Neuropsychologia 47 (2009) 2604–2614

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

The impact of negative attentional set upon target processing in RSVP: An ERP study

Dexuan Zhang [a,b], Xiaolin Zhou [a,c,*], Sander Martens [d]

[a] Center for Brain and Cognitive Sciences and Department of Psychology, Peking University, Beijing 100871, China
[b] Department of Psychology, School of Educational Sciences, Hangzhou Normal University, Hangzhou, Zhejiang 310036, China
[c]

color (and thus matching the target-defined attentional set) as the target.

Similarly, the negative attentional set may play a role in actively suppressing task-irrelevant distractors (e.g., Loach & Mari-Beffa, 2003; Maki & Padmanabhan, 1994; Olivers & Meeter, 2008; Olivers et al., 2007). For example, Maki and Padmanabhan (1994) used an AB task in which T1 was a white letter and T2 was a black digit among black letter distractors. The target digit was shown at the beginning of each trial. Participants were instructed to remember this digit and decide whether it was presented in the RSVP stream, in addition to detecting the T1 letter. They performed this task repeatedly for over 10 days and T2 performance was improved with extensive practice. However, performance on T2 detection dropped substantially in the test session in which the distractors were changed into a mixture of letters and digits. The authors argued that the participants used an inhibitory attentional set against distractors, and by including digits in the distractor set in the test session the digit T2 was also inhibited.

However, as discussed by Maki and Padmanabhan (1994), the impaired T2 performance in the mixture condition could also be explained in terms of retrieval competition between digits within visual short term memory. Whether the negative attentional set functions online in the AB needs to be investigated further. This issue is important partly because it is related to a recent debate on the AB mechanisms. In contrast to traditional models of the AB, which assume that the AB is due to a post-perceptual bottleneck or depletion of limited resources (Chun, 1997; Chun & Potter, 1995; Duncan, Ward, & Shapiro, 1994; Isaak, Shapiro, & Martin, 1999; Jolicoeur, 1998; Shapiro, Raymond, & Arnell, 1994), the temporary loss of control (TLC) hypothesis (Di Lollo et al., 2005; Kawahara, Kumada, & Di Lollo, 2006) posits that the sensory system is initially configured to be an input filter which is optimized to process T1 and to exclude distractors. This configuration is assumed to be governed by top-down signals from the central control system. When T1 passes through the filter, the central control system becomes engaged in processing T1 and the top-down control signals are interrupted. The distractors following T1 change the filter settings which are now under the control of the properties of the bottom-up input, resulting in difficulty in selecting T2 because the filter configuration no longer matches the specifications of T2. If the impaired T2 performance in the mixture condition in Maki and Padmanabhan (1994) was indeed due to retrieval competition during reporting, then the TLC hypothesis of loss of central control can possibly stand. If, on the other hand, the negative attentional set cannot be disrupted by T1 processing and it impacts upon T2 performance online, then the TLC hypothesis is disapproved.

In event-related potentials (ERPs), the online target selection can be indexed by a number of components. One component is the N2pc (N2 posterior contralateral), which is typically elicited within a post-stimulus 200–300 ms time window on posterior electrodes contralateral to the target. It reflects the spatial attention allocation to the target (e.g., Eimer, 1996; Luck & Hillyard, 1994; Ruge, Stoet, & Naumann, 2006) after the target features are initially processed (Hopf, Boelmans, Schoenfeld, Luck, & Heinze, 2004) or after the covert attentional shifts are completed (Kiss, Van Velzen, & Eimer, 2008). Following the N2pc, a component called sustained posterior contralateral negativity (SPCN), is elicited on the posterior electrodes contralateral to the target. The SPCN typically starts at about 300 ms post-onset of the target, and it is commonly thought to reflect in-depth processing of target representations in working memory for further response selection or target reporting (e.g., Dell'Acqua, Sessa, Jolicoeur, & Robitaille, 2006; Kiss et al., 2008; McCollough, Machizawa, & Vogel, 2007; Vogel & Machizawa, 2004). Previous studies have found that both the N2pc and the SPCN to T2 are suppressed and delayed when T2 is presented during the AB period relative to a period outside the AB (e.g., Jolicoeur, Sessa, Dell'acqua, & Robitaille, 2006). These results suggest that the N2pc and the SPCN are sensitive to the activation level of target representations.

