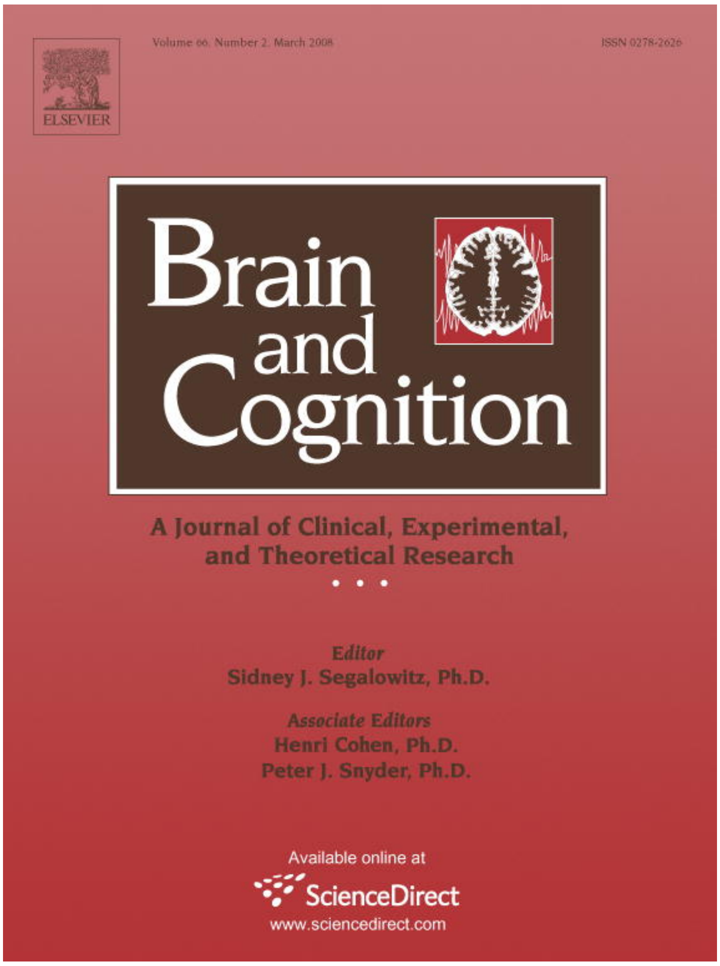
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Hemispheric asymmetries for temporal information processing: Transient detection versus sustained monitoring ☆

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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 duration of the first checkerboard presentation was 120 ms irrespective of the gap duration. The duration of second presentation, however, varied with respect to the gap duration (110, 100, and 80 ms for the 10, 20, and 40 ms gap durations, respectively). For the noise stimuli (i.e. the gap was absent), the checkerboard was presented continuously for 240 ms. Therefore, the entire stimulus duration was 240 ms irrespective of whether a gap was presented or not.

2.1.5. Procedure

Participants were seated in a dark room approximately 570 mm away from the display with their head positioned on a chinrest. Prior to the experiment, participants were adapted to the mean luminance of the display for 5 min. Each trial began with the onset of a fixation point, followed by the checkerboard pattern, which was presented either to the LVF-RH or RVF-LH. Participants indicated whether or not they saw a temporal gap during the stimulus presentation by pressing two keys simultaneously with their index or middle fingers of both hands (i.e. participants responded bimanually). The finger-response mapping was counterbalanced across participants. Importance of response accuracy, not response speed, was stressed. The trial was automatically terminated if there was no response within 2500 ms. Participants directed their gaze toward the fixation point until after they had made their responses. Eye movements were monitored on-line via a CCD camera with an infrared lens.

Participants received a total of 288 trials, which were divided into six blocks of 48 trials. The gap durations were blocked, with two blocks for each of the gap durations (10, 20, 40 ms). There were 12 repetitions of the orthogonal combinations of two visual fields, and two stimulus status conditions within a block. The presentation order of the blocks was randomized between participants. Participants were shown the stimuli prior to the experiment and were given 12 practice trials.

