preliminary settings, it came out that the small differences between the stimuli was difficult to detect outside the fovea ($>3^\circ$), giving rise to near-chance performance. In Experiments 1 and 2, the stimuli were arranged on an imaginary arc: 30, 60, 90, 120 and 150° clockwise for the right side displays, and anticlockwise for the left side displays. The target stimulus was either an upright or an inverted T. Distractor stimuli were constructed by displacing the vertical line on the left or the right from the middle of the horizontal line. This manipulation resulted in distractors that shared the same basic features as the target and had low, medium or high physical similarity with the latter (Fig. 1): a 3-pixel displacement resulted in crosses, with the vertical line being slightly displaced from the center (*low similarity*); a 6-pixel displacement resulted in T-like crosses with the vertical line being slightly displaced from the edges of the horizontal line (*medium similarity*); finally, a 9-pixel displacement resulted in Ts (*high similarity*). In Experiment 3, the stimuli were the same as in Experiments 1 and 2, except that they were tilted 90° clockwise (Fig. 1). The target was either a left or a right pointing T. All stimuli were arranged on an imaginary arc: -60, -30, 0, +30 and $+60^\circ$ to the vertical plane for upper