The main purpose of this study is to obtain electrophysiological evidence for the impact of a negative attentional set upon online T2 processing in the RSVP stream. We conducted two ERP experiments in which participants had to search for a digit (T2) among letter distractors following a unique red letter (T1). Importantly, a special distractor, D1, which was from the same semantic category as T2 (i.e., digit), was presented before T1 in some of trials. Given that this D1 has to be ignored, a negativeT2rel40.17.9(o)eginiss h(e)-digit

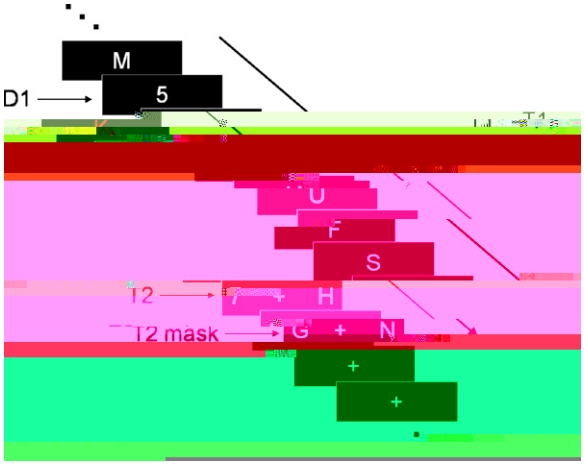


Fig. 1. A schematic representation of the trial procedure in Experiments 1 and 2. Each item was presented for 100 ms, with no blank interval between consecutive items.

before T1, and D1 at lag −3 in which D1 was presented as the third item preceding T1. For each critical condition, T2 appeared at the left or right to the fixation with equal probability (100 trials for each side in each D1 condition). Two types of filler trials were intermixed with the critical trials. There were 100 filler trials in which an RSVP stream consisted of only letter distractors (i.e., without D1, T1, and T2) and 100 filler trials in which only D1 and distractors were presented. A letter distractor replaced T2 at the left or right location in the filler trials. In total, there were 800 trials for each participant, divided over 20 blocks. In addition, there were 24 practice trials before the formal experiment.

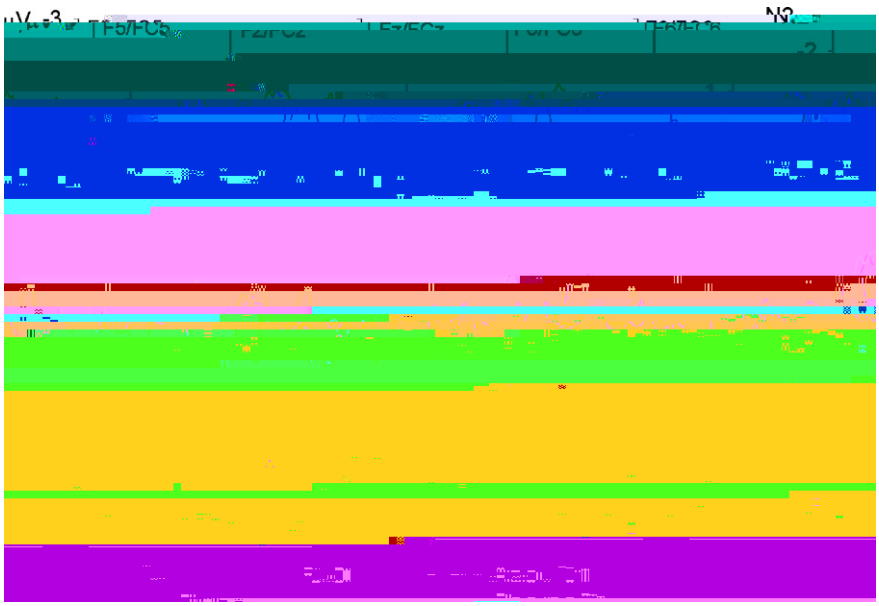
The participant sat comfortably about 1 m in front of a computer screen in a sound-attenuated room and held a bi-handle joystick with both hands for manual response. Stimuli were presented on a CRT monitor with a refresh rate of 100 Hz. The participant pressed a button on the joystick with right thumb to initiate each trial. A central fixation cross was presented for 1 s, followed by the RSVP stream. D1 and T2 were Arabic digits, drawn from the set of 2–9, whereas distractors were uppercase letters (extte-0.1(r)13.9(o)-0.1(m)-288(m)-288(m)-288(m)-288(m)4is(m)-288(m)-2hmm byThe

