Brain and Cognition 118 (2017) 54–62

Contents lists available at ScienceDirect

Brain and Cognition

journal homepage: www.elsevier.com/locate/b&c

Lateralization of spatial rather than temporal attention underlies the left hemifield advantage in rapid serial visual presentation

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ARTICLE INFO

Keywords:
Spatial attention
Temporal attention
Attentional blink
Lateralization
Hemispheric asymmetry
LVF advantage

ABSTRACT

In bilateral rapid serial visual presentation (RSVP), the second of two targets, T1 and T2, is better identified in the left visual field (LVF) than in the right visual field (RVF). This LVF advantage may reflect hemispheric asymmetry in temporal attention or/and in spatial orienting of attention. Participants performed two tasks: the "standard" bilateral RSVP task (Exp.1) and its unilateral variant (Exp.1 & 2). In the bilateral task, spatial location was uncertain, thus target identification involved stimulus-driven spatial orienting. In the unilateral task, the targets were presented block-wise in the LVF or RVF only, such that no spatial orienting was needed for target identification. Temporal attention was manipulated in both tasks by varying the T1-T2 lag. The results showed that the LVF advantage disappeared when involvement of stimulus-driven spatial orienting was eliminated, whereas the manipulation of temporal attention had no effect on the asymmetry. In conclusion, the results do not support the hypothesis of hemispheric asymmetry in temporal attention, and provide further evidence that the LVF advantage reflects right hemisphere predominance in stimulus-driven orienting of spatial attention. These conclusions fit evidence that temporal attention is implemented by bilateral parietal areas and spatial attention by the right-lateralized ventral frontoparietal network.

1. Introduction

1.1. LVF advantage in bilateral RSVP

Holländer, Corballis, and Hamm (2005) utilized a bilateral variant of the rapid serial visual presentation (RSVP) paradigm (Broadbent & Broadbent, 1987) to study lateralization of attention. This bilateral RSVP task consisted of two simultaneous streams of distractors, presented in the left and right visual fields (LVF & RVF), and two targets, T1 and T2, occurring in either visual field (VF) with 50/50 probability and with varying T1-T2 lags (ranging from 100 to 800 ms). Holländer et al. (2005) obtained a striking LVF advantage in T2 identification: left T2s were identified up to 30% better than right T2s, which contrasts with small VF effect sizes usually observed in other tasks (see Hellige, Laeng, & Michimata, 2010 for review). This LVF advantage has been replicated repeatedly (Asanowicz, Śmigasiewicz, & Verleger, 2013; Holländer, Hausmann, Hamm, & Corballis, 2005; Kranczioch, Lindig, & Hausmann, 2016; Verleger, Dittmer, & Śmigasiewicz, 2013; Verleger et al., 2009; Verleger, Śmigasiewicz, & Möller, 2011; Śmigasiewicz et al., 2010) and evidence has been brought forward that it reflects lateralization of exogenously triggered spatial attention (Śmigasiewicz, Asanowicz, Westphal, & Verleger, 2015; Śmigasiewicz, Westphal, & Verleger, 2017). In the present study, we investigated whether there is also a contribution of hemispheric lateralization of temporal attention to this LVF advantage, as originally proposed by Holländer et al. (2005).

1.2. Right hemisphere advantage in temporal attention

We define temporal attention as a process of transient temporal modulations, both enhancements and suppressions, of information processing by a mechanism of attentional gating or filtering, which allows to select and single out relevant events from a continuous flow of perceptual information (Bowman & Wyble, 2007; Olivers & Meeter, 2008). The need for selective attention arises from resource limitations; information processing must be selective when demands exceed capacity of perceptual or cognitive systems (Lavie & Dalton, 2014; Mozer & Sitton, 1998). In the RSVP tasks, demands for temporal attention are largest when T2 occurs within 200–500 ms after T1 (i.e., with a short T1-T2 lag) and the two targets are separated by at least one