2.2. Results

Trials exhibiting changes in eye position (0.8% of all the trials) were excluded from the statistical analyses. For each participant, percentage of correct responses was computed for the 12 experimental conditions described in Section 2.1.3. Table 1 shows the mean percent correct for each of the conditions. The data were subjected to a 2 (Visual Field: LVF-RH vs. RVF-LH) × 3 (gap duration: 10, 20, or 40 ms) × 2 (stimulus status: signal vs. noise) repeated measures analysis of variance (ANOVA). Accuracy increased with longer gap durations, $F(2,48) = 11.60$, $p < .001$. Responses were significantly more accurate for the noise condition than for the signal condition, $F(1,24) = 8.48$, $p = .007$. There was a two-way interaction between visual field and gap duration, $F(2,48) = 3.49$, $p < .03$, reflecting a RVF-LH advantage for the shortest gap duration and a LVF-RH advantage for the longer durations. This two-way interaction was qualified by a three-way interaction between visual field, gap duration and stimulus status, $F(2,48) = 8.89$, $p < .001$. Other two-way interactions were all significant, $F\text{s} > 8.70$, $p\text{s} < .006$.

To clarify the three-way interaction, a separate ANOVA was conducted for each stimulus status condition. For the signal stimuli, an interaction between visual field and gap duration was significant, $F(2,48) = 10.74$, $p < .001$. There was a significant RVF-LH advantage for the 10-ms gap duration, $t(24) = 3.59$, $p = .001$, but not for the other gap durations, $p\text{s} > .16$. For the noise stimuli, responses were more accurate for the LVF-RH than for the RVF-LH, $F(1,24) = 6.25$, $p = .02$.

The results of a signal detection analysis are shown in Table 2. Sensitivity and response bias were measured as d' and c, respectively (Macmillan & Creelman, 1991). Sensitivity and response bias data were analyzed with repeated measures ANOVAs with visual field and gap duration as factors. A main effect of gap duration was significant for d', $F(2,48) = 5.99$, $p = .004$, and for c, $F(2,48) = 10.41$,

Table 1
Mean percentage of correct responses (%) as a function of visual field, gap duration (ms) and stimulus status for the temporal gap detection across Experiments 1–3

Experiment	Gap duration	Stimulus status			
		Signal		Noise	
		LVF-RH	RVF-LH	LVF-RH	RVF-LH
Experiment 1	10	79.27 (3.68)	86.67 (3.30)	96.99 (1.09)	92.95 (2.16)
	20	96.30 (0.81)	94.12 (1.65)	97.15 (0.75)	95.62 (1.40)
	40	97.46 (0.69)	97.83 (0.84)	97.13 (0.67)	95.56 (1.14)
Experiment 2	10	81.88 (3.54)	86.87 (3.00)	93.62 (1.21)	93.14 (1.74)
	20	93.16 (1.50)	95.79 (1.17)	93.14 (1.44)	93.00 (1.46)
	40	92.24 (1.89)	94.18 (1.33)	91.09 (2.10)	91.76 (1.70)
Experiment 3	10	89.31 (3.23)	90.86 (2.64)	97.92 (1.14)	95.30 (1.19)
	20	92.97 (3.22)	92.95 (1.60)	97.91 (0.76)	92.69 (2.00)
	30	95.83 (2.38)	95.31 (1.07)	97.92 (0.66)	94.01 (1.52)

Standard errors are shown in parentheses.

Table 2
Measures of d' (sensitivity) and c (response bias) for the temporal gap detection task as a function of visual field, gap duration (ms) across Experiments 1–3

Experiment	Gap duration	d'		c	
		LVF-RH	RVF-LH	LVF-RH	RVF-LH
Experiment 1	10	4.32 (0.47)	4.60 (0.44)	0.77 (0.47)	0.35 (0.44)
	20	5.40 (0.36)	5.47 (0.44)	0.20 (0.35)	0.34 (0.44)
	40	5.74 (0.38)	5.80 (0.41)	0.02 (0.38)	−0.19 (0.41)
Experiment 2	10	3.48 (0.34)	4.21 (0.41)	0.38 (0.17)	0.39 (0.19)
	20	4.49 (0.39)	4.86 (0.40)	0.12 (0.18)	−0.06 (0.17)
	40	3.93 (0.35)	4.39 (0.41)	0.02 (0.16)	−0.05 (0.16)
Experiment 3	10	5.46 (0.52)	4.26 (0.52)	0.83 (0.16)	0.40 (0.18)
	20	5.22 (0.47)	4.85 (0.54)	0.65 (0.19)	−0.05 (0.24)
	40	5.35 (0.44)	5.16 (0.49)	0.46 (0.21)	−0.27 (0.22)

Standard errors are shown in parentheses.