Table 1
Mean values for D1 conditions in Experiment 1. The significance of *F* value refers to the main effect in ANOVA.

	D1 absent	D1 at lag −1	D1 at lag −3	Significance of *F* value
T1 accuracy (%)	96.9	97.7	96.7	$p > 0.1$
T2|T1 accuracy (%)	79.7	70.7	73.8	$p < 0.001$
Intrusion rate (%)	–	14.6	8.3	$p < 0.001$
D1 N2 amplitude (μV)	–	−1.37	−1.13	$p > 0.1$
D1 N2 latency (ms)	–	278	278	$p > 0.1$
T1 P300 amplitude (μV)	7.82	7.87	8.03	$p > 0.1$
T1 P300 latency (ms)	254	253	254	$p > 0.1$
T2 N2pc amplitude (μV)	−1.27	−1.18	−1.19	$p > 0.1$
T2 N2pc onset latency (ms)	181	220	209	$p < 0.01$
T2 SPCN peak amplitude (μV)	−1.40	−1.47	–	

Table 2
Mean values for D1 conditions in Experiment 2. The significance of *F* value refers to the main effect in ANOVA.

	D1 absent	Arabic D1	Chinese D1	Significance of *F* value
T1 accuracy (%)	97.6	98.2	95.7	$p < 0.05$
T2|T1 accuracy (%)	78.0	70.3	70.8	$p < 0.001$



from letters would impair the digit T2 performance and delay the N2pc latency to T2 even though D1 is not in the same semantic category as T2. A variant of this category-unspecific mechanism is that a feature-deviant D1 captures attention and the depletion of attentional resources by D1 somehow impairs T2 performance. As discussed previously, however, this attentional capture account is unlikely to stand as the digit D1 did not impair the report of T1, which was closer to D1 than T2, and as D1 evoked the frontocentral N2 rather than the P300 in the above two experiments.

Experiment 3 was conducted to rule out the category-unspecific, general negative attentional set account. To this end, we employed three types of D1: in addition to the Arabic D1 and the Chinese D1, a keyboard symbol D1, differing from T2 and letter distractors in terms of both perceptual features and category membership, was used. If it was the general negative attentional set, rather than a category-specific negative attentional set, that impaired T2 performance and delayed the N2pc latency to T2 in Experiments 1 and 2, then this symbol D1 should have similar negative impacts uponmpairth25.3(b)0783.1(up.3(same)Ftional)-24949495T2thr-8.1(y)13.9(110(1)]TJ

D1 in current and the previous two experiments was simply due to a general, category-unspecific negative attentional set elicited by a perceptually deviant D1. The absence of a symbol D1 effect on T2 performance also rules out, again, the possibility that the impairment of T2 performance (and the delay of the N2pc latency to T2) by the Arabic or the Chinese D1 was simply due to attentional capture and depletion of attentional resources by D1. Although the symbol D1 did impair T1 performance, possibly through attentional capture, it had no effect on T2 performance.

This experiment also showed that the Arabic and the Chinese D1 impaired the report of T2 at both the short TOA (lag 3) and the long TOA (lag 8). Thus, although the TOA of lag 5 that was used in Experiments 1 and 2 may not be the position with the maximal AB effect and the maximal effect of negative attentional set upon T2 performance, given the constraints upon the ERP design, the TOA of lag 5 was sufficient to reveal the effect of a negative attentional set elicited by D1 on T2 performance and the N2pc latency to T2.