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http://dx.doi.org/10.1016/j.bandc.2017.07.010
Received 5 May 2017; Received in revised form 25 July 2017; Accepted 31 July 2017
Available online 08 August 2017
0278-2626/

distractor, i.e., during a period of visual constraints known as the attentional blink (Raymond, Shapiro, & Arnell, 1992). The LVF advantage in T2 identification was interpreted by Holländer et al. (2005) in this line, as evidence that "*the right hemisphere is superior in performing an attentional blink task, and therefore in the modulation of temporal attention*" (p.39), and they concluded that temporal attention is subserved mainly by the right hemisphere. It is often assumed that the left hemisphere (LH), rather than the right hemisphere (RH), is specialized in temporal processing of visual information (Nicholls, 1996; Nicholls, Gora, & Stough, 2002; Okubo & Nicholls, 2005). Nonetheless, there are results suggesting that temporal attention may indeed be lateralized to the RH. Decoding of temporal order of visual events or determining when exactly an event occurs in a stream of stimuli is performed better in the LVF than in the RVF (Funnell, Corballis, & Gazzaniga, 2003), also in bilateral RSVP (Matthews & Welch, 2015; Matthews, Welch, Festa, & Clement, 2013), and these asymmetries may reflect lateralization of temporal attention, as temporal attention is a major factor determining which perceptual event has priority and which information enters to consciousness more quickly (Hilkenmeier, Olivers, & Scharlau, 2012). Battelli, Pascual-Leone, and Cavanagh (2007) have suggested that temporal/transient attention is controlled in both VFs by the right inferior parietal lobe (IPL), a crucial node for the processing of the temporal dimension (termed by those authors the 'when' pathway). Furthermore, the RH advantage in temporal processing is more likely to become evident when a task requires sustained temporal monitoring (Okubo & Nicholls, 2008; Whitehead, 1991), which is the case in the RSVP task. Finally, there is evidence from lesion (Husain, Shapiro, Martin, & Kennard, 1997), transcranial magnetic stimulation or TMS (Cooper, Humphreys, Hulleman, Praamstra, & Georgeson, 2004), and fMRI imaging studies (Marois, Chun, & Gore, 2000) suggesting a critical role of the right intraparietal sulcus (IPS) in target selection during the attentional blink period. Thus far, however, the hypothesis that the LVF advantage in the RSVP task reflects lateralization of temporal attention has not been further pursued and there is therefore no experimental evidence available.

1.3. Right hemisphere advantage in spatial attention

The bilateral RSVP task, in addition to uncertainty of the targets' temporal locations (lag variation) which is standard for this paradigm, adds uncertainty of their spatial locations (VF variation). Thus, also spatial attention is engaged in the task of T2 identification. A large number of studies has shown that spatial orienting of attention to behaviorally relevant stimuli occurring at unpredictable, uncertain, or uncued locations is controlled by a right-lateralized ventral frontoparietal network comprising the right temporoparietal junction (TPJ) and the right ventral frontal cortex (see Corbetta, Patel, & Shulman, 2008; Singh-Curry & Husain, 2009, for reviews). More recent studies have suggested that this network is also related to the transition from monitoring to target detection (Shulman & Corbetta, 2012). These two functions are crucial for successful T2 identification in bilateral RSVP. The LVF advantage may therefore be caused by this RH predominance in stimulus-driven orienting of spatial attention, rather than lateralization of temporal attention. We examined this hypothesis in our recent study (Śmigasiewicz et al., 2015) varying involvement of spatial orienting in T2 identification by displaying spatially valid, invalid, or neutral exogenous cues before T2 onset. The results showed that the LVF advantage increased with increased involvement of spatial attention in target identification (invalid cue condition) and was almost abolished with decreased involvement of spatial attention (valid cue condition), suggesting that the asymmetry may indeed be caused by lateralization of stimulus-driven spatial orienting. A follow-up study has confirmed these findings (Śmigasiewicz, Westphal, et al., 2017). However, two other studies showed that the LVF advantage can also be significantly reduced, but not abolished, by endogenous spatial cueing (Śmigasiewicz, Hasan, & Verleger, 2017; Verleger et al., 2009, Exp.2). A possible reason of this difference in cueing effects is that while the endogenous cueing signaled T2's spatial location only (thereby only reducing the asymmetry), the exogenous cueing actually signaled both the spatial and temporal locations of T2, as cues popped out always right before T2 onset (and abolished the asymmetry). This again hints at temporal attention as one of possible causes of the asymmetry. Plausibly, when only spatial location is known before T2 onset, temporal attention still needs to be engaged in T2 identification, thus there is still the LVF advantage, in line with the hypothesis of lateralization of temporal attention. However, when both spatial and temporal locations of T2 are known in advance, the asymmetry is abolished, because then there is no need for further involvement of attentional resources in T2 identification. In conclusion, the LVF advantage may be produced by combined impact of lateralization of both spatial and temporal attention.

