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Hemispheric asymmetries for temporal information processing: Transient detection versus sustained monitoring ☆

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Abstract

This study investigated functional differences in the processing of visual temporal information between the left and right hemispheres (LH and RH). Participants indicated whether or not a checkerboard pattern contained a temporal gap lasting between 10 and 40 ms. When the stimulus contained a temporal signal (i.e. a gap), responses were more accurate for the right visual field-left hemisphere (RVF-LH) than for the left visual field-right hemisphere (LVF-RH). This RVF-LH advantage was larger for the shorter gap durations (Experiments 1 and 2), suggesting that the LH has finer temporal resolution than the RH, and is efficient for transient detection. In contrast, for noise trials (i.e. trial without temporal signals), there was a LVF-RH advantage. This LVF-RH advantage was observed when the entire stimulus duration was long (240 ms, Experiment 1), but was eliminated when the duration was short (120 ms, Experiment 2). In Experiment 3, where the gap was placed toward the end of the stimulus presentation, a LVF-RH advantage was found for noise trials whereas the RVF-LH advantage was eliminated for signal trials. It is likely that participants needed to monitor the stimulus for a longer period of time when the gap was absent (i.e. noise trials) or was placed toward the end of the presentation. The RH may therefore be more efficient in the sustained monitoring of visual temporal information whereas the LH is more efficient for transient detection.

Keywords: Hemispheric asymmetries; Temporal information processing; Visual half-field technique

1. Introduction

There is a growing consensus that the left hemisphere (LH) has a capacity for finer visual temporal resolution than does the right hemisphere (RH). The LH advantage in temporal resolution has been found for a broad range of tasks, including: Flicker fusion (Goldman, Lodge, Hammer, Semmes, & Mishkin, 1968), perception of simultaneity (e.g. Efron, 1963; Nicholls, 1994a, 1994b), temporal gap detection (Nicholls, 1994a, 1994b), inspection time (Elias, Bulman-Fleming, & McManus, 1999; Nicholls & Cooper, 1991; Okubo & Nicholls, 2005) and temporal order judgments (Swisher & Hirsh, 1972). The LH temporal processing advantage is also observed within the auditory and tactual modalities (Nicholls, 1996).

While the majority of temporal processing tasks yield a reliable LH advantage, there are notable exceptions. For example, Funnell, Corballis, and Gazzaniga (2003) required a split-brain patient to report whether the offset of two circles was simultaneous or not. For offset asynchronies ranging from 35 to 59 ms, a consistent left visual field (LVF) (hence RH) advantage was observed. This result contrasts with the data reported by Nicholls (1994a). In this case, normal participants judged whether the onset of two LEDs was simultaneous or successive. For stimulus onset asynchronies ranging from 10 to 25 ms, a consistent right visual field (RVF) (hence LH) advantage was observed.

One could argue that the results of Funnell et al. (2003) are specific to split-brain populations and are therefore

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not typical of the broader population. It is possible, however, that the discrepancy reflects more interesting methodological differences between the studies. One such difference relates to whether the simultaneity judgment was made for the offset or the onset of the stimuli. In the study by Funnell et al. (2003), participants detected the *offset* of a stimulus within a 250 ms presentation period. Thus participants were required to monitor the stimulus and to withhold their response. In contrast, Nicholls (1994a) required participants to detect differences in the *onset* of two stimuli. This version of simultaneity judgment did not require sustained monitoring or response restraint. In addition, the asynchronies in offset/onset between the stimuli are shorter in Nicholls (1994a) (10–25 ms) than Funnell et al. (2003) (35–59 ms). Bearing these points in mind, the critical difference between the two studies may be the period of time over which the stimuli are presented. Thus, the study by Funnell et al. (2003) may have been better suited to *sustained monitoring*, which can be defined as an ability to monitor relatively slow or sustained temporal change occurring over time. In contrast, the study by Nicholls (1994a) may have better suited to *transient detection*, which can be defined as an ability to detect rapid or transient temporal change in a visual scene.