$p < .001$. The d' value increased with longer gap durations while the c value decreased with duration. Neither a main effect of visual field nor an interaction between visual field and gap duration was significant for d' or c, $F\text{s} < 1.46$.

2.3. Discussion

The three-way interaction between visual field, gap duration, and stimulus status for the accuracy data support dissociation between the hemispheres for sustained monitoring and transient detection. A RVF-LH advantage was observed for the signal stimuli that contained a gap with a short duration. This type of stimulus would be suited to a transient detection system, which may be located in the LH. For the noise stimuli, a LVF-RH advantage was observed. These stimuli would require monitoring for a longer period of time and may therefore be better suited to a sustained monitoring system located in the RH.

One might argue that the present results can be explained in terms of response bias. For example, if the LH and RH employed generous and conservative response criteria, a RVF-LH and LVF-RH advantage would be observed for the gap-present and gap-absent conditions, respectively. The results of the signal detection analysis, however, do not support this interpretation. The response bias (c) did not differ between visual fields. For both visual fields, participants adopted a slightly conservative criterion on average ($M = 0.25$), which decreased with gap duration.

3. Experiment 2

Experiment 1 assumed that the prolonged stimulus duration (240 ms) would place *more* demand on sustained monitoring for the noise trials because participants needed to monitor the stimuli for a longer period of time. Following this logic, shorter stimulus durations should place *less* demand on sustained monitoring for the noise trials. To test this hypothesis, this study reduced stimulus duration to 120 ms. If the asymmetry is determined by stimulus duration, the LVF-RH advantage for the noise condition should be attenuated or eliminated. The short durations, however, should suit the transient detection mechanisms in the LH, leading to a replication of the RVF-LH advantage for the shorter gaps in the signal trials.

3.1. Methods

Experiment 2 was conducted in the same manner as Experiment 1 unless otherwise noted. Participants were 25 right-handed university students ($F = 21$, $M = 4$), none of whom took part in Experiment 1.

For the signal trials, the duration of the first checkerboard presentation was 60 ms irrespective of the gap duration. Following gap periods of 10, 20, and 40 ms, the second checkerboard stimulus was presented for a period of 50, 40, and 20 ms (respectively). For the noise trials, the checkerboard was presented continuously for 120 ms.

3.2. Results

Results were processed in the same manner as Experiment 1. Trials exhibiting changes in eye position (0.5% of all the trials) were excluded from the statistical analyses. Table 1 shows the mean percentage of correct responses. Accuracy increased with gap duration, $F(2, 48) = 6.24$, $p = .002$. The main effect of gap duration was observed for the signal trials but not for the noise trials, resulting in an interaction between visual field and stimulus status, $F(2, 48) = 9.52$, $p < .001$.

Responses were significantly more accurate for the RVF-LH than for the LVF-RH, $F(1, 24) = 5.27$, $p = .03$. While there is some suggestion that the RVF-LH advantage was present for signal trials, but not for noise trials, the interaction between visual field and stimulus status failed to reach significance, $F(1, 24) = 2.73$, $p = .11$. Although post hoc tests should not be carried out without higher-order interactions, the effect of visual field was investigated separately for the signal and noise conditions because of its theoretical importance. Analysis of the signal condition revealed that responses were more accurate in the RVF-LH than in the LVF-RH, $F(1, 24) = 6.01$,

$p = .02$. In contrast, there was no visual field asymmetry for the noise condition, $F < 1.00$.

Results of signal detection analyses are shown in Table 2. The RVF-LH advantage for sensitivity (d') approached significance, $F(1,24) = 3.21$, $p = .08$. Response bias, as measured by c, showed no main effect of visual field $F < 1.00$, though c values did decline with decreases in gap duration, $F(2,48) = 10.41$, $p < .001$.

3.3. Discussion

Experiment 2 replicated the RVF-LH advantage for the signal condition observed in Experiment 1. Like Experiment 1, the RVF-LH advantage was more pronounced for the shorter gap durations. Unlike Experiment 1, there was no sign of a LVF-RH advantage for the noise trials. In the present experiment, the entire duration was shortened so the stimuli were less amenable to sustained monitoring and more suited to transient detection. This change in temporal properties appears to have brought about a shift away from a LVF-RH processing advantage. Like Experiment 1, the signal detection analysis demonstrated that the asymmetry is the result of an asymmetry in threshold, and not a change in response criterion.

