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How handedness influences perceptual and attentional processes during rapid serial visual presentation

Kamila Śmigasiewicz[a,*], Matthias Liebrand[a], Johannes Landmesser[a], Rolf Verleger[a,b]

[a] Dept. of Neurology, University of Lübeck, Germany
[b] Inst. of Psychology II, University of Lübeck, Germany

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ABSTRACT

Stimulus-driven orienting of visual attention is lateralized to the right hemisphere (RH). This lateralization has been studied in the dual-stream rapid serial visual presentation task (*dual RSVP*). In this task a second target (T2), hard to discern by being embedded in one of two lateral streams of rapidly changing distractors, is better identified on the left than on the right. This phenomenon is called the left visual field advantage (LVFA). Furthermore, in terms of event related potentials (ERPs), the N2pc component and visual evoked potentials (VEPs) are evoked earlier at the RH than at the left hemisphere (LH). All previous *dual RSVP* experiments were performed on right-handers. In the present study it was investigated how the LVFA and its neural correlates are modulated by handedness. To that end, the size of the LVFA and ERPs (VEPs and N2pc) were compared between right- and left-handers. VEPs were evoked earlier at the RH than the LH in right-handers but not in left-handers. Besides this effect, handedness modulated neither the size of the LVFA nor T2-evoked N2pc. Thus, the LVFA seems to be independent of handedness. Rather than for lateralization of attention, handedness might be relevant for lateralization of early visual perception processes.

1. Introduction

Selective attention is the ability of the cognitive system to select relevant stimuli from irrelevant ones when all stimuli are competing for being processed (Desimone and Duncan, 1995). One way to simulate perceptually and attentionally challenging environments in the lab is by dual-stream rapid serial visual presentation (*dual RSVP*) (Asanowicz et al., 2013; Goodbourn and Holcombe, 2015; Holländer et al., 2005a, 2005b; Scalf et al., 2007; Verleger et al., 2009). During this task participants are asked to monitor two streams of rapidly (each 130 ms) changing stimuli (usually black letters), presented left and right from a fixation point. Two targets have to be identified, first a colored letter (T1) and then a black digit (T2), which can appear randomly in either stream. Studies investigating *dual RSVP* showed a visual-field asymmetry: T2 was identified better when presented in the left visual field (LVF) than in the right visual field (RVF). Unlike T2, T1 usually was equally well identified in both streams, probably due to its salient color (see: Śmigasiewicz et al., 2010, 2017a; Verleger et al., 2011, 2013; Verleger and Śmigasiewicz, 2015).

In line with neuroimaging studies (Corbetta et al., 1993; Nobre et al., 1997), this left visual field advantage (LVFA) in T2 identification has been recently ascribed to dominance of the right hemisphere (RH) in attentional processes (Śmigasiewicz et al., 2015, 2017b), in particular in stimulus-driven orienting of attention (see also Corbetta and Shulman, 2002). In the study of Śmigasiewicz et al. (2015), salient task-irrelevant cues were presented 50 ms before T2 onset in the same stream as T2 (valid cues), in the other stream than T2 (invalid cues) or at the fixation point (neutral cues). The LVFA was almost eliminated with valid cues because with attention attracted to T2, no further shift of attention was required. Furthermore, the LVFA increased with invalid cues as compared to neutral cues. Based on the follow-up experiment (Śmigasiewicz et al., 2017b) this increase in the size of LVFA with invalid cues was assigned to harder disengagement of attention from left than from right cues. Finally, in another study, explicit valid cues delivered before trial onsets reduced the LVFA, probably through facilitation of stimulus-driven orienting toward right T2 (Śmigasiewicz et al., 2017a).

Apart from attentional modulation, the LVFA turned out to be independent of many factors: eye movements (Verleger et al., 2009), type of stimuli (letters vs. non-verbal stimuli, Asanowicz et al., 2013), negative and positive priming from task-irrelevant lure stimuli (Verleger et al., 2012), and interhemispheric interactions (Śmigasiewicz et al., 2014; Verleger et al., 2010). The LVFA was slightly modulated by habits of reading direction (Śmigasiewicz et al.,

* Correspondence to: Klinik für Neurologie, Universität Lübeck, D 23538 Lübeck, Germany.
E-mail address: k.smigasiewicz@gmail.com (K. Śmigasiewicz).

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2010) and fluctuated with menstrual cycle in women (Holländer et al., 2005a, 2005b). All these studies demonstrate the LVFA to be a rather general phenomenon describing asymmetry between hemispheres in attentional processes. However, in order to mitigate unwanted variation in the data, only right-handers were included in these studies. Therefore it is unclear if these results can be generalized to the population of left-handers, since right- and left-handers differ in the lateralization of many cognitive processes.

