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Vertical asymmetries in pre-attentive detection of changes in motion direction

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Abstract

Stimulus localization affects visual motion processing. Vertical asymmetries favouring lower visual field have been reported in event-related potentials (ERPs) and behavioural studies under different attention conditions. However, there are no studies examining such asymmetries to non-attended motion changes. The present study investigated whether the asymmetry in processing information from the upper and lower visual fields also affects the automatic detection of motion-direction changes as indexed by visual Mismatch Negativity (vMMN). We recorded vMMN to changes in sinusoidal gratings differing in motion direction presented in the periphery of visual field in three different locations: upper and lower (ULVF), upper (UVF) and lower (LVF) along the vertical meridian. The N2 component elicited to peripheral motion presented lower amplitudes when the UVF was stimulated. The vMMN elicited to infrequent motion-direction changes was present in all stimulation conditions. However, it was reduced to UVF stimulation. These results suggest that the visual system automatically detects motion-direction changes presented at both upper–lower visual fields; however they also indicate that the process is favoured when stimuli are presented in the LVF alone.

Keywords: Visual evoked potentials; Motion-direction changes; vMMN; Upper/lower hemifield stimulation

1. Introduction

Human visual processing depends on the location of information in the visual field. Behavioural studies have found vertical asymmetries favouring the lower visual field (LVF) in contrast-sensitivity (Cameron et al., 2002; Carrasco et al., 2002), spatial resolution (Carrasco et al., 2002; Rezec and Dobkins, 2004), orientation (Raymond, 1994) and hue (Levine and McAnany, 2005). Neurophysiological studies have also confirmed the higher sensitivity of the LVF to contrast patterns (Portin et al., 1999), high contrast checkerboards (Fioretto et al., 1995), and non-attended colour changes (Czigler et al., 2004).

Lower–upper visual field asymmetries have also been found in motion processing (see Christman and Niebauer, 1997 for a review). Employing behavioural measures, a LVF advantage has been found in sensitivity to motion in depth (Edwards and Badcock, 1993), sensitivity to chromatic motion (Bilodeau and Faubert, 1997), discrimination thresholds for motion (Rezec and Dobkins, 2004), lateral motion perception (Levine and McAnany, 2005), anisotropy in motion coherence thresholds for upwards and downwards movement (Raymond, 1994), and for moving targets embedded in static distracters demanding segmentation by motion (Lakha and Humphreys, 2005). Finally, in a motion-onset visual evoked potential (VEP) study, Kremláček et al. (2004) found greater amplitudes and shorter latencies when the LVF was stimulated.

Vertical asymmetries have been interpreted in terms of attentional mechanisms, suggesting a higher attentional resolution in the LVF, especially in crowding paradigms or when the attentional load is manipulated (He et al., 1996). However, visual sensory constraints may also contribute to these asymmetries and therefore the LVF advantage cannot be solely explained by attentional biases across the visual field (Levine and McAnany, 2005). Moreover, upper visual field (UVF) advantages have been shown in various visual tasks such as visual search (Previc and Blume, 1993), and object recognition (Chambers et al., 1999).

Most studies have examined visual field asymmetries employing experimental conditions that required different degrees of attention. In motion processing there are no studies

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having examined these upper–lower differences under non-attention conditions. Previous studies (Pazo-Alvarez et al., 2004a,b) have shown that it is possible to record an electrophysiological response to changes in motion direction, the visual Mismatch Negativity (vMMN), which indexes the ability of the human brain to pre-attentively detect those changes. Moreover, a vMMN to changes in motion direction has been recently obtained in an independent laboratory (Kremláček et al., 2006) confirming the existence of such automatic detection mechanism for motion stimulation. In this context, the present study aimed to investigate whether the asymmetry in processing information from UVF and LVF also affects the pre-attentive detection of motion-direction changes.

2. Materials and methods

Twelve healthy subjects (7 females, 5 males, 25.3 ± 4.75 years, range 18–35) with normal or corrected-to-normal vision participated in the experiment. Subjects gave informed consent to participate in this study.

To assess the effects of upper and lower visual field stimulation on the automatic processing of infrequent changes in motion direction, we presented upper (UVF), lower (LVF), or simultaneous upper–lower (ULVF) visual field stimulation in separate conditions (one block per condition). Stimuli consisted in sinusoidal gratings differing in the direction of motion placed in the periphery (10.70° to the center of the grating) of the visual field (1 cd/m^2 mean luminance). The gratings (20% contrast, 0.70 c/degree of spatial frequency, 4.13° of visual angle, 17 cd/m^2 mean luminance) were presented in oddball sequences of repetitive upward ($p=0.8$) and infrequent downward-drifting gratings ($p=0.2$). Gratings drifted with a speed of 1.95°/s for 133 ms and were followed by a blank screen interstimulus interval of 665 ms (mean luminance 1 cd/m^2). Frequent and infrequent stimuli were presented randomly with the restriction that at least one standard motion direction would occur before each deviant motion direction.