4. Experiment 3

In contrast to Experiment 2, which made *less* demand on sustained monitoring, Experiment 3 made *more* demand on it. As was the case for Experiment 1, the exposure duration was 240 ms. Unlike the first two experiments, however, the gap was placed toward the end of the stimulus presentation rather than in the middle (i.e. a 60 ms shift in the gap onset from Experiment 1 to Experiment 3). Because of this 60 ms shift, more observation time would be needed to detect a gap in the signal stimulus. It is anticipated that increased observation times would increase the need for sustained monitoring, rendering the signal stimuli less amenable to the LH's transient detection system. A reduction or annulment of the RVF-LH advantage was therefore predicted for the signal trials. For the noise trials, which replicated the noise condition in Experiment 1, a LVF-RH advantage was expected.

4.1. Methods

Experiment 3 was conducted in the same manner as Experiment 1 unless otherwise noted. Participants were 16 right-handed university students ($F = 8$, $M = 8$). None of them took part in Experiments 1 and 2.

A Sony 19PS CRT monitor (Refresh rate = 100 Hz) and an Apple Power Macintosh G4/800 MHz personal computer were used for presentation of stimuli and for recording participants' responses. A ten-key pad (Sanwa Supply NT-M5UW) was connected to the computer and served as a four-key response console.

The overall duration of the signal and noise stimuli was 240 ms. In the gap-present condition, there were two presentation of the checkerboard stimuli, separated by a temporal gap. The temporal position of the gap was shifted 60 ms after the middle of the centre. Thus, the duration of the fist presentation was 180 ms. Following a gap of 10, 20, and 40 ms, the second checkerboard stimulus was presented for 50, 40, and 20 ms (respectively).

4.2. Results

Results were processed in the same manner as Experiments 1 and 2. Trials exhibiting changes in eye position (0.3% of all the trials) were excluded from the statistical analyses. As can be seen in Table 1, responses were more accurate for the LVF-RH than for the RVF-LH, $F(1,15) = 6.01$, $p = .03$. Although the interaction between stimulus status and visual field was not significant $F(1,15) = 2.05$, $p = .17$, post hoc tests of the effect of visual field for signal and noise trials were carried out. There was a significant LVF-RH advantage for noise trials $F(1,15) = 11.86$, $p = .004$, but no asymmetry for signal trials, $F < 1$. There was a significant interaction between gap duration and stimulus status, $F(2,30) = 3.41$, $p = .046$, indicating that accuracy increased with gap durations for the signal trials, but not the noise trials.

Results of signal detection analyses are shown in Table 2. The LVF-RH advantage for sensitivity (d') approached significance, $F(1,15) = 3.99$, $p = .06$. The response bias measure revealed a main effect of visual field $F(1,15) = 8.82$, $p = .009$, indicating that participants adopted a more conservative criterion for the LVF-RH than for the RVF-LH. The c value declined with decreases in gap duration, $F(2,30) = 3.60$, $p = .04$.

4.3. Discussion

Although the overall stimulus duration and gap durations used in the current study were identical to those used in Experiment 1, quite different results were observed. In Experiment 1, a strong RVF-LH advantage was observed in the signal condition for the shortest gap duration. This RVF-LH advantage most likely arose because the stimuli suited the transient detection style of the LH. In the present study, there was no sign of a RVF-LH advantage for any gap duration. The lack of a RVF-LH advantage probably reflects the fact that the gap was shifted towards the end of the stimulus, rendering the stimulus less amenable to transient detection. Like Experiment 1, but unlike Experiment 2, there was a LVF-RH advantage for the detection of noise stimuli. This result clearly demonstrates that the LVF-RH advantage is dependent on stimulation duration and is present only when participants engage sustained monitoring mechanisms.

In Experiment 3, participants adopted a more conservative criterion for LVF-RH trials than for RVF-LH trials. But this can be attributable to high accuracy in the LVF-

RH trials, which can be explained by the RH's superiority for sustained monitoring. More importantly, the sensitivity data showed an interesting interaction involving visual field in a post hoc analysis. Although there was not a significant asymmetry for d' in the current study, post hoc tests comparing the effect of visual field between Experiments 2 and 3 revealed a significant interaction, $F(1,39) = 6.57$, $p = .01$. The interaction was brought about by higher sensitivity in the RVF-LH for Experiment 2 and a higher sensitivity in the LVF-RH in Experiment 3. The interaction observed for sensitivity cannot be attributed to an asymmetry in response bias. The results are therefore consistent with left and right hemisphere specialization for transient and sustained monitoring, respectively.