1.4. Present study

We conducted two RSVP experiments aiming to further investigate whether the attentional blink/temporal attention is lateralized, and whether the LVF advantage in T2 identification can be explained by lateralization of temporal or/and spatial attention. In Exp.1, participants performed two RSVP tasks: the "standard" bilateral task (Holländer et al., 2005; Verleger et al., 2011), and its modified version, a unilateral task. Involvement of temporal attention was varied within the tasks by the trial-by-trial lag manipulation, from least (lag 8) to moderate (lag 4) and to most (lag 2) involvement. Involvement of spatial attention was varied between the tasks. In the bilateral task, spatial locations of the targets were uncertain due to trial-by-trial manipulation of T1/T2 VFs (LVF or RVF), so that participants did not know where the targets would occur, and T2 identification involved exogenous spatial orienting of attention triggered by T2 onsets. In the unilateral task, this spatial uncertainty was removed. The two lateral streams of distractors were presented simultaneously in the two VFs, like in the bilateral task, and the two targets, T1 and T2, were presented in one stream only, in the LVF or in the RVF (block-wise), so that participants did know in advance where both targets would occur. Therefore, a steady spatial focus was kept on the target stream endogenously during the whole trial, whereas the need for exogenous spatial orienting was eliminated. (Similar methods of presentation of lateral targets at one VF block-wise while keeping central fixation have been used before in other experimental paradigms, e.g., Bisiacchi et al., 1994; Slagter, Prinssen, Reteig, & Mazaheri, 2016). In Exp.2, we utilized a longer version of the unilateral task, aiming to confirm the results of the unilateral task from Exp.1, which were new findings, unlike the results of the bilateral task.

If the LVF advantage is caused by lateralization of temporal attention, the asymmetry should be a function of the degree of involvement of temporal attention. Thus, the shorter is the lag, the larger should be the LVF advantage. Assuming no additional influence of spatial attention, the effects of lag on the LVF advantage should be similar in the unilateral and bilateral tasks, and no LVF advantage should be found at lags beyond the attentional blink (i.e., lag 8; T2 identification is easy, which diminishes the need for temporal attention). However, since previous studies have suggested that at least part of this asymmetry may be caused by lateralization of spatial attention, the LVF advantage may be generally larger in the bilateral task than in the unilateral task due to additive effects of temporal and spatial attention, and be present also in the no-blink lag 8 condition of the unilateral task. Alternatively, if caused solely by lateralization of exogenous orienting of spatial attention, the LVF advantage should be present, as usual, in the bilateral task, in which spatial attention is necessary for T2 identification, but should be absent in the unilateral task, in which spatial uncertainty, and thereby the need for exogenous orienting, is removed. As a third option, if caused by lateralization of endogenous spatial attention, the LVF advantage should even increase in the unilateral task, where a steady,