Psychophysiology, 53 (2016), 1878–1888. Wiley Periodicals, Inc. Printed in the USA.

DOI: 10.1111/psyp.12766

Electrophysiological revelations of trial history effects in a color oddball search task

EUNSAM SHIN[a] AND SANG CHUL CHONG[b,c]

[a]The Center for Cognitive Science, Yonsei University, Seoul, Korea
[b]Graduate Program in Cognitive Science, Yonsei University, Seoul, Korea
[c]Department of Psychology, Yonsei University, Seoul, Korea

Abstract

In visual oddball search tasks, viewing a no-target scene (i.e., no-target selection trial) leads to the facilitation or delay of the search time for a target in a subsequent trial. Presumably, this selection failure leads to biasing attentional set and prioritizing stimulus features unseen in the no-target scene. We observed attention-related ERP components and tracked the course of attentional biasing as a function of trial history. Participants were instructed to identify color oddballs (i.e., targets) shown in varied trial sequences. The number of no-target scenes preceding a target scene was increased from zero to two to reinforce attentional biasing, and colors presented in two successive no-target scenes were repeated or changed to systematically bias attention to specific colors. For the no-target scenes, the presentation of a second no-target scene resulted in an early selection of, and sustained attention to, the changed colors (mirrored in the frontal selection positivity, the anterior N2, and the P3b). For the target scenes, the N2pc indicated an earlier allocation of attention to the targets with unseen or remotely seen colors. Inhibitory control of attention, shown in the anterior N2, was greatest when the target scene was followed by repeated no-target scenes with repeated colors. Finally, search times and the P3b were influenced by both color previewing and its history. The current results demonstrate that attentional biasing can occur on a trial-by-trial basis and be influenced by both feature previewing and its history.

Descriptors: Visual attention, Selection bias, Trial history, Event-related potentials (ERPs), Distractor previewing effect

Many studies have shown that searching for an oddball target in a visual scene is influenced by recent visual experience (e.g., Ariga & Kawahara, 2004; Found & Müller, 1996; Goolsby, Grabowecky, & Suzuki, 2005; Lleras, Kawahara, Wan, & Ariga, 2008; Maljkovic & Nakayama, 1994). For example, the speed at which a red target presented among green distractors is identified increases for green, rather than red, items presented in a preceding target-absent scene. Further, visual experience leaves a memory trace and accumulates over time (Brascamp, Pels, & Kristjánsson, 2011; Chun & Jiang, 1998; Maljkovic & Nakayama, 2000), as repeatedly previewed features influence current target searches. Some researchers have recently found that a selection bias occurs due to previous trials, and this history-dependent intertrial effect differs from the top-down control of attention (Lamy & Kristjánsson, 2013) and needs to be considered as another source of selection bias in addition to bottom-up and top-down sources (Awh, Belopolsky, & Theeuwes, 2012).

The distractor previewing effect is an example of this intertrial effect. As shown in the above example, the distractor previewing effect is observed when target-absent and target-present displays are intermixed in visual oddball search tasks. Typically, search times for targets are shorter when distractor features are previewed (distractor preview or DP) than when target features are previewed (target preview or TP) in preceding no-target displays (Ariga & Kawahara, 2004; Levinthal & Llearas, 2008). It has been suggested that the distractor previewing effect reflects attentional bias against previewed features (i.e., old features) shown in no-target displays and toward nonpreviewed features (i.e., new features) in a subsequent visual scene (Levinthal & Llears, 2008; Lleras et al., 2008; Lleras, Levinthal, & Kawahara, 2009). More specifically, viewing a scene in which a target is absent is implicitly assessed as a failed search, and features associated with the failed search are negatively tagged in the memory. As a result, the failed features are inhibited and nonfailed features are preferred in the subsequent trial (Lleras et al., 2008, 2009). In short, selection failure leads to attentional biases toward nonpreviewed features in a subsequent visual scene. This indicates that the attentional set is biased for the upcoming visual scene, which is contingent on feature previewing history.

This work was supported by the National Research Foundation (NRF) of Korea grant funded by the Korean government [NRF-2011-354-H00011] and also by the Brain Research Program through the National Research Foundation of Korea funded by the Ministry of Science, ICT & Future Planning (2006-2005108). We are grateful to Hyejin Kim for her assistance with data collection.

Address correspondence to: Eunsam Shin, Ph.D., The Center for Cognitive Science, Yonsei University, 107 Weedang Hall, 50 Yonsei-ro, Seodaemun-gu, Seoul 120-749, Korea. E-mail: eunsam.shin@yonsei.ac.kr

PSYCHOPHYSIOLOGY

A question then arises as to what neural evidence supports this account. Previously, Shin, Wan, Fabiani, Gratton, and Lleras (2008) recorded ERPs and found that the N2pc component, an index of attention allocation to a target location (Luck & Hillyard, 1994; Woodman & Luck, 2003), developed earlier for DP than for TP trials (also see Shin & Bartholow, 2013). In an fMRI study, the ventral attentional system, associated with stimulus-driven control of attention (Asplund, Todd, Snyder, & Marois, 2010; Corbetta & Shulman, 2002; Han & Marois, 2014), showed greater activation for TP than for DP trials (Scalf, Ahn, Beck, & Lleras, 2014). The occipitotemporal area is known to be the neural generator for the N2pc component (Hopf et al., 2000; Hopf, Boelmans, Schoenfeld, Heinze, & Luck, 2002; Luck, Girelli, McDermott, & Ford, 1997) and partly (if not completely) overlaps with the ventral attentional system. Therefore, these studies have demonstrated an application of attentional biases to a current target scene in the distractor previewing effect. In other words, it has been shown how a recent failed search changes neural processes associated with attention when a target appears, supporting the notion of history-dependent attentional biases. However, these studies fell short of demonstrating neural evidence of the time course of attentional biasing that is contingent on feature previewing history. It has not been shown how history-dependent attentional biases emerge and are maintained or changed until a target appears—that is, the evolution of history-dependent biasing of attention.

The current study aimed to reveal trial-by-trial adjustments of attention using a distractor-previewing-effect paradigm in which no-target displays are included. Thus, the manipulations of the no-target display could effectively induce selection failure and negative tagging of specific features without being confounded by target processing, allowing clear predictions about dynamic shifts of attention. Specifically, as the number of no-target displays increases, negative feature tagging should be reinforced and maximized, particularly for the previewing trials with an upcoming target feature. Moreover, in cases where the no-target display is presented twice in succession, if the features shown in the two displays are identical (i.e., repeated), they should be inhibited. If they differ (i.e., changed), the feature shown in the second no-target display should be selected and attended to. In short, attention should shift toward changed features in the second no-target display. Furthermore, this history-dependent attentional modulation should continue to the target display. Two no-target displays with their item colors repeated would show greater inhibition than one no-target display or two no-target ones with their item colors changed.

Figure 1 shows how these manipulations were implemented in the current study. No-target displays containing single colored items were followed by a target display in which a uniquely colored item (target) was included with distractors (Figure 1A). According to the number of no-target displays, the display sequences were numbered 0, 1, and 2. The item colors selected for Sequence 1 and 2 could be shown as a target or a distractor color in the target display. Specifically, for Sequence 1, the color selected for the single no-target display could be shown as a target or a distractor color in the target display, generating TP and DP trials, respectively. For Sequence 2, the colors shown in the first and second no-target displays could be different or the same, generating 2-diff and 2-same sequences, respectively (Figure 1B).

We used ERPs, which were particularly useful for observing no-target-elicited epochs from which overt behavioral data were absent. We then focused on attention-related ERP components: the frontal selection positivity (FSP), the N2pc, the anterior N2, and the P3. The FSP is observed maximally over frontal electrodes

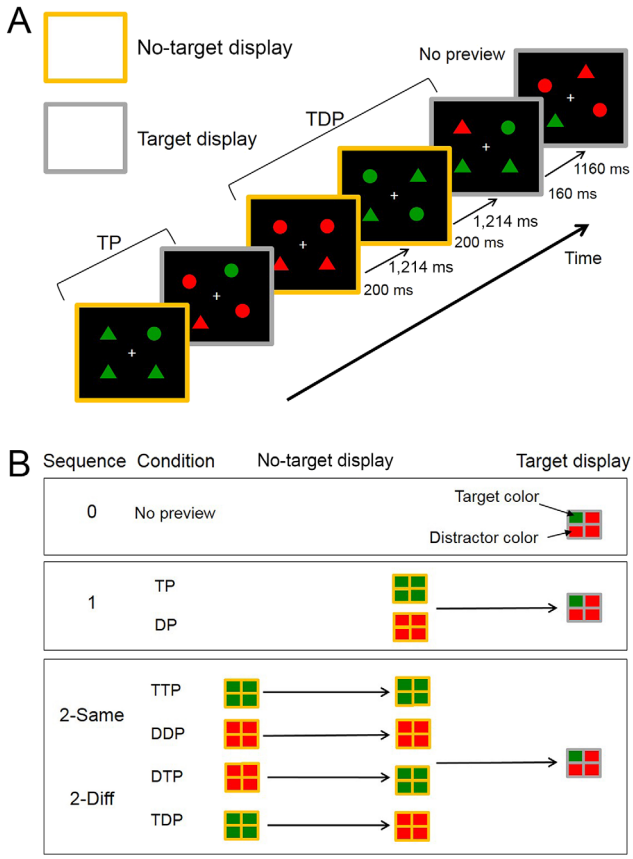

Figure 1. A: Trial examples in the current color-oddball search task. Participants were instructed to find a color oddball (i.e., target) in each display and respond to the target (if any) based on the oddball's shape. B: A schematic illustration of trial sequences and conditions. The number of sequences (0, 1, and 2) indicates how many no-target displays were shown prior to the target display. For brevity of illustration, green is specified as the target color and red as the distractor color. No-target displays are shown within the orange frames. Target displays are shown within the gray frames. All conditions were randomly distributed and not blocked in the actual experiment. TP = target color preview; DP = distractor color preview; DTP = distractor-target color preview; TDP = target-distractor color preview; TTP = target-target color preview; DDP = distractor-distractor color preview.

between 100 and 300 ms poststimulus, and is thought to reflect the early selection of features such as spatial frequency, orientation, and color (Kenemans, Kok, & Smulders, 1993; Ruijter, De Ruiter, & Snel, 2000; Smid, Jakob, & Heinze, 1999). Thus, if viewing the first no-target display results in an attentional bias against the previewed color and the selection of nonpreviewed colors in the subsequent visual scene, the FSP should be larger for changed colors than for repeated colors in the second no-target display. The N2pc arises between 200 and 300 ms after target onset as an increased negativity at posterior electrode sites contralateral (compared to ipsilateral) to the hemifield to which attention is deployed. We reexamined this component upon target appearance to test whether the previous result (Shin et al., 2008) could be replicated.

The anterior N2 component is frontocentrally distributed and peaks relatively early (200–350 ms). The N2 is often followed by a positive-going wave, forming the N2-P3 complex (e.g., Loveless, 1986). The N2 is thought to index perceptual or template mismatch

Table 1. *Summary of Manipulations, Cognitive Processes, and Neural Indices Associated with the Preview- and Target-Related Events*

Event	Manipulation	Cognitive process	Neural index
Preview-related	Number of no-target displays combined with color change in the no-target displays	Color-specific selection	FSP
		Stimulus discrimination	Anterior N2
		Attention to selected color	P3
Target-related	Relationship between preview color(s) and target color	Target selection	N2pc
	Number of no-target displays combined with color change in no-target displays	Cumulative inhibition	Anterior N2
		Attention to target	P3

(for review, Folstein & van Patten, 2009) and cognitive control, for example, the top-down inhibition of feature-specific attentional sets (Eimer, Kiss, Press, & Sauter, 2009; Folstein & van Patten, 2009). Thus, two predictions were possible for the second no-target displays. First, a mismatch of the second item color to the first one could result in a larger N2 for the changed than for the repeated color trials. Second, the opposite effect—a larger N2 for the repeated than for the changed color trials—should (if observed) indicate inhibition of a repeated color at the second no-target display. Further, assuming that attentional biases occurring in the successive no-target displays are carried over to the target display, the item color in Sequence 2-same should be inhibited more than that in the other sequences.

The P3 component can refer to the P3a (Courchesne, Hillyard, & Galambos, 1975) or the P3b (Smith, Donchin, Cohen, & Starr, 1970; Sutton, Braren, Zubin, & John, 1965), both of which have different latencies and scalp distributions. The P3a is elicited earlier than the P3b, and is observed at frontocentral electrode sites rather than at posterior sites in which the P3b is typically observed (Gaeta, Friedman, & Hunt, 2003). Thus, a P3 following the N2 is close to the P3a in terms of its latency and scalp distribution. The elicitation of a P3a is modulated by the physical salience of a stimulus in a given task context regardless of the task relevance of the stimulus (Gaeta et al., 2003), but the P3b is elicited by a stimulus that is deviant in a task-relevant attribute (Donchin, 1981; Gaeta et al., 2003). Despite these differences, both P3a and P3b are sensitive to the trial history of a stimulus (Donchin, 1981; Gaeta et al., 2003; Squires, Wickens, Squires, & Donchin, 1976). The amplitude of each component increases for a stimulus that is unexpected based on the history of stimulus presentations, and grows as more attentional resources are available for task conditions (Donchin, 1981; Israel, Chesney, Wickens, & Donchin, 1980; Kramer, Wickens, & Donchin, 1983). In the current study, a larger amplitude was expected for the changed than for the repeated color trials as attentional resources should be allocated more to the changed color no-target display than to the repeated one. Moreover, the P3a and P3b responses should differ by color previewing history in that the P3b is sensitive to the color history of the oddball target that was linked with the task of the current study (i.e., oddball target identification).

The current paradigm allowed for investigating color previewing history effects emerging from no-target previewing until target viewing. As shown in Table 1, these effects arose as a function of the number of no-target displays and the item colors in the no-target and target displays, which were designed to induce selection failures and biases in attentional sets. Using ERPs, we tracked dynamic attentional shifts by revealing the time course of selection and inhibition for both preview- and target-related events.

Method

Participants

Eighteen adults (eight men, age range: 18–33 years) participated in the study. All were right-handed (as assessed by the Edinburgh Handedness Inventory; Oldfield, 1971), reported normal or corrected-to-normal vision, and underwent screening for color blindness via an online version of the Ishihara Color Blindness Test. They received monetary compensation for their participation. One participant was excluded due to large eye-movement artifacts; therefore, data from 17 participants were analyzed.

Stimuli and Procedures

Stimuli comprised a combination of two colors and shapes: They were green or red and circles or triangles (subtending 0.95° × 0.95° of visual angle), resulting in four different stimuli. As shown in Figure 1A, these stimuli were used for four items presented in the no-target and target displays. The four items were placed on an imaginary 3.18° circle (centered on a fixation cross), one in each quadrant, with the constraint that at least one was of a different shape. Each no-target display showed four identically colored items, and each target display showed one uniquely colored item (i.e., the target) and three identically colored items (i.e., the distractors). Whereas the items in the no-target display were placed at fixed locations (45°, 135°, 225°, and 315° relative to the vertical meridian), those in the target display were placed at varied locations, with the constraint that they should be 90° apart, and none should fall within 5° of the vertical meridian. These location changes allowed the target to appear in one of the 12 possible locations, ensuring that its location was difficult to predict.

Figure 1B shows schematic descriptions of four sequences and their corresponding conditions. All conditions, with the exception of the no-preview condition, were determined by whether the color of the target or distractors in the current target display was presented in the preceding no-target display(s). As the TP and DP were labeled, the target-target preview (TTP) and distractor-distractor preview (DDP) of the 2-same sequence represented target-target and distractor-distractor color previews, respectively. In other words, the item color was repeated during the presentations of two successive no-target displays and was used for target and distractor colors in the target display, respectively. The distractor-target preview (DTP) and target-distractor preview (TDP) for the 2-diff sequence represented distractor-target and target-distractor color previews, respectively. Unlike the TTP and DDP conditions, the item color changed from the first to the second display in the stream of two no-target displays. The DTP represents the condition in which the item colors that had been presented in

Table 2. *Time Windows and Electrode Sites for Calculating Mean Amplitudes for Preview- and Target-Related ERP Components*

Event	Component	Time window (ms)	Averaged electrode sites
Preview-related	FSP	140–190	Fp1, Fp2, F3, F4, Fz, F7, F8
	N2	270–350	F3, Fz, F4
	P3	350–450	Frontal (F3, Fz, F4, F7, F8)
			Central (C3, Cz, C4, T3, T4)
			Parietal (P3, Pz, P4, PO1, PO2)
			Temporooccipital (T5, T6, O1, O2)
Target- related	N2pc	200–350	T5/T6
	N2	260–360	Fp1, Fp2, F7, F8, F3, Fz, F4
	P3	340–600	Frontal (F3, Fz, F4, F7, F8)
			Central (C3, Cz, C4, T3, T4)
			Parietal (P3, Pz, P4, PO1, PO2)
			Temporooccipital (T5, T6, O1, O2)

the first and second no-target displays became distractor and target colors in the target display, respectively, and the TDP represents a condition with a reversed color order (i.e., target and distractor colors). In summary, the Sequence 1, 2-same, and 2-diff yielded TP, DP, TTP, DDP, DTP, and TDP conditions. As the TP, TTP, and DTP conditions have the preview of the target color in the immediately preceding no-target display in common, these conditions will hereafter be referred to as TP-like conditions. Similarly, the DP, DDP, and TDP conditions will be referred to as DP-like conditions. The no-preview trials were included to provide a baseline condition in which target search was not influenced by previewing effects.

Participants were seated 90 cm from a computer monitor in a dimly lit room. Each block began with a 1,500-ms fixation cross. The no-target display, shown for 200 ms, preceded the target display, which was presented for 160 ms, followed by a 1,140-ms response interval. An interstimulus interval of 1,214 ms separated the displays within a sequence, and each sequence was separated by a 1,160-ms interval. The presentation of target color, shape, and hemifield was randomized and occurred with equal probability in each condition. Furthermore, the seven conditions were randomly selected and presented with approximately equal probability, resulting in probabilities of 0.14, 0.29, and 0.57 for Sequence 0, 1, and 2 (including both 2-diff and 2-same), respectively. Participants were told that a uniquely colored item could appear in each display. When a color oddball was present, participants were asked to respond to the oddball shape as quickly and accurately as possible. When a color oddball was absent, participants were told to simply view the display without any response. They were given 1,300 ms to press the *Q* or *P* key on a computer keyboard, using each hand for each key, with hand assignment counterbalanced across participants. A total of twenty-four 50-trial blocks were run (1,200 trials), preceded by one 30-trial practice block.

ERP Recording and Analysis

The EEG was recorded from 23 scalp locations (10-20 electrode system; Jasper, 1958) using an elastic electrocap (Compumedics, Charlotte, NC). The right mastoid served as an online reference, and an average reference was derived offline. The recording locations included three midline sites (Fz, Cz, Pz), 10 lateral sites to the left of the midline (Fp1, F3, F7, C3, T3, P3, T5, PO1, O1, left mastoid), and their homologous sites to the right of the midline. Vertical and horizontal electrooculogram (EOG) were recorded bipolarly. Impedance was kept below 5 kΩ. All signals were amplified using NeuroScan NuAmps amplifiers (Compumedics). A 0.1–30 Hz band-pass filter was used for all online recordings. EEG and EOG were sampled at 500 Hz and epoched starting 200 ms before the presentation of each display and ending 1,000 ms poststimulus.

Blinks were corrected offline using a regression-based procedure (Semlitsch, Anderer, Schuster, & Presslich, 1986). For the target displays, we excluded epochs with horizontal eye movements exceeding $\pm$ 10 μV between the 200-ms prestimulus and 500-ms poststimulus intervals, wherein the N2pc is typically observed. In addition, epochs containing scalp and mastoid potentials exceeding 100 μV were excluded from further analyses. Average waveforms were obtained for each participant, electrode, and condition. N2pc effects were derived by subtracting the brain potentials at electrodes ipsilateral to the target side from those at the contralateral ones, separately for each condition.

Table 2 summarizes the time windows and electrode sites used to calculate mean amplitudes of the preview- and target-related ERP components. According to our visual inspection, these components were best identified within these time windows and electrode sites. In most analyses, mean amplitudes were measured at these locations within these time windows, averaged, and submitted to repeated measures analyses of variance (ANOVAs). Thus, only the analyses that were performed distinctly from this approach will be described in detail. The no-preview condition was excluded from the ERP analyses because we focused on uncovering electrophysiological markers associated with history-dependent attentional bias, and this condition could not provide such information. Furthermore, N2pc effects were tested at the T5/T6 electrode pair locations. Typically, the N2pc is the largest in the more posterior electrodes such as PO7/PO8. However, the electrocaps used in the current study provided limited recording locations, and the largest N2pc effect was observed at the former electrode pair.

For the preview-related events, ERP waveforms differed depending on whether the previewed colors were repeated or changed. The changed color trials showed more positive potentials than the repeated color trials in the FSP and P3 components. Following the FSP, the anterior N2 was also larger for the changed than for the repeated trials. The FSP and N2 effects were observed rather early at frontal electrode sites. The P3 effect was observed later at most electrode sites but was more visible in the central and posterior locations. Thus, mean amplitudes were measured for the repeated (TTP and DDP combined) and changed (DTP and TDP combined) conditions within the second no-target epoch, and the difference between the two conditions was tested for the FSP, the N2, and the P3. Due to the wide distribution of the P3, we divided

the electrode sites into four areas (frontal, central, parietal, temporooccipital) and obtained average voltages representing each area (Table 2). From these averages, mean amplitudes were measured between 350 and 450 ms and submitted to a 4 Location (frontal, central, parietal, temporooccipital) × 2 Color Change (repeated, changed) repeated measures ANOVA.

For the target-related events, we first assessed whether an N2pc development was significant relative to the baseline in all conditions. The mean amplitudes of the N2pc (measured between 200 and 350 ms poststimulus) were submitted to one sample *t* tests. Second, the DP-like conditions (i.e., DP, TDP, and DDP) appeared to peak earlier and develop larger than their counterparts (i.e., TP, DTP, and TTP). Thus, we measured the maximum amplitude and corresponding latency within the time window between 160 and 375 ms poststimulus for each participant. These measurements were tested separately for the peak amplitude and latency; onset latency differences were also tested. To measure onset latency, we estimated the time at which the N2pc exceeded 50% of the maximum amplitude within the time window between 200 and 350 ms poststimulus for each condition (Kiesel, Miller, Jolicœur, & Brisson, 2008). Statistical tests were performed using the jackknife-based method (Kiesel et al., 2008; Miller, Patterson, & Ulrich, 1998) employed in previous studies (Shin & Bartholow, 2013; Shin et al., 2008).

A target-related N2 component was also observed at frontal electrode sites, peaking at ~300 ms poststimulus. The mean amplitudes, obtained from the average voltages of the frontal electrode sites (Table 2), were submitted to a 2 Color Previewing (TP-like, DP-like) × 3 Sequence (1, 2-diff, 2-same) repeated measures ANOVA. Moreover, a positive-going wave was accompanied by the N2 component at the frontocentral sites and a P3b-like slow wave was elicited in the posterior areas. Given the wide extent of the P3 scalp distribution, we followed the same procedure as that applied for analyzing preview-related events, with the exceptions that mean amplitudes were measured between 340 and 600 ms and submitted to a 4 Location (frontal, central, parietal, temporooccipital) × 2 Color Previewing (TP-like, DP-like) × 3 Sequence (1, 2-diff, 2-same) repeated measures ANOVA.

Results

Response Times

Figure 2 shows the mean reaction time (RT) results[1] for the seven conditions. A 2 Color Previewing (TP-like, DP-like) × 3 Sequence (1, 2-diff, 2-same) repeated measures ANOVA revealed that search times were significantly faster in the DP-like than in the TP-like condition, $F(1,16) = 126.40$, $p < .001$, $\eta^2 = .89$, indicating the occurrence of the distractor previewing effect. Also, there was a significant sequence effect, $F(2,32) = 7.06$, $p < .003$, $\eta^2 = .31$, in which search times increased significantly from Sequence 1, 2-diff, to 2-same, indicating the accumulation of trial history. Moreover, a significant interaction was found between color previewing and sequence, $F(2,32) = 24.62$, $p < .001$, $\eta^2 = .61$, suggesting that the cumulative effect of trial history varied depending on the color that had been previewed. For each sequence, the TP-like condition was compared with the corresponding DP-like condition (i.e., TP vs. DP, DTP vs. TDP, and TTP vs. DDP), resulting in a significantly different RT for each sequence, Fs$(1,16) > 8.67$, ps$ < .01$, η^2s$ > .34$. In particular, Sequence 2-diff showed a significantly faster response in the TDP condition than that in the DTP condition, $F(1,16) = 8.68$, $p < .01$, $\eta^2 = .35$, indicating that the recently seen colors exerted a greater influence on target identification speed than remotely seen colors.

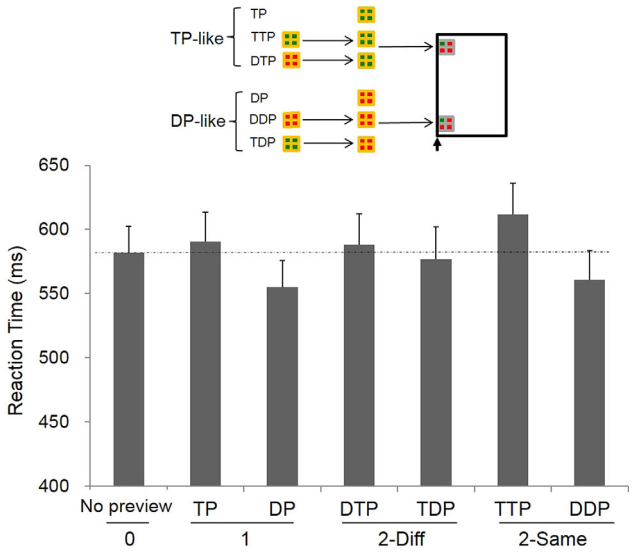

Figure 2. Mean reaction time results ($n = 17$). The error bars represent standard errors of the mean.

We compared the no-preview with each previewing condition, to determine whether RTs were facilitated or delayed as a function of color previewing history. Whereas both the DP and DDP conditions showed significantly shorter RTs than the no-preview condition, Fs$(1,16) > 8.81$, ps$ < .009$, η^2s$ > .35$, the TTP condition showed significantly longer RTs than the no-preview condition, $F(1,16) = 18.38$, $p < .001$, $\eta^2 = .54$. The remaining comparisons did not reach statistical significance. These results suggest that color previewing induced both facilitation and inhibition in some previewing conditions, which explains the similarity between RTs for the no-preview and the average of the previewing conditions (582 and 581 ms, respectively), $t(16) = 0.23$, *n.s.*

Finally, we compared the three TP-like conditions to determine their relative degrees of inhibition. The TTP condition showed significantly longer RTs than the TP, $F(1,16) = 31.11$, $p < .001$, $\eta^2 = .66$, and DTP, $F(1,16) = 45.58$, $p < .001$, $\eta^2 = .74$, conditions. The DP-like conditions were also compared to determine their relative degrees of facilitation. The DP and DDP conditions showed significantly shorter RTs than the TDP, $F(1,16) = 10.68$, $p < .005$, $\eta^2 = .40$, and $F(1,16) = 13.08$, $p < .002$, $\eta^2 = .45$, respectively. Other comparisons did not yield any significant differences. Further, we found that the difference between the TTP and TP conditions (21.27 ms) was significantly larger than that between the DDP and DP conditions (5.52 ms), $F(1,16) = 11.40$, $p < .01$, $\eta_p^2 = .42$. Thus, it appears that previewing target colors delayed search times to a greater extent than previewing distractor colors facilitated search times.

1. Due to technical errors, correct trials were not separated from incorrect ones. Thus, RT and ERP results were obtained from all trials (with the exception of no-response trials). Shin (2015) conducted a behavioral study (Experiment 2B, $n = 20$) using the same experimental paradigm. Accuracy was 95% on average and distributed very similarly across all seven conditions, resulting in no significant differences between conditions. Therefore, the current data represent almost all correct trials without conditional biases.

Preview-Related ERPs

Figure 3 shows grand-averaged ERP waveforms elicited by the second no-target displays. The FSP was significantly greater for the changed (1.04 μV) than for the repeated (0.67 μV) trials, $F(1,16) = 24.30$, $p = .001$, $\eta_p^2 = .60$ (Figure 3A), indicating that attention was oriented to the changed colors rather than the repeated ones. Likewise, the N2 was significantly larger for the changed (-0.80 μV) than for the repeated (-0.53 μV) trials, $F(1,16) = 6.49$, $p < .05$, $\eta_p^2 = .29$ (Figure 3A). This effect may have been induced by a mismatch (rather than an inhibition) of the second item color with the perceptual template that participants had formed prior to the second no-target display. The P3 was also significantly larger for the changed than for the repeated trials,

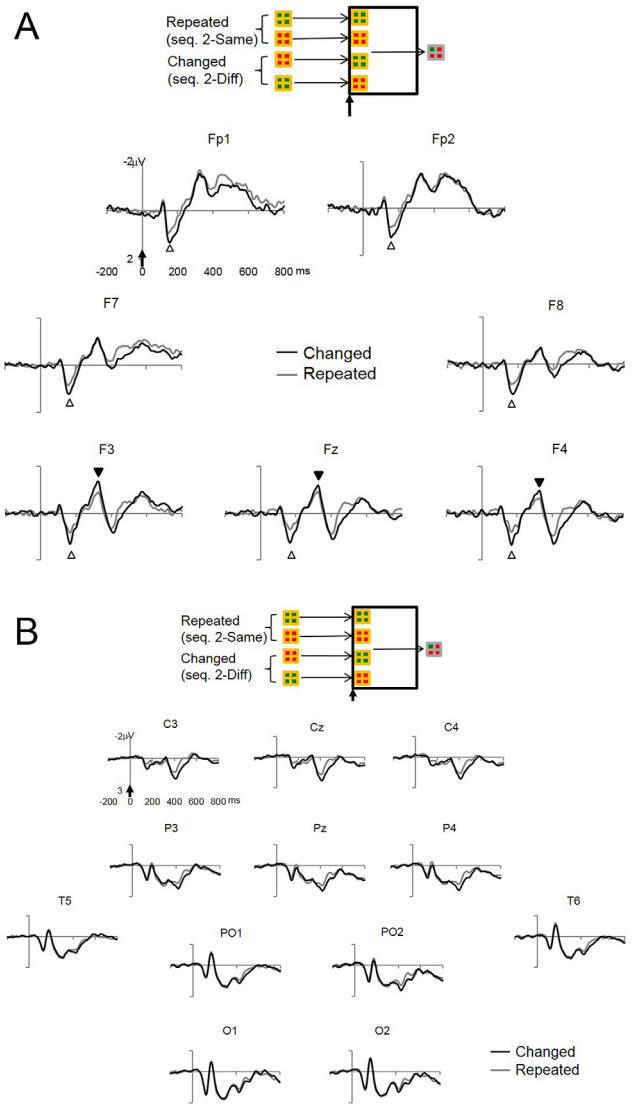

Figure 3. Preview-related events. A: Grand-averaged waveforms ($n = 17$) obtained at the frontal electrode sites for the second no-target display in which item color was repeated (2-same) or changed (2-diff). The open and filled triangles indicate FSP and N2 responses, respectively. B: Grand-averaged waveforms ($n = 17$) obtained at the central and posterior electrode sites for the repeated and changed color trials. The black lines representing the changed trials show larger P3 responses than the gray lines representing the repeated trials. Negativity is plotted up.

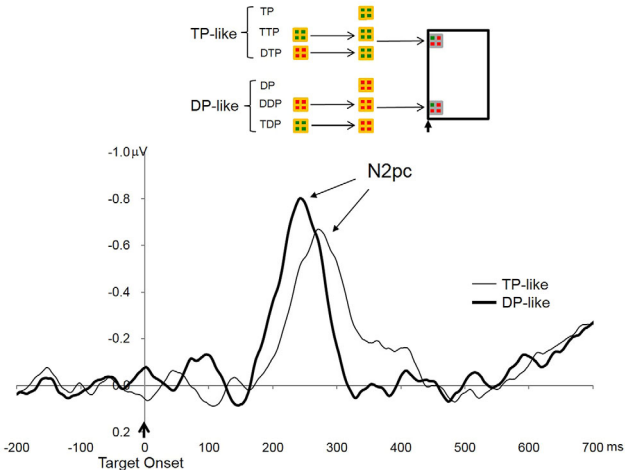

Figure 4. Target-related events. Grand-averaged N2pc waveforms ($n = 17$) obtained at the T5/T6 electrode pair. Negativity is plotted up.

$F(1,16) = 14.56$, $p < .001$, $\eta_p^2 = .48$, and significantly increased from the anterior to the posterior direction, $F(1,16) = 15.12$, $p < .001$, $\eta_p^2 = .49$ (Figure 3B). However, there was no significant interaction between location and color change, $F(1,16) = 1.51$, *n.s.* As it has been suggested that the P3 responses observed in the anterior and posterior areas can be driven by different processes (e.g., Gaeta et al., 2003; Polich, 2007), paired t tests for color change effects were performed in each of the four areas. The P3 was larger for the changed than for the repeated trials in the central and posterior areas, Fs$(1,16) > 8.01$, ps$ < .12$, η_p^2s$ > .33$, but not in the frontal area, $F(1,16) = 3.12$, *n.s.* These P3 effects suggest that attentional resources were allocated to changed colors and that the colors continued to be evaluated as attention had shifted toward the changed colors (which was suggested by the FSP effect). All these results suggest that attention was shifted toward the changed colors at the second no-target display.

Target-Related ERPs

Figure 4 shows the grand-averaged N2pc waveforms. An N2pc was significantly developed relative to the baseline in all conditions, ts$(16) > 5.24$, ps$ < .001$, Cohen's ds$ > 1.26$. Compared to the TP-like condition (276 ms), the DP-like condition (243 ms) reached the maximum amplitude significantly earlier, $F(1,16) = 35.11$, $p < .001$, $\eta_p^2 = .69$. However, no other effects (including the sequence effect) were found in peak latency or amplitude measurements, Fs$(2,32) < 0.75$, *n.s.* Similar to the peak latency result, the DP-like (207 ms) condition elicited a marginally significant earlier onset than the TP-like (224 ms) condition, $t(16) = 2.05$, $p = .06$, Cohen's $d = 0.13$. These N2pc latency effects were consistent with those of the previous study (Shin et al., 2008) and suggest that attention was allocated to the target earlier in the DP-like than in the TP-like condition.

The anterior N2 and its succeeding P3 (i.e., the P3a) were evident at the frontal electrode sites, as shown in Figure 5. The N2 analysis revealed that the main effect of sequence (i.e., previewing history) was significant, $F(1,16) = 3.65$, $p < .05$, $\eta_p^2 = .19$, although that of color previewing and an interaction between sequence and color previewing were not significant. The significant sequence effect was driven primarily by a large difference between Sequence 1 (-0.29 μV) and 2-same (-0.55 μV), $t(16) = -2.80$, $p < .05$, Cohen's $d = 0.23$, as revealed by paired t tests (see also

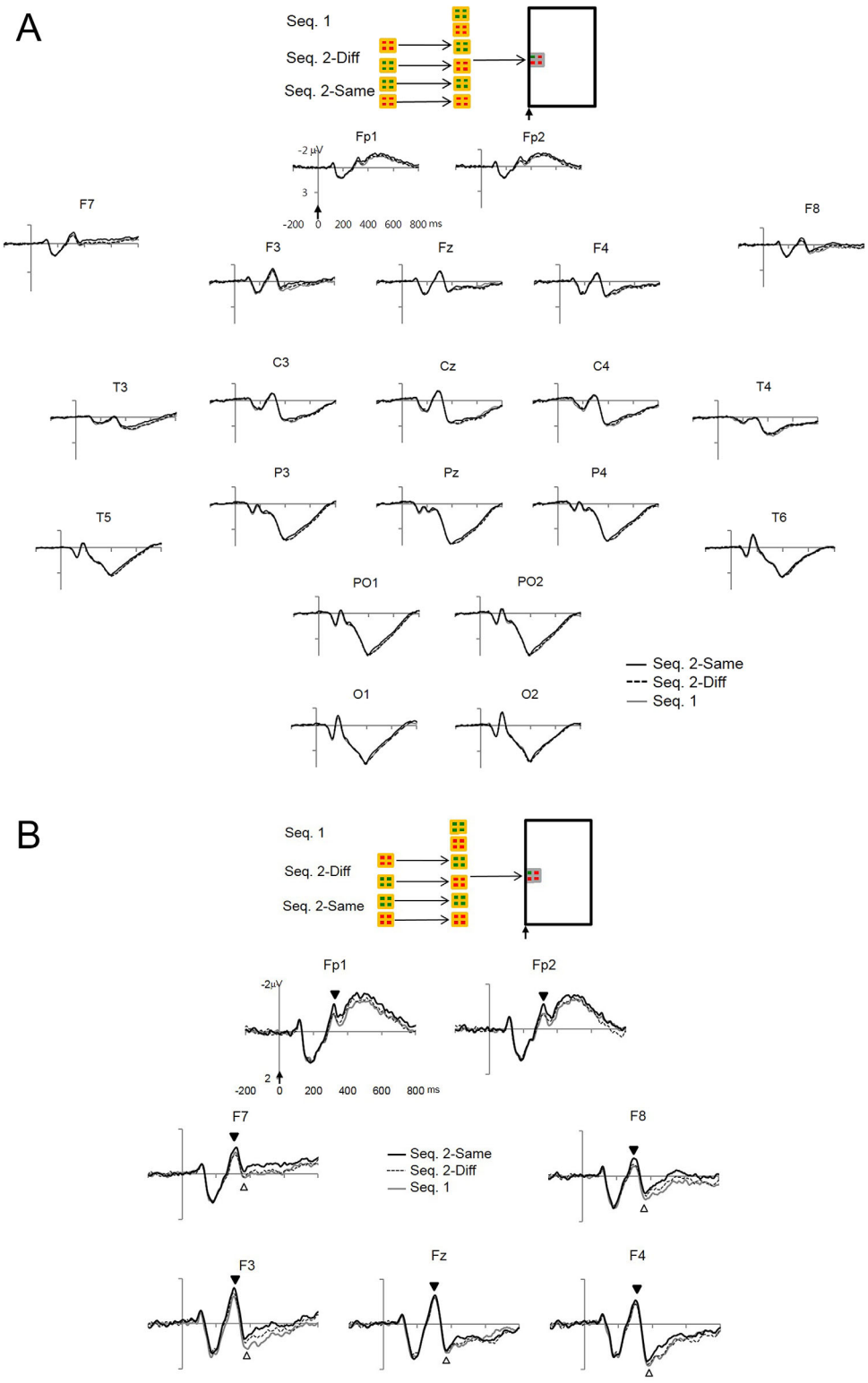

Figure 5. Target-related events. A: Grand-averaged waveforms ($n = 17$) obtained at all scalp electrodes for the three different sequences. B: Enlarged grand-averaged waveforms ($n = 17$) obtained at the frontal electrode sites for the three sequences. The solid gray lines represent Sequence 1, and the solid and dashed black lines represent Sequence 2-same and 2-diff, respectively. The filled and open triangles indicate N2 and P3 responses, respectively. Negativity is plotted up.

Figure 5B). No other comparisons showed significant differences, $ts(16) < 1.66$, *n.s.* For the P3, its amplitude differed significantly by sequence, $F(1,16) = 8.33$, $p < .001$, $\eta_p^2 = .34$, with this difference mostly visible at the frontal sites, resulting in a significant interaction between location and sequence, $F(6,96) = 26.28$, $p < .001$, $\eta_p^2 = 0.62$ (Figure 5A). As shown in Figure 5B, the P3a had a

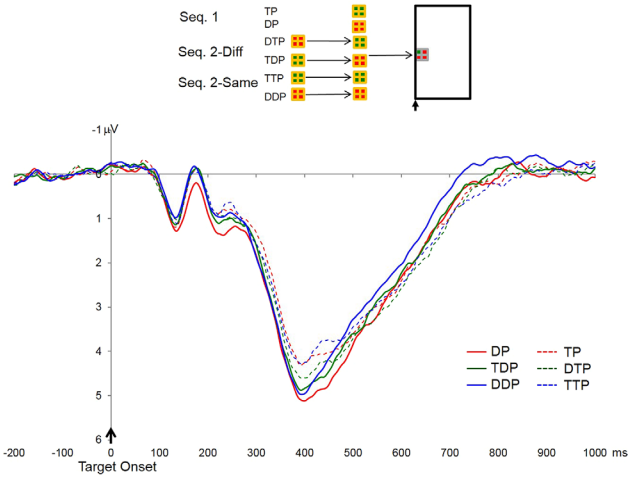

Figure 6. Target-related events. Grand-averaged P3b waveforms ($n = 17$) collapsed across the parietal electrode sites P3, Pz, P4, PO1, and PO2. Red, green, and blue represent Sequence 1, 2-diff, and 2-same, respectively. The solid and dashed lines represent the DP-like and TP-like conditions, respectively. Negativity is plotted up.

graded amplitude pattern. The positive amplitude of Sequence 1 (0.66 μV) was greatest, followed by the 2-diff (0.53 μV) and 2-same (0.31 μV) sequences, although a significant difference was only observed between Sequence 1 and 2-same, $t(16) = 3.43$, $p < .01$, Cohen's $d = 0.29$, as revealed by paired t tests. We found that both N2 and P3a were modulated by the sequences. This suggests that the salience of the target display was enhanced more after the exposure to a single color than to a repeatedly presented color, presumably because of the greater extent of inhibition of the repeated color than of the single one.

Despite the effect of the P3 in the frontal area, the amplitude of the P3 component was significantly larger in the central and posterior areas than in the frontal area, $F(1,16) = 82.35$, $p < .001$, $\eta_p^2 = .84$. In particular, the difference between TP- and DP-like conditions (i.e., color previewing effect) was more visible in the posterior areas in which the P3b is typically observed. This observation was corroborated by a significant interaction between location and color previewing, $F(3,48) = 4.86$, $p < .05$, $\eta_p^2 = .23$. Although there was no significant three-way interaction, $F(6,96) = 2.02$, *n.s*, our visual inspection indicated that an interaction between sequence and color previewing was visible in the parietal electrode sites. Thus, we narrowed our scope of analysis in relation to area and time. Mean amplitudes were measured from the average of the parietal area (defined in Table 2) in a time window between 360 and 500 ms, and were submitted to a 2 Color Previewing (TP-like, DP-like) × 3 Sequence (1, 2-diff, 2-same) repeated measures ANOVA. As shown in Figure 6, the DP-like (4.46 μV) condition showed a significantly larger parietal-P3b than the TP-like (4.05 μV) condition, $F(1,16) = 18.68$, $p < .01$, $\eta_p^2 = .54$, and that this color previewing effect significantly differed as a function of the sequences, $F(2,32) = 5.60$, $p < .01$, $\eta_p^2 = .26$, with Sequence 1 showing the largest color previewing effect and Sequence 2-diff the smallest. We also performed paired t tests and confirmed that the parietal-P3b amplitude was significantly larger in the DP than in the TP condition and also in the DDP than in the TTP condition, $ts(16) > 2.55$, $ps < .05$, Cohen's $ds > 0.27$, but that the difference between the TDP and DTP conditions was not significant, $ts(16) = 1.22$, *n.s*. This seems to be the time window in which both color previewing and previewing history influence target processes, with more attentional resources allocated to the target item and the target being collectively evaluated based on its color previewing history.

Additionally, we examined relations among the preview- and target-related ERPs, and RT. First, we correlated the target-related N2pc, N2, and its succeeding P3 (i.e., P3a), parietal-P3b with RT. We noticed that, as N2 amplitudes increased, RTs became slower in all sequences. In contrast, as P3a amplitudes increased, RTs decreased. To test these observations, the mean amplitudes obtained separately from the N2 and P3 time windows (see Table 2) were averaged across the three sequences, and were correlated with RT data that were also averaged across the sequences. Results showed that the amplitudes of the N2 and P3a were significantly correlated with RTs, $r = -0.67$, $p = .01$; $r = -0.75$, $p = .001$, respectively. Moreover, the mean amplitudes of parietal-P3b elicited in each of the six conditions were significantly correlated with the mean RTs in the corresponding condition (e.g., a correlation between P3b and RT in the DP condition), $rs > -0.50$, $ps < .05$, indicating that, as the P3b increased, responses to the target became quicker. Second, we moved one visual event back and correlated the preview-related P3b with the target-related ERPs (N2pc, N2, P3a, parietal-P3b) and RT. Our results from the preview-related event included only Sequence 2 trials. Thus, the target-related ERP measurements were also obtained from Sequence 2 trials only. Within Sequence 2, ERP amplitudes were averaged across all trial types for both preview- and target-related events. Our visual inspection indicated that (a) as the preview-related P3b amplitudes decreased, the target-related N2 amplitudes and RTs increased; (b) as the preview P3b amplitudes increased, the target P3a and parietal-P3b amplitudes also increased. These were confirmed by significant correlations of preview P3b amplitudes with target N2, P3a, and P3b amplitudes, $rs > 0.52$, $ps < .05$, and also RTs, $r = -0.59$, $p < .05$. These results suggest that, as preceding items were attended more, (a) current items were less inhibited and rather perceived to be salient, and (b) the target in the current display was attended more and identified faster. N2pc amplitudes and latencies were not significantly correlated with either RTs or preview P3b amplitudes.

Discussion

The current study investigated selection bias contingencies on trial history using a distractor-previewing-effect paradigm. The existence of no-target scenes separated from target scenes allowed us to investigate history-based selection biases without the influence of target processing. Trial history was manipulated in a color oddball search task as follows. First, the number of no-target scenes was varied from zero to two, which increased the number of selection failures. Second, the item colors shown in the successive no-target scenes were repeated or changed, which led to systematic attentional biases. According to the attentional account of the distractor previewing effect (Lleras et al., 2008, 2009), selection failure leads to negative tagging of failed features and biasing attentional sets toward nonfailed features, resulting in the selection of nonfailed features and inhibition of failed features. Therefore, increasing no-target scenes was expected to increase negative tagging of failed features, hence enhancing the inhibition of the failed features. In contrast, a changed color in the second no-target scene was expected to be selected and attended to as a newly presented color. In other words, attention shifts most likely toward a newly presented color with less history of selection failure, and least

likely toward a recently presented color with a repeated history of selection failure.

We examined a trial-by-trial attention shift for both target-absent and target-present scenes by using ERPs. The course of attentional biasing was revealed as a function of the number of no-target scenes and item colors in the no-target and target scenes. The preview-related ERP results demonstrated that selection failures led to the selection of, and attention to, changed colors. More specifically, the second no-target display elicited FSP, N2, and P3b responses. All three components showed larger amplitudes for the changed than for the repeated colors in different time windows: early (< 200 ms), middle (~300 ms), and late (~400 ms) for the FSP, N2, and P3b, respectively. This time course suggests that the selection of a new color was followed by a perceptual discrimination of the current color with a previous one and further evaluation of the selected color, to which more attentional resources were allocated. All these results indicate that attention was shifted to previously unseen, new colors. However, the fact that the amplitudes of all three components grew at the changed, rather than repeated, color preview may suggest an alternative—the occurrence of neural habituation or efficiency to the repeated color—rather than the shift of attention to the changed color. To address this possibility, we examined an early posterior N1 component in which perceptual fluency effects can be reflected (Grossi & Coch, 2005; Shin et al., 2008). Interestingly, the N1 was larger for the repeated (−0.01 μV) than for the changed (0.22 μV) color trials in the parietal area, suggesting that neural habituation is unlikely to be the cause of our preview-related effects. We rather postulate that, upon the presentation of the second no-target scene, attentional set was updated and ready before the subsequent trial began, allowing the distractor previewing effect to start as early as within 100 ms after target onset (Lleras et al., 2008).

These preview-related effects were carried over to the target-present event. The target-related ERP results demonstrate how attentional biases were applied to the target display with respect to selection, inhibition, and evaluation. These processes were displayed in the N2pc, anterior N2, and P3 components in broadly distributed areas and varying time windows. The N2pc was observed at 150–300 ms after target onset. Consistent with Shin et al. (2008), the N2pc wave peaked earlier in DP-like trials than in TP-like trials, indicating earlier target selection with unseen or remotely seen (rather than seen or recently seen) colors in the no-target displays.

Independent of this posterior modulation, the effect of previewing history was observed in the frontal area slightly later (> 300 ms) than the time of the posterior N2pc effect. The anterior N2 showed the largest amplitude in Sequence 2-same, in which the same color was presented repeatedly in the preceding no-target displays. This enhanced negativity seems to show a cumulative effect of inhibition, which has been built up during preceding no-target trials. Alternatively, this N2 effect may reflect the detection of some type of mismatch in stimulus color. One of two colors in the target scene was mismatched with a successively formed color template in Sequence 2-same. However, in Sequence 2-diff, two colors in the target scene were already exposed to participants during the no-target scenes. Moreover, Sequence 1 had a shorter previewing history than that of Sequence 2-same, although one of the two colors was new to participants. The P3a was also modulated by the different sequences, although the effect was the opposite to that of the N2; the amplitude of the P3a was the largest for Sequence 1 and smallest for Sequence 2-same. Coupled with the N2 effect, the P3a effect may be a response to the target display (rather than to the target itself) in which the target display's salience was the greatest after one no-target display compared to two consecutive no-target displays in the current task context. Because of this enhanced salience, more attention should have been allocated to the Sequence 1 target display than to the Sequence 2 ones.

The P3b component showed a color previewing effect and an interaction between color previewing and previewing history at about the time (400 ms) at which the previewing history effect was taking place in the frontal area. Its amplitude was larger for the DP-like than for the TP-like trials. This indicates that attentional resources were made more available for targets with unseen or remotely seen colors than for those with seen or recently seen colors. This color previewing effect could have been carried over from the differential target selection, reflected in the earlier N2pc effect. Concurrently, both 1 and 2-same sequences, but not the 2-diff sequence, yielded significant color previewing differences. This interaction between color previewing and previewing history suggests that the current P3b responses reflect postselection, target-evaluation processes according to the previewing history of the target color, in turn being significantly correlated with target identification responses.

RT analyses revealed the main effects of color previewing and sequence, as well as an interaction between the two. RTs were shorter for DP-like trials than for TP-like trials. Interestingly, responses were faster for TDP trials than for DTP trials in the 2-diff sequence. In this sequence, the target and distractor colors were equally previewed, but the target identification speed was determined by the color immediately preceding the target display. In addition, search times increased with the number of no-target scenes. Shin (2015) increased the number of no-target scenes even further up to five and found that RTs increased continuously with the number of no-target scenes. This increase suggests that memory traces accumulate with more visual experiences and durable representations are formed over time (Brascamp et al., 2011; Maljkovic & Nakayama, 2000). Target identification speed also differed as a function of the history of color previewing. The extent to which TP- and DP-like trials differed was greatest for the 2-same sequence, followed by the 1 and 2-diff sequences. Moreover, we found that previewing target and distractor colors could delay or facilitate RTs compared to no-color previewing. In addition, the extent to which previewing target colors delayed search times was greater than that to which distractor colors facilitated them.

The selection bias shown in this study seems to require two functions in the application of biased attention for target search: tracking and updating the trial history of task-relevant features, and biasing feature-specific attentional sets according to that history. Top-down attentional biases are likely to be a major force driving such selection bias. However, history-dependent biases possess important characteristics, in that they are not directed explicitly and changes are made according to feature previewing history. In this respect, one may wonder how visual marking differs from the distractor previewing effect because visual marking brings a preview benefit (e.g., fast target identification) in conjunction visual search tasks. In a typical visual-marking paradigm, participants performed a color-form conjunction task. They first view a set of items of one color that does not contain a target, and then another set of items that contains distractors of the same preview color and a target of a different color (Watson & Humphreys, 1997; Watson, Humphreys, & Olivers, 2003). Based on this paradigm, visual marking appears to resemble the distractor previewing effect. However, the two phenomena are different, especially in one important respect (see Lleras et al., 2008, for a detailed comparison). In visual marking, the preview color always

becomes the distractor, not the target, color, thus making participants predict the target color with great certainty. In the distractor previewing effect, the preview color is shown as a distractor or target color with 50% probability. Thus, the item color in the preview display does not carry any predictive value for the target color. Furthermore, Sequence 0, 1, and 2 were distributed randomly in the current study, making it difficult to predict which type of display would be presented.

Nevertheless, the second no-target display was always followed by the target display. Hence, a target-display expectancy of participants could have led to general increases in their cognitive control. We tested whether this predictability induced or confounded the anterior ERP effects (i.e., FSP, N2, and P3a) in both the preview- and target-related events. We reasoned that, as time-on-task increased, participants might have demonstrated more of a predictability effect (see Shin, Fabiani, & Gratton, 2004, for a similar logic). Thus, we analyzed data from the first and second halves of the experimental trials and compared ERP results between the two periods. Results indicated that there was a predictability effect but separable from trial-history ERP effects in its distribution and amplitude patterns. Nonetheless, it is clear that the predictability of the target display played some role in the current P3 responses. As introduced earlier, both P3a and P3b are sensitive to the trial history of stimulus presentations. Here, a trial history comprises the visual experience provided by both no-target and target displays. A large P3 response is elicited when an expectancy that has been cumulated during stimulus presentations is violated (Courchesne et al., 1975; Squires et al., 1976). In the current study, the P3 response to the target display was larger in Sequence 1 than in Sequence 2. This could have stemmed from the combination of two reasons: (1) one no-target display was followed by another no-target or a target display, still leaving participants uncertain about the time of target appearance; (2) Sequence 1 trials were presented less frequently (approximately half as often) than Sequence 2 trials, leading participants to expect Sequence 1 trials less often than Sequence 2 trials. Taken together, the target presented after one no-target display could have violated the target-display expectancy more than that after two no-target displays, and this expectancy violation could have elicited the larger P3b response in Sequence 1 than in Sequence 2. However, it is important to note that this influence on P3 modulations did not impede the revelations of trial history effects in the current study.

The growing demands that history-based selection biases should be treated differently from top-down biases are noteworthy (Awh et al., 2012; Lamy & Kristjánsson, 2013). The question then arises as to how history-based selection biases differ from top-down selection biases and how they interact with each other. One way to answer this question would be to identify the brain regions responsible for these types of biases and their interconnectivity. Pollmann (2004, 2012) noted the role of the anterior portions of the prefrontal cortex (especially the frontopolar and lateral regions) in the implicit control of attention. The anterior prefrontal cortex has shown increased activation when targets changed from one dimension to another (e.g., color to motion) during a visual oddball search task (Pollmann, Weidner, Müller, & von Cramon, 2000) and when target locations changed in learned visual arrays (Pollmann & Maginelli, 2009). This activation indicates that changes in stimuli are detected in comparison to past stimuli and that there is a need to change attentional sets for optimal selection. Clearly, the anterior prefrontal cortex is different from the more posteriorly located areas such as the frontal eye field and the intraparietal sulcus (known as the dorsal attentional system) associated with the network for top-down attentional control (Corbetta & Shulman, 2002). Recently, the lateral prefrontal area has been discussed as a hub for attentional control in which both stimulus-driven orienting of attention and goal-directed task-set updating occur (Asplund et al., 2010; Brass, Ullsperger, Knoesche, von Cramon, & Phillips, 2005; Han & Marois, 2014; Pollmann et al., 2000).

The current study provides a glimpse into the brain areas that participate in history-dependent selection biases. As discussed, the anterior prefrontal cortex could be responsible for setting up and updating attentional biases toward task-relevant features, which was reflected in the frontal ERP components observed in the current study but not reported in previous ones (Scalf et al., 2014; Shin et al., 2008). In addition, the P3b effects could have been generated by the temporoparietal junction as it showed sustained activity while attention-demanding stimulus evaluation was required. Scalf et al. (2014) have already reported activity in this area related to the distractor previewing effect. Although several brain regions could be relevant, fMRI studies employing paradigms similar to that used in the current study should offer a more definitive answer as to the neural origins underlying history-based attentional biasing.

The current study investigated history-based selective attention in a color oddball search task in which no-target scenes were systematically manipulated. We revealed that visual search was influenced by both what had been seen previously and how many times it had been seen. These influences manifested in attention-related ERP responses to no-target and target scenes. Feature-specific selection and attention to the selected feature were observed in the no-target scenes. The cumulative effects of these processes culminated in differential target selection, feature inhibition, and target evaluation in the target scenes. These findings are explained by attentional biases contingent on feature previewing history. The ERP successfully demonstrated the evolution of attentional shift on a trial-by-trial basis.

References

Ariga, A. & Kawahara, J. (2004). The perceptual and cognitive distractor-previewing effect. *Journal of Vision*, *4*, 891–903. doi: 10.1167/4.10.5

Asplund, C. L., Todd, J. J., Snyder, A. P., & Marois, R. (2010). A central role for the lateral prefrontal cortex in goal-directed and stimulus-driven attention. *Nature Neuroscience*, *13*, 507–512. doi: 10.1038/nn.2509

Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: A failed theoretical dichotomy. *Trends in Cognitive Sciences*, *16*, 437–443. doi: 10.1016/j.tics.2012.06.010

Brascamp, J. W., Pels, E., & Kristjánsson, Á. (2011). Priming of pop-out on multiple time scales during visual search. *Vision Research*, *51*, 1972–1978. doi: 10.1016/j.visres.2011.07.007

Brass, M., Ullsperger, M., Knoesche, T. R., von Cramon, D. Y., & Phillips, N. A. (2005). Who comes first? The role of the prefrontal and parietal cortex in cognitive control. *Journal of Cognitive Neuroscience*, *17*, 1367–1375. doi: 10.1162/0898929054985400

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*, *36*, 28–71. doi: 10.1006/cogp.1998.0681

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*, 201–215. doi: 10.1038/nrn755

Courchesne, E., Hillyard, S. A., & Galambos, R. (1975). Stimulus novelty, task relevance, and the visual evoked potential in man. *Electroencephalography and Clinical Neurophysiology*, *39*, 131–143. doi: 10.1016/0013-4694(75)90003-6

Donchin, E. (1981). Surprise! ... Surprise? *Psychophysiology*, *18*, 493–513. doi: 10.1111/j.1469-8986.1981.tb01815.x

Eimer, M., Kiss, M., Press, C., & Sauter, D. (2009). The roles of feature-specific task set and bottom-up silence in attentional capture: An ERP study. *Journal of Experimental Psychology*, *35*, 1316–1328. doi: 10.1037/a0015872

Folstein, J. R., & van Patten, C. (2009). Influence of cognitive control and mismatch on the N2 component of the ERP: A review. *Psychophysiology*, *45*, 152–170. doi: 10.1111/j.1469-8986.2007.00602.x

Found, A., & Müller, H. J. (1996). Searching for unknown feature targets on more than one dimension: Investigating a "dimension-weighting" account. *Perception & Psychophysics*, *55*, 88–101. doi: 10.3758/BF03205479

Gaeta, H., Friedman, D., & Hunt, G. (2003). Stimulus characteristics and task category dissociate the anterior and posterior aspects of the novelty P3. *Psychophysiology*, *40*, 198–208. doi: 10.1111/1469-8986.00022

Goolsby, B. A., Grabowecky, M., & Suzuki, S. (2005). Adaptive modulation of color salience contingent upon global form coding and task relevance. *Vision Research*, *45*, 901–930. doi: 10.1016/visres.2004.10.003

Grossi, G., & Coch, D. (2005). Automatic word form processing in masked priming: An ERP study. *Psychophysiology*, *42*, 343–355. doi: 10.1111/j.1469-8986.2005.00286.x

Han, S. W., & Marois, R. (2014). Functional fractionation of the stimulus-driven attention network. *Journal of Neuroscience*, *34*, 6958–6969. doi: 10.1523/JNEUROSCI.4975-13.2014

Hopf, J-.M., Boelmans, K., Schoenfeld, A. M., Heinze, H-.J., & Luck, S. J. (2002). How does attention attenuate target-distractor interference in vision? Evidence from magnetoencephalographic recordings. *Cognitive Brain Research*, *15*, 17–29. doi: 10.1016/S0926-6410(02)00213-6

Hopf, J-.M., Luck, S. J., Girelli, M., Hagner, T., Mangun, G. R., Scheich, H., & Heinze, H-.J. (2000). Neural sources of focused attention in visual search. *Cerebral Cortex*, *10*, 1233–1241. doi: 10.1093/cercor/10.12.1233

Israel, J. B., Chesney, G. L., Wickens, C. D., & Donchin, E. (1980). P300 and tracking difficulty: Evidence for multiple resources in dual-task performance. *Psychophysiology*, *17*, 259–273. doi: 10.1111/j.1469-8986.1980.tb00146.x

Jasper, H. H. (1958). The ten-twenty electrode system of the International Federation. *Electroencephalography and Clinical Neurophysiology*, *10*, 371–375.

Kenemans, J. L., Kok, A., & Smulders, F. T. Y. (1993). Event-related potentials to conjunctions of spatial frequency and orientation as a function of stimulus parameters and response requirements. *Electroencephalography and Clinical Neurophysiology*, *99*, 51–63. doi: 10.1016/0168-5597(93)90028-N

Kiesel, A., Miller, J., Jolicœur, P., & Brisson, B. (2008). Measurement of ERP latency differences: A component of single-participant and jackknife-based scoring methods. *Psychophysiology*, *45*, 250–274. doi: 10.1111/j.1469-8986.2007.00618.x

Kramer, A. F, Wickens, C. D., & Donchin, E. (1983). An analysis of the processing requirements of a complex perceptual-motor task. *Human Factors*, *25*, 597–621. doi: 10.1177/001872088302500601

Lamy, D. F., & Kristjánsson, Á. (2013). Is goal-directed attentional guidance just intertribal priming? A review. *Journal of Vision*, *13*, 1–19. doi: 10.1167/13.3.14

Levinthal, B. R., & Lleras, A. (2008). Inter-trial inhibition of attention to features is modulated by task relevance. *Journal of Vision, 8*, *12*, 1–15. doi: 10.1167/8.15.12

Lleras, A., Kawahara, J.-I., Wan, X. I., & Ariga, A. (2008). Inter-trial inhibition of focused attention in pop-out search. *Attention, Perception & Psychophysics*, *70*, 114–131. doi: 10.3758/PP.70.1.114

Lleras, A., Levinthal, B. R., & Kawahara, J. (2009). The remains of the trials: Goal-determined inter-trial suppression of selective attention. In N. Srinivasan (Ed.), *Attention. Progress in brain research* (Vol. *176*, pp. 195–213). Amsterdam, The Netherlands: Elsevier. doi: 10.1016/S0079-6123(09)17611-2

Loveless, N. E. (1986). Potentials evoked by temporal deviance. *Biological Psychology*, *22*, 149–167. doi: 10.1016/0301-0511(86)90042-6

Luck, S. J., Girelli, M., McDermott, M. T., & Ford, M. A. (1997). Bridging the gap between monkey neurophysiology and human perception: An ambiguity resolution theory of visual selective attention. *Cognitive Psychology*, *33*, 64–87. doi: 10.1006/cogp.1997.0660

Luck, S. J., & Hillyard, S. A. (1994). Spatial filtering during visual search: Evidence from human electrophysiology. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 1000–1014. doi: 10.1037/0096-1523.20.5.1000

Maljkovic, V., & Nakayama, K. (1994). Priming of pop-out: I. Role of features. *Memory and Cognition*, *22*, 657–672. doi: 10.3758/BF03209251

Maljkovic, V., & Nakayama, K. (2000). Priming of pop-out: III. A short term implicit memory system beneficial for rapid target selection. *Visual Cognition*, *7*, 571–595. doi: 10.1080/135062800407202

Miller, J., Patterson, T., & Ulrich, R. (1998). Jackknife-based method for measuring LRP onset latency differences. *Psychophysiology*, *35*, 99–115. doi: 10.1111/1469-8986.3510099

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, *9*, 97–113. doi: 10.1016/0028-3932(71)90067-4

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*, 2128–2148. doi: 10.1016/j.clinph.2007.04.019

Pollmann, S. (2004). Anterior prefrontal cortex contributions to attention control. *Experimental Psychology*, *51*, 270–278. doi: 10.1027/1618-3169.51.4.270

Pollmann, S. (2012). Anterior prefrontal contributions to implicit attention control. *Brain Sciences*, *2*, 254–266. doi: 10.3390/brainsci2020254

Pollmann, S., & Manginelli, A. A. (2009). Anterior prefrontal involvement in implicit contextual change detection. *Frontiers in Human Neuroscience*, *3*, 1–13. doi: 10.3389/neuro.09.028.2009

Pollmann, S., Weidner, R., Müller, H. J., & von Cramon, D. Y. (2000). A fronto-posterior network involved in visual dimension changes. *Journal of Cognitive Neuroscience*, *12*, 480–494. doi: 10.1162/089892900562156

Ruijter, J., De Ruiter, M. N., & Snel, J. (2000). The effects of caffeine on visual selective attention to color: An ERP study. *Psychophysiology*, *37*, 427–439. doi: 10.1111/1469-8986.3740427

Scalf, P. E., Ahn, J., Beck, D. M., & Lleras, A. (2014). Trial history effects in the ventral attentional network. *Journal of Cognitive Neuroscience*, *26*, 2789–2797. doi: 10.1162/jocn_a_00678

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology*, *23*, 695–703. doi: 10.1111/j.1469-8986.1986.tb00696.x

Shin, E. (2015). Adaptive visual search in the distractor previewing effect: Focusing on feature previewing history and task context. *Korean Journal of Cognitive and Biological Psychology*, *27*, 253–274.

Shin, E., & Bartholow, B. D. (2013). Category-based inhibition of focused attention across consecutive trials. *Psychophysiology*, *50*, 365–376. doi: 10.1111/psyp.12022

Shin, E., Fabiani, M., & Gratton, G. (2004). Evidence of partial response activation in a memory-search task. *Cognitive Brain Research*, *20*, 281–293. doi: 10.1016/j.cogbrainres.2004.03.004

Shin, E., Wan, X. I., Fabiani, M., Gratton, G., & Lleras, A. (2008). Electrophysiological evidence of feature-based inhibition of focused attention across consecutive trials. *Psychophysiology*, *45*, 804–811. doi: 10.1017/S0048577299971135

Smid, H. G. O. M., Jakob, A., & Heinze, H.-J. (1999). An event-related brain potential study of visual selective attention to conjunctions of color and shape. *Psychophysiology*, *36*, 264–279. doi: 10.1017/S0048577299971135

Smith, D. B., Donchin, E., Cohen, L., & Starr, A. (1970). Auditory averaged evoked potentials in man during selective biaural listing. *Electroencephalography and Clinical Neurophysiology*, *28*, 146–152. doi: 10.1016/0013-4694(70)90182-3

Squires, K. C., Wickens, C., Squires, N. K., & Donchin, E. (1976). The effect of stimulus sequence on the waveform of the cortical event-related potential. *Science*, *193*, 1142–1146. doi: 10.1126/science.959831

Sutton, S., Braren, M., Zubin, J., & John, E. R. (1965). Evoked potential correlates of stimulus uncertainty. *Science*, *150*, 1187–1188. doi: 10.1126/science.150.3700.1187

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: Prioritizing selection for new objects by top-down attentional inhibition. *Psychological Review*, *104*, 90–122. doi: 10.1037/0033-295X.104.1.90

Watson, D. G., Humphreys, G. W., & Olivers, C. N. L (2003). Visual marking: Using time in visual selection. *Trends in Cognitive Sciences*, *7*, 180–186. doi: 10.1016/S1364-6613(03)00033-0

Woodman, G. F., & Luck, S. J. (2003). Serial deployment of attention during visual search. *Journal of Experimental Psychology: Human Perception & Performance*, *29*, 121–138. doi: 10.1037/0096-1523.29.1.121

(Received August 27, 2015; Accepted August 31, 2016)