5. General discussion

The present set of experiments tested the hypothesis that the LH is specialized for transient detection whereas the RH is specialized for sustained monitoring. In line with previous research (for a review Nicholls, 1996), a RVF-LH advantage emerged when the temporal processing task favored transient detection (Experiments 1 and 2). In contrast, when participants were required to observe the stimuli for a longer period of time, a LVF-RH advantage was observed (Experiments 1 and 3)—suggesting a RH advantage for sustained monitoring.

Dissociation between the hemispheres for sustained monitoring and transient detection can account for many of the discrepancies observed in the temporal processing asymmetry literature. For example, Funnell et al. (2003) may have observed a RH advantage because their tasked required participants to detect the offset of stimuli with a longer gap duration—making the task suitable for sustained monitoring. A distinction between sustained monitoring and transient detection may also account for two fMRI studies, which have reported more RH activation for temporal processing. For example, Kaufmann, Elbel, Gossl, Putz, and Auer (2001) reported more activation in right occipital regions compared to the left during the continuous observation of a temporally modulated dartboard pattern presented at various temporal frequencies (0–22 Hz). Similarly, Rao, Mayer, and Harrington (2001) found more activation in the RH than in the LH for temporal duration judgments for relatively long stimulus durations (e.g. 1.00 s vs. 1.32 s). In both cases the temporal processing task involves the discrimination of relatively long intervals and therefore favors RH sustained monitoring.

One might argue that the term 'sustained' is not an accurate description of the relatively short temporal ranges used in the present study (i.e. less than 1 s). The terms 'transient detection' and 'sustained monitoring' were first coined by Nakayama and Mackeben (1989) when describing transient and sustained attention. Transient attention refers to fast and involuntary deployment of attention induced by sudden and salient stimulation (Jonides, 1981; Müller & Rabbitt, 1989; Nakayama & Mackeben, 1989). Sustained attention refers to slow and voluntary deployment of attention, usually controlled by higher-order cognitive mechanisms. Temporal judgments for stimuli lasting less than 150 ms, like the signal stimuli in Experiments 1 and 2, most likely require the fast deployment of attention. In contrast, the signal and the noise (Experiment 3) stimuli required monitoring for over 150 ms. These stimuli are therefore likely to require slower, voluntary deployment of attention.

The distinction between transient detection and sustained monitoring observed for visual stimuli is remarkably similar to that observed for auditory stimuli. McKibbin, Elias, Saucier, Deborah, & Engebregston, (2003) used a dichotic listening procedure to present a frequency transition discrimination task where the transitions were either fast (40 ms) or slow (200 ms). A RH advantage was observed for slow frequency transitions. For fast transitions, there was no asymmetry. Pardo, Mäkelä, and Sams (1999) recorded responses to transient frequency and amplitude modulations in tones lasting 620 ms. Magnetoelectroencephalographic recordings revealed a stronger response in the LH for the detection of 3 ms frequency modulations—but only when the signal occurred early in the sound. If the modulation occurred in the middle of the sound, there was more activation in the RH. On the basis of research such as this, Zatorre, Belin, and Penhune (2002) have suggested that the hemispheres are differentially specialized for processing auditory stimuli. The LH is specialized for processing sounds that change rapidly over time whereas the RH is specialized for processing sounds that change more slowly and have a spectral content.

Research investigating asymmetries in spatio-temporal processing may also be relevant to the present results. Mecacci (1993) demonstrated that the amplitude of steady-stage visual evoked potentials was larger in the LH than in the RH when the stimulus contained high temporal and low spatial temporal frequencies. The opposite was found when the stimulus had low temporal and high spatial frequencies (but see Grabowska, Nowicka, & Szatkowska, 1992; Rebaï, Bagot, & Viggiano, 1993; Rebaï, Bernard, Lannou, & Jouen, 1998 for different results). More recently, Peyrin, Mermillod, Chokron, and Marendaz (2006) found LVF-RH and RVF-LH advantages for low and high spatial frequencies, respectively, when the stimulus duration was brief (30 ms). In contrast, when the duration was long (150 ms), a LVF-RH advantage was observed for both high and low spatial frequencies. These results support a transient/sustained distinction between the hemispheres and also demonstrate that the effect can be modulated by spatial frequency. While the present set of experiments has not manipulated spatial frequency, this would be something worthwhile investigating in future research.