5. General discussion

This study investigates whether the negative attentional set elicited by a pre-T1 special distractor (D1) could influence the online target processing indexed by the report accuracy and the lateral ERPs in response to T2 in an RSVP stream. A D1 from the same conceptual category as the digit T2 was presented while the N2pc to T2 was measured. In Experiments 1 and 2, the N2pc was substantially suppressed in trials in which T2 was misreported relative to trials in which T2 was correctly identified. Moreover, the Arabic digit D1 at either lags −1 or −3 (Experiment 1) and the Arabic and the Chinese D1 at lag −1 (Experiment 2) evoked a frontocentral N2 component and delayed the onset of the N2pc to T2. In contrast, the P300 to T1 was not influenced by D1 manipulation in either experiment, although the accuracy of T1 report was somehow reduced by the Chinese D1. The behavioral data in the two experiments were consistent with the ERP results and showed that the Arabic or Chinese D1, belonging to the same semantic category as the digit T2, impaire T2 performance and cause intrusion errors in T2 report. Experiment 3 provided further behavioral evidence that while the Arabic or Chinese D1 impaired T2 performance, a keyboard symbol D1, which is perceptually deviant from distractor letters and T2 but does not share the category membership with T2, had no effect on T2 performance. Both the symbol D1 and the Chinese D1 impaired T1 performance, consistent with Experiment 2. These findings demonstrate that the online processing of the target in the RSVP stream can be impaired by a negative attentional set elicited by D1 sharing semantic properties with the target.

It is assumed that the processing system uses a negative attentional set to inhibit the processing of distractors in the RSVP stream (Maki & Padmanabhan, 1994; Olivers & Meeter, 2008; Olivers & Watson, 2006). An early study by Maki and Padmanabhan (1994) demonstrated that the AB effect was enlarged when items from the same category of T2 were inserted into the RSVP stream. Olivers and Watson (2006) also observed that T2 performance was impaired when T2 shared the same, task-irrelevant color as distractors preceding T1. Our previous behavioral study (Zhang et al., submitted for publication) extended these two studies by showing that the negative attentional set could be built upon abstract semantic categories and on a trial-by-trial basis. In the present study, we also observed that, for both the Arabic digit and the Chinese number character, D1 impaired performance on the digit T2 in the RSVP stream and induced intrusion errors in T2 report. However, these behavioral data do not provide unequivocal evidence pertaining to the question whether the impairment of T2 performance is due

effect at the abstract, semantic level when a visual distractor (a picture of a DOG) was presented on one trial and an auditory probe (the word CAT) in the subsequent trial. In an inattentional blindness task, Koivisto and Revonsuo (2007) found that an unexpected stimulus that belongs to the same semantic category as the attended stimulus but does not share its perceptual features was more likely to be detected than a semantically unrelated stimulus. Together with the present findings, we may argue for a general presence of abstract, category-based attentional sets in attentional selection over time or space.

To conclude, by measuring both behavioral performance and ERP responses to targets in the RSVP stream, we demonstrate that a special distractor D1 before T1 in the stream elicits a negative

.6(bal.)-pc02mepc02mepairs31c02mepbl(me,31c02me)dunrtmeasc02me 2meep13.9(3929(of)-239.6(t29(of)T2.(t29(of)This(t29(of)-3929neg)8(o)

Yeung, N., Botvinick, M. M., & Cohen, J. D. (2004). The neural basis of error detection: Conflict monitoring and the error-related negativity. *Psychological Review*, *111*(4), 931–959.

Zhang, D. X., Shao, L., Nieuwenstein, M., & Zhou, X. (2008). Top-down control is not lost in the attentional blink: Evidence from intact endogenous cuing. *Experimental Brain Research*, *185*(2), 287–295.

Zhang, D. X., Shao, L. P., & Zhou, X. L. (2007). Opening the attentional window in attentional blink: An attentional cuing study. *Progress in Natural Science*, *17*, 39–46.

Zhang, D. X., Zhang, H. Y., Zhou, X. L., Martens, S. (submitted for publication). Negative attentional set in the attentional blink.