Subjects were requested to ignore the peripheral gratings and to keep their eyes in a small fixation cross placed at the centre of the visual field. Over this point one of nine possible digits (i.e., 1 to 9; 1.03° height and 0.66° width of visual angle) was equiprobably presented in three different colours (red, green and blue) for 40 ms. Subjects were required to press the left button of a standard mouse with their left hand in response to odd numbers (except 9, that required no response), and the right button with their right hand in response to even numbers, as rapidly and accurately as possible. Assignment of response keys and the order of stimulation conditions were counterbalanced across subjects. Each experimental block consisted of 770 trials (500 trials corresponded to task-irrelevant gratings, 400 frequent and 100 deviant, and 270 to task-relevant digits). Digits and gratings alternated asynchronously. All stimuli were presented with a stimulus onset asynchrony (SOA) of 798 ms.

Reaction times (RTs) were on-line recorded for each trial, and hit rates were defined as the percentage of correct responses to target digits with RTs no longer than 798 ms. RTs were analyzed for hits only. Hit rates and mean RTs were compared across conditions using repeated-measures ANOVA with condition (UVF, LVF, ULVF) as the within-subject factor.

The electroencephalogram (EEG) was recorded with a NeuroScan system using scalp electrocaps (ECI, Inc.) with electrodes placed at FP1, FPz, FP2, F3, Fz, F4, F7, F8, FCz, C3, Cz, C4, CP3, CPz, CP4, P3, Pz, P4, T3, T4, T5, T6, PO3, POz, PO4, O1, Oz, and O2 (10/20 International System). Two extra electrodes were fixed to the scalp, located halfway between O1 and T5 (OL), and O2 and T6 (OR). The active electrodes were referred to the nose-tip and grounded with an electrode at the nasion. Electrical activity elicited to vertical and horizontal eye movements was monitored by EOG recorded bipolarly from above and below the left eye and from the outer canthi of both eyes. EEG was acquired as continuous signals digitized at 500 Hz and filtered on-line with a bandpass of 0.05–100 Hz. Trials with eye blinks, eye movements, or exceeding ±100 μV were excluded from analyses. EEG epochs (500 ms post-stimulus and 50 ms pre-stimulus) were obtained off-line and averaged separately for standard and deviant gratings in each subject and condition. Averages were off-line filtered between 0.1 and 30 Hz.

To sample possible differences between the event-related potentials (ERPs) elicited to standard and deviant gratings, we analyzed successive mean voltage values over separate regions of the scalp. Thus, mean amplitudes of the ERP waveforms were measured separately across consecutive 20 ms latency windows within a 105 and 225 ms latency range. Analyses were restricted to this latency range at occipital (OL, O1, Oz, O2, OR), parieto-occipital (PO3, POz, PO4) and temporal (T5, T6) locations. This decision was based on previous results (Pazo-Alvarez et al., 2004a) showing that the reliable difference between deviant and standard ERPs was located at these time ranges and scalp derivations. For each latency window mean amplitude values were entered into separate repeated-measures ANOVAs with factors of condition (UVF, LVF, ULVF), deviance (standard, deviant) and hemisphere (left, right) at the above detailed electrodes.

Difference waveforms (vMMN) were obtained for each subject and condition by subtracting the ERPs elicited to standard from those elicited to deviant stimuli. In the resulting waves, mean amplitude values were calculated separately across consecutive 20 ms latency windows within the above referred time range. One-sample t tests were used to determine whether the obtained mean amplitudes were significantly different from zero (alpha level 0.05). The hemispheric differences in scalp distribution of vMMN and among stimulation conditions were analyzed using repeated-measures ANOVAs with the within-subject factors of condition (UVF, LVF, ULVF) and hemisphere (left, right) at the same occipital, parieto-occipital and temporal electrodes. When appropriate, degrees of freedom were corrected using the Greenhouse–Geisser estimate. Post hoc comparisons were performed using the Bonferroni adjustment for multiple comparisons (alpha level 0.05).

Moreover, voltage maps were computed for both the ERPs elicited by standard and deviant gratings, and for vMMN. EEGLAB open source toolbox (Delorme and Makeig, 2004), which plots topographic maps of EEG fields as a 2D