If the capacity for sustained monitoring and transient detection were differentially lateralized, it could explain the discrepancy between the studies by Funnell et al. (2003) and Nicholls (1994a). To investigate this issue, we conducted three visual half-field experiments using a temporal gap detection task to test the hypothesis that the LH and RH are specialized in transient detection and sustained monitoring, respectively.

According to the previous studies (Nicholls, 1994a, 1994b), the transient detection mechanisms in the LH may be better suited to process 10–25 ms temporal differences in the gap detection task. On the other hand, the sustained monitoring may be better suited to process much longer period of time. The time course of *visual sustained attention*, which is defined as a voluntary allocation of visual attention usually induced slowly by symbols (e.g. an arrow) and/or instruction, may provide critical information for the temporal characteristics of sustained monitoring because the allocation of visual sustained attention is indispensable to monitor the event lasting for relatively long time. Using Posner's (1980) attentional cueing paradigm, Müller & Rabbitt, (1989) examined the time course of visual sustained attention, and found that the facilitative effect of sustained attention arose around 100 ms after the onset of an attentional arrow cue. The size of facilitation steadily increased until at 275 ms after the cue onset, and kept a stable level for a longer period of time. In Müller & Rabbitt, (1989), the attentional cue was virtually ineffective at 100 ms but was effective at 175 ms. It is therefore reasonable to assume that the sustained monitoring is effective 175 ms after an onset of an event.

2. Experiment 1

In Experiment 1, gap duration was varied from 10 to 40 ms in a visual stimulus lasting 240 ms. For the detection of temporal signals (i.e. a gap), a RVF-LH advantage was predicted because the task requires fine temporal resolution. This RVF-LH was expected to be especially pronounced for the shorter gap durations. In contrast, the detection of noise trials (i.e. trials without gaps) required participants to monitor the stimulus for 240 ms. This sustained monitoring was expected to favor the processing style of the RH—leading to a LVF-RH advantage.

2.1. Methods

2.1.1. Participants

Twenty-five right-handed university students ($F = 20$, $M = 5$) participated as a part of their course requirement. All of them had normal or corrected-to-normal visual acuity. Handedness was assessed with the Edinburgh Handedness Inventory (Oldfield, 1971).

2.1.2. Apparatus

A Sony G420 19-inch CRT monitor (Refresh rate = 100 Hz) and an Apple Power Macintosh G3/266 MHz personal computer were used to present the stimuli and record participants' responses. The experiment was controlled by Matlab with Psychophysics Toolbox extensions (Brainard, 1997; Pelli, 1997). A ten-key pad (Sanwa Supply NT-MAC 2) was connected to the computer and served as a four-key response console.

2.1.3. Design

The experiment was a 2 (Visual Field: LVF-RH or RVF-LH) × 3 (gap duration: 10, 20 or 40 ms) × 2 (Stimulus Status: signal or noise) factorial design. All variables were manipulated within participants. Gap duration was varied between blocks to provide a consistent point of reference for discriminating signal (i.e. gap) and noise (i.e. no gap) trials. A consistent context for noise trials alongside signal trials allowed us to analyze the effect of gap duration for both types of trials. The dependent variable was percentage of correct responses. A signal detection analysis was used to assess sensitivity and response bias.

2.1.4. Stimuli

A bright and dark checkerboard pattern was parafoveally presented against a gray background (10.33 cd/m^2) through a circular aperture of 4.8 degree of visual angle (deg). Luminance of the bright and dark checks was 19.33 and 0.03 cd/m^2, respectively. Each check subtended 0.26 deg in size. The centermost edge of the checkerboard was 2.4 deg away from the fixation point (0.3 deg), which was presented at the center of the display.

For the signal stimuli (i.e. the gap was present), the checkerboard was presented twice in succession, separated by variable gap durations (10, 20, or 40 ms). The