Right-handed people represent about 90% of the general population, whereas only 10% are left-handed (Hardyck and Petrinovitch, 1977). In about 95% of strong right-handers the language network is lateralized to the LH. This typical lateralization is weaker in left-handers, with language lateralized to the LH still in 75% (Isaacs et al., 2006; Knecht et al., 2000; Szaflarski et al., 2002). In the left-handers language functions are more often bilaterally distributed or lateralized atypically to the RH than in right-handers (Pujol et al., 1999; Szaflarski et al., 2002). Overall, Knecht et al. (2000) found that RH language dominance increases linearly with the degree of left-handedness. The lateralization pattern of spatial abilities has not so extensively been studied as language, but there is some evidence that in about 95% of right-handers and 80% of left-handers spatial abilities are lateralized to the RH (Flöel et al., 2005). Nevertheless, the relation between the lateralization of spatial abilities and handedness is far from being clear. Some studies suggested dependence of some aspect of attention or spatial processing on handedness (Bareham et al., 2015; Marzi et al., 1988), in line with the view that the lateralization of language to one hemisphere is accompanied by lateralization of spatial functions to the other hemisphere (Cai et al., 2013; Knecht et al., 2000). For example, Liu et al. (2009) observed that brain regions involved in attentional networks are more strongly right-lateralized in right- than in left-handers. Based on these studies it may be expected that left-handers will have reduced or even absent LVFA in *dual RSVP* when compared to right-handers. However, in other studies, despite differences in language lateralization, spatial attention was equally lateralized to the RH for both handedness groups (Badzakova-Trajkov et al., 2010; Petit et al., 2015; Zago et al., 2015), rather indicating independence of the lateralization of language and spatial functions (Rosch et al., 2012; Whitehouse and Bishop, 2009;). Based on this, it may be expected that the size of the LVFA will not depend on handedness. Thus, the aim of the current study is to examine whether stimulus-driven orienting of attention, as reflected by the LVFA, is related to handedness or not.

Possible differences between right- and left-handers will be studied with electroencephalography (EEG). We will focus on those event-related potentials (ERPs) that were related to the LVFA in previous studies: Visual evoked potentials (VEPs) elicited by distractors and the T2-evoked N2pc component. VEPs are P1-N1 complexes recorded above the lateral temporo-occipital cortex that are evoked by the series of distractor stimuli that precede T1 (Śmigasiewicz et al., 2014; Verleger et al., 2011, 2013). In previous studies, these VEPs were evoked slightly earlier at the RH than at the LH, possibly indicating that the RH has better abilities in constructing percepts at early stages of information processing (Asanowicz et al., 2017; Verleger et al., 2011). The N2pc is a negative component evoked by correctly identified targets and is measured at lateral sites overlying the temporo-occipital cortex. It is measured as difference in activity between electrodes located at the contralateral and ipsilateral hemisphere to the target (Eimer, 1996; Luck et al., 1993; Wascher and Wauschkuhn, 1996). N2pc may reflect involvement of attention in selecting and identifying relevant stimuli (Eimer, 1996; Liu et al., 2016). In previous studies, N2pc evoked by T2 had shorter latencies with left than right T2. This suggests that left T2 is selected faster by the RH than right T2 by the LH (Śmigasiewicz et al., 2015; Verleger et al., 2009, 2011, 2013). In the present study, it is expected that neural correlates of the LVFA will be influenced by handedness in the same way as the LVFA.

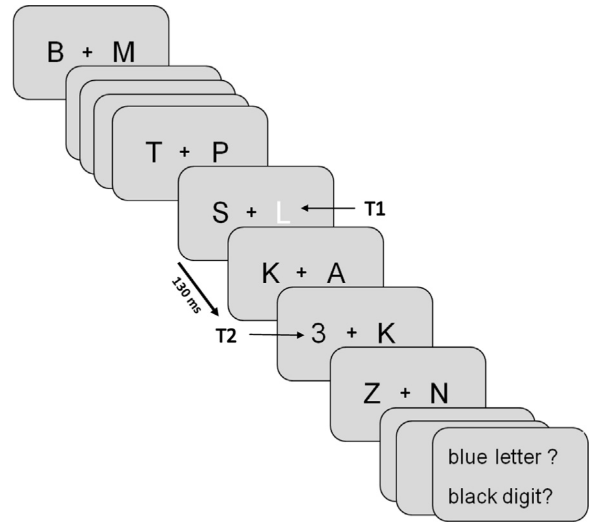

Fig. 1. Sequence of events in a trial. The sequence of events is exemplified for a trial where T1 (blue color of T1 is replaced here by white) was presented right and T2 (the digit) left.

2. Methods

2.1. Participants

Thirty-two students from the University of Lübeck participated in the study. Half of them were right-handed (6 males, mean age =26 years, SD =3.2) with an average score in the Edinburgh Handedness Inventory (Oldfield, 1971) of 94 (SD =11.5) and half were left-handed (9 males, mean age =25 years, SD =3.2) with an average handedness score of −77 (SD =30). Another 8 participants (4 right-handers and 4 left-handers) were excluded from data analysis: three due to eye movements and five due to low T1- or T2- identification that was below 3 SD of the other participants. All participants provided informed written consent and were paid 7 € per hour. They reported normal or corrected-to-normal vision and no history of neurological disorders. The study was approved by the ethics committee of the University of Lübeck.

2.2. Task design, stimuli and apparatus

Fig. 1 illustrates the task. The goal of the task was to identify two targets. The first target (T1) was a blue letter (D, F, G, J, K, L) and the second target (T2) was a black digit (1, 2, 3, 4, 5, 6). T1 and T2 were embedded in a stream of black letters, which served as distractors. These distractors consisted of all letters of the alphabet, except the letters used as T1 and the letters H and W. In some of the trials only one target (T1 or T2) was presented. Participants were sitting 1.2 m away from a 16″ cathode ray tube (CRT) computer screen (driven with 100 Hz) that was used to display stimuli. In the center of the screen a small fixation cross (.1°×.1°) was displayed. Right and left appeared targets and distractors, being capital letters of the Latin alphabet, and the digits 1–6 (Helvetica font, .4°×.5°). Their midpoints were 16 mm away from fixation. All stimuli were presented on a white background and Presentation® software, version 14.1 (Neurobehavioral Systems Inc.) was used for experimental control.

2.3. Procedure

Participants were seated in a darkened room in front of the computer screen, with the keyboard placed on an adjustable table. Each trial started with the presentation of the fixation cross that was displayed during the entire trial. With a delay of 800 ms the first stimulus pair appeared left and right from fixation, was displayed for