Although the present set of experiments has demonstrated a hemispheric dissociation for transient detection and sustained monitoring, it does appear that the relative specialization is determined by a delicate balance of processing demands. For example, despite the fact that the gap and stimulus durations were the same in Experiments 1 and 3, a RVF-LH advantage was observed for the former experiment, but not for the latter. It is likely that moving the gap toward the end of the stimulus in Experiment 3 increased the demands on sustained attention. As a result, even though the short gap duration may have suited the transient processing of the LH, its placement late within the flanking stimulus favored the sustained processing style of the RH. The two competing specializations may have counteracted each other, resulting in no asymmetry for short gap durations in Experiment 3. It has been shown that two competing specializations can eliminate or even reverse a robust visual field advantage, such as a RVF-LH advantage for letter identification (e.g. Hellige, 1980; O'Boyle and Hellige, 1982) and for lexical decision (e.g. Bradshow, Hicks, & Rose, 1979; Pring, 1981). For example, a RVF-LH advantage for letter identification was reversed when stimulus visibility was degraded by masking and, thus, visuo-spatial demand increased (e.g. Hellige, 1980; O'Boyle and Hellige, 1982; see Sergent, 1983 for a review). In this example, the LH's specialization for language may compete with the RH's specialization for visuo-spatial processing, resulting in the reversal of the visual field advantage. In the present study, this kind of two competing specializations (i.e. the LH for transient detection and the RH for sustained monitoring) might have eliminated the visual field difference in Experiment 3.

Nicholls (1994a, 1994b) found a RVF-LH advantage in sensitivity for the gap detection task. On the other hand, visual difference in sensitivity was not observed in the present study, but visual field difference in bias was observed in Experiment 3 (not in Experiments 1 and 2). Although the reason for discrepancy between the previous and present results was not very clear, methodological differences may be responsible. Compared with the present study which used a CRT monitor, Nicholls (1994a, 1994b) used LEDs, and controlled temporal parameters more precisely in the stimulus presentation. It is possible that the precise measurement detected small differences undetected by a less precise measurement. The second possibility is that not only the sensory factors but also the cognitive factors affecting a response bias were involved in the gap detection task in the present study. The sustained monitoring can be a higher cognitive mental operation and thus may possibly affect a decision criterion, yielding a LVF-RH advantage in response bias in Experiment 3. However, as was mentioned in Section 4.3 of Experiment 3, the sensitivity data produced a significant interaction indicating the RVF-LH advantage for transient detection in Experiment 2 and the LVF-RH advantage for sustained monitoring in Experiment 3. This interaction in sensitivity cannot be explained by an asymmetry in response bias and, thus, supports the idea of LH and RH specializations for transient detection and sustained monitoring, respectively.

Across three experiments, accuracy increased with gap durations for the signal trials, but not much for the noise trials (i.e. a gap duration × stimulus status interaction was significant). This interaction can be explained by a slightly conservative response criterion adopted in the present study. Conservative criterion increases accuracy in the noise trials (i.e. increase of correct rejection). Such an increase may have a larger effect on the performance at a near-threshold level (10 ms) than at a ceiling level (40 ms), producing the gap duration × stimulus status interaction.

The model of temporal processing proposed by Nicholls (1996) focused on the LH's enhanced capacity for temporal processing, but largely ignored the temporal processing capacity of the RH. The model developed in this study suggests that the hemispheres are differentially specialized for temporal processing. Thus, while the LH may be better suited to processing stimuli with a very brief duration, the RH is superior for temporal stimuli which require sustained monitoring. This duality in temporal processing may allow the brain to process information more efficiently over a wider temporal range. Stimuli that require fine temporal analysis are processed more efficiently in the LH—but at the cost of perceiving the overall contour of the stimulus as it changes over time. A good example of this might be the discrimination of stop consonants in speech, for which the LH is specialized (Stefanatos, Gershkoff, & Madigan, 2005). In contrast, the RH may be less able to detect rapid transitions, but can perceive the longer-term temporal dynamics of the signal. A good example of this might be the detection of melody, for which the RH is specialized (Lim, Lambert, & Hamm, 2001).

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