Opening the attentional window in attentional blink: An attentional cuing study*

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Abstract To investigate whether the functioning of cognitive control is contingent upon the attentional set in attentional blink (AB), which is a deficit in reporting the second (T2) of two targets when it occurs 200—500 ms after the first (T1) in a rapid serial visual presentation (RSVP) stream, this study examined the pattern of cuing effects in which two kinds of colored cues match (i.e., in the same attentional set) or mismatch (i.e., in a different attentional set) the color of the upcoming T2. Participants of the study were asked to monitor T1 and T2 in triple RSVP streams while the cue-T2 onset synchrony (CTOA) varied from 90 ms to 270 ms and the cue and T2 might or might not occur in the same RSVP stream as T1. Relative to the uncued condition, both the same-color and the different-color cues produced cuing effects, but the effect was larger and lasted for a longer time for the former than for the latter, whether the cue (and T2) and T1 occurred in the same stream or not. Cues with short CTOA in general enhanced T2 performance more greatly during the AB period than outside of the AB period, suggesting that cues with short CTOA could open the attentional window in advance of T2 and thus facilitate the T2 processing. These findings are consistent with the theory that the salient stimulus captures attention and opens the attentional window irrespective of the attentional set defined for the target; but the attention capture effect of the cue can be quickly overridden by the top-down control when the cue does not match the attention set. Thus both the top-down attentional control setting and the bottom-up attentional capture process function during attentional blink.

Keywords: attentional blink, attentional window, attentional set, cuing effect.

When observers monitor a rapid serial visual presentation (RSVP) of stimuli, such as letters, digits, words or pictures, and search for two targets in the stream, they usually have no difficulties in reporting the first target (T1) but show deficits in reporting the second target (T2), if the T1-T2 onset asynchrony (TOA) is within 200—500 ms[1]. This deficit in reporting T2 is called attentional blink (AB)[2].

A number of models[3—7] have been proposed to account for the AB. Although these models differ in detail in their explanation of the mechanisms underlying the AB, almost all of them assume that there are two different stages in the target processing: a high-capacity early stage (i.e. Stage I) and a severely capacity-limited second stage (i.e., Stage II). In Stage I, representations of items in the RSVP stream are retained briefly and are easily erased by items that subsequently enter Stage I. The ability to report items from RSVP depends critically on whether their representations can be transferred into more durable forms in short-term memory (i.e. Stage II). An attention gate or window is assumed to control the transfer of RSVP targets from the early stage of representation into the late stage of short-term memory[3,8—13]. The opening of the attentional window results in a transient (i.e. 100—200 ms) release of attentional resources that constitutes what is known as an attentional episode. During this attentional episode, visual representations can be sustained so that they can be fully identified and consolidated in short-term memory[14,15].

Based on the proposals above, Nieuwenstein et al.[16] and Nieuwenstein[17] recently suggested a delayed attentional engagement model to account for the AB. According to this account, shortly after selecting T1, the opening of the attentional window (i.e., attentional engagement) for T2 is delayed, resulting in the deficit in processing and reporting T2. However, cuing can truncate this delay by capturing attention and initiating a new processing episode in advance of the presentation of T2. T2, with no need to initiate a new episode for itself, could then be included into this episode and the performance on it is thus enhanced.

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But this cuing effect at the long TOA is not as large as at the short TOA, because the attentional engagement to T2 is not delayed outside of the AB period and the cue could not increase the T2 performance much. Thus, the index of whether the cue counteracts the delay of attentional engagement to T2 is the larger beneficial cuing effect in the short than in the long TOA condition, i.e., the significant interaction between the cue condition (cued vs. uncued) and the TOA condition (short vs. long).

An important assumption of the delayed engagement account is that the cuing effect is contingent upon the match between the cue and the attentional control setting for the target[17]. That is, during the AB period, the response to a stimulus event is under sustaining top-down control (but see Di Lollo et al.[18]), which decides which stimulus deserves the processing resources. When the feature (e.g. color) of a cue does not match with the attentional set for the target, this cue cannot capture attention[19], i.e. cannot open the attentional window before the T2 presentation. This contingent cuing account is based on the contingent capture hypothesis proposed by Folk et al.[19] who suggested that the capturing of attention occurs only if the event shares the feature property (e.g. color) which is critical to the performance of the task at hand and which is programmed into the attentional control setting. However, this hypothesis was challenged by some empirical evidence, including studies by Theeuwes and his colleagues[20—24] who demonstrated that a singleton or salient stimulus not matching the attentional set also captures attention. Nevertheless, the effect of attentional capture of the salient singleton is relatively brief, because this bