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Can attenuation of attentional blink also evoke removal of repetition blindness?

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ABSTRACT

A recent study showed that attentional blink (AB), which has been considered to reflect the capacity limitation of visual temporal attention, can be attenuated after a short period of the color-salient training, in which the second target (T2) within the AB period is given a salient color (Choi et al., 2012). The current study explored whether the effect of the color-salient training could be transferred to another phenomenon. In addition to AB, repetition blindness (RB) was employed, which is phenomenologically similar to, but fundamentally different from AB. After completion of the color-salient training with a nonrepeated T2 (corresponding to AB), RB was still observed, whereas AB was completely removed. However, the color-salient training with a repeated T2 (similar to RB) induced not only a significant reduction of RB but also an attenuation of AB. This result provides further evidence for dissociation between AB and RB. In addition, it implies that the color-salient training improves the attentional control mechanism related to target–distractor discrimination rather than to the perceptual system.

1. Introduction

Although human mental ability seems infinite, the actual information-processing capacity of the human mind is limited in many aspects. We can only hold the visual information of fewer than four items in the visual working memory (Cowan, 2001; Luck & Vogel, 1997), and we find it difficult to conduct two (relatively) simple tasks in succession, especially when the second task is given after a very brief interval (psychological refractory period; Pashler, 1994).

One piece of good news, however, is that we can sometimes overcome this limitation with appropriate training. In our previous study, we showed that a deficit in temporal attention can be removed through specific types of attentional training (Choi et al., 2012). Identification of a second visual target (T2) is impaired in a rapid serial visual presentation (RSVP) when it is presented within half a second after the appearance of the first target (T1; Raymond, Shapiro, & Arnell, 1992). This deficit in identifying T2, called attentional blink (AB), has been considered too robust to be removed even after repetitive practice (Braun, 1998; Maki & Padmanabhan, 1994; Taatgen et al., 2009). However, AB can be entirely eliminated through only one day of a specific type of attentional training called "color-salient training", during which T2 presented within the AB period is always made salient by displaying it in a color (red) different from the other items, including T1 and distractors, both of which are white.

An interesting quality of this learning effect on AB is its generalization (Choi et al., 2012). Many aspects of the color-salient training were highly restrictive. Targets were always presented at a fixed serial position (i.e., T1 was always the second item in RSVP, and T2 was the fourth), a fixed stimulus onset asynchrony (SOA; i.e., T2 always followed 200 ms after T1), and a fixed lag (i.e., T2 was always at Lag 2: the second item after T1, with an intervening distractor). However, the learning effect was not specific to this trained condition; at untrained SOA, AB was successfully removed, and even T1 performance when T2 was at Lag 1 significantly increased.[1]

From the generalization of the color-salient training, we developed our subsequent research question: Can this training effect on AB be transferred to another untrained task that is highly similar to AB (and vice versa)? Repetition blindness (RB; Kanwisher, 1987) also refers to impairment in identification of T2 with a short SOA

[1] When T2 is at Lag 1 in normal RSVP, AB does not occur but the performance of T1 identification is worse than when T2 is at the other lags. After the color-salient training, this deficit in T1 performance was attenuated. This result was reported in the supporting information section of our previous report (see Figure S2 in Choi et al., 2012).

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in RSVP. The only difference between RB and AB is that, in RB, T2 is identical to T1. Despite its similarity to AB in terms of our perception, numerous previous studies have suggested that RB's mechanism is different from that of AB. For example, Chun (1997) demonstrated that AB and RB have different time courses (AB is most severe when SOA is 200–300 ms, whereas RB is maximal when T2 is temporally adjacent to T1) and that they occur independently (RB occurs without AB, and vice versa). These results suggest that AB results from a failure to encode T2 information into the working memory, whereas RB occurs due to a failure to individuate T1 and T2 as distinct items.

In the current study, we explored the task specificity of the color-salient training. In Experiment 1, during the color-salient training, the red T2 was not identical to T1, as is the case for AB. We tested whether the training could eliminate not only AB but also RB. In Experiment 2, AB and RB were measured before and after the color-salient training with T2 identical to T1, as is the case for RB.

2. Experiment 1: Can training with AB attenuate RB?

We first explored whether the color-salient training with AB could attenuate not only AB but also RB. During training, T2 was always presented at Lag 2 (within the AB period) in a salient color (red). Because T2 was different from T1, the employed condition corresponded to AB. To measure the learning effect induced by the color-salient training, both AB and RB were measured before (pre-test) and after (post-test) the training, with a normal RSVP task in which a color-salient T2 was not employed.

2.1. Method

2.1.1. Participants

Twelve university students from the Boston area participated in this experiment in exchange for monetary compensation. All the participants had normal or corrected-to-normal visual acuity and normal color vision. All of the participants were naïve to the purpose of the study and signed a consent form approved by the Internal Review Board of Boston University.

2.1.2. Apparatus

The experiment was constructed using the Psychophysics Toolbox (Brainard, 1997; Pelli, 1997) for MATLAB (MathWorks, Natick, MA) on a Mac G5 computer. All displays were presented on a 19-in. CRT monitor with a resolution of 1280 × 1024 pixels and a refresh rate of 85 Hz. Participants were positioned approximately 56 cm from the monitor so that the display subtended a visual angle of 36° by 27°. A chin rest was used to maintain the participants' head positions. The experiment was conducted in a darkened room.

2.1.3. Stimulus

On each trial, RSVP with ten items was displayed. As the items, we employed eight single digits (excluding 0 and 1, to avoid confusion), and 22 upper- and lowercase letters (excluding B, I, O, and Q). Participants were asked to identify digits in RSVP so that digits were targets and letters were distractors. The items were randomly generated, and no letter was shown twice in one trial. The sequence of items was presented within a white circular frame, 1.4° in diameter, at the center of the screen. Each item was presented for 100 ms and presented within a visual angle of 0.4° by 0.6°.

2.1.4. Procedures

The experiment consisted of one pre-test session, two training sessions, and one post-test session (see Fig. 1a), taking place over 4 days at a rate of one session per day. The participants were not allowed to suspend sessions for longer than 2 successive days.

During all sessions, the participants were asked to identify all digits in RSVP. The participants were informed that there would be one or two digits and that, sometimes, two digits could be identical. The experiment was self-paced. The participants began each trial by pressing any key on the computer keyboard. After participants viewed an empty circular frame that lasted for 200 ms in the center of the screen, the RSVP appeared within the circle. When the RSVP disappeared, the participants reported the one or two digits they had observed using a number pad on the computer keyboard.

2.1.4.1. Pre- and post-test. To measure the learning effect of the color-salient training, identical tests were conducted before (pre-test) and after (post-test) two days of the training. Crucially, none of the targets appeared in red in the pre- and the post-test.

To measure RB, we employed two types of SOA. In the short-SOA condition, T2 was always presented at Lag 2 (the second serial position after T1, with a single intervening distractor), which corresponded to 200 ms SOA, while T2 was at Lag 6 (600 ms SOA) in the long-SOA condition (see Fig. 1b). Because neither AB nor RB occurs for T2 with SOA longer than 500 ms, a comparison between the short- and long-SOA conditions is expected to show a deficit in T2 identification.

In addition to RB, AB was measured to check whether the color-salient training worked successfully. Whereas T2 was always identical to T1 in the repetition condition (for measuring RB), T2 differed from T1 in the nonrepetition condition (for measuring AB).

As catch trials, the single-target condition was also employed. Here, only one digit was presented, and the trials in this condition were not included in our formal analyses and results. There were 40 trials per condition, and all trials were presented in an interleaved manner.

2.1.4.2. Training (the color-salient training). In all trials of training, two targets were presented, with T1 at serial position 2 and T2 at serial position 4 (thus, Lag 2). T2 differed from T1 (which corresponded to AB) and was consistently made salient by displaying it in red; meanwhile, all of the other items, including T1, were displayed in white (Fig. 1c). There were 720 trials per day.

2.2. Results

2.2.1. Accuracy of performance (T2|T1)

The conditional percentages for correctly identifying T2 given the correct identification of T1 (T2|T1) are shown in Fig. 2.[2] A three-way repeated measures ANOVA (with SOA, training, and repetition) revealed significant effects on all main factors: (a) SOA ($F(1,11) = 36.796$, $p < .001$, $\eta_p^2 = .77$), (b) training ($F(1,11) = 5.678$, $p = .036$, $\eta_p^2 = .34$) and (c) repetition ($F(1,11) = 151.435$, $p < .001$, $\eta_p^2 = .93$). It also showed significant interactions (a) between SOA and training ($F(1,11) = 11.524$, $p = .006$, $\eta_p^2 = .51$) and (b) between SOA and repetition ($F(1,11) = 68.170$, $p < .001$, $\eta_p^2 = .86$), although the interaction between training and repetition was not significant ($F(1,11) = .187$, $p = .674$, $\eta_p^2 = .02$). Most interestingly, the interaction among all three factors was significant ($F(1,11) = 4.889$, $p = .049$, $\eta_p^2 = .31$), indicating that the color-salient training with a nonrepeated T2 evoked different learning effects on AB and RB tasks.

As in a previous study (Choi et al., 2012), AB was absolutely attenuated after training. In the nonrepetition condition where

[2] In all conditions, participants were good at identifying T1, demonstrating around 90% correctness: 89.8% (pre-test) and 91.6% (post-test) at short-SOA with a nonrepeated T2, 94.0% (pre-test) and 93.5% (post-test) at long-SOA with a nonrepeated T2, 94.2% (pre-test) and 93.3%(post-test) at short-SOA with a repeated T2, and 94.6% (pre-test) and 93.8% (post-test) at long-SOA with a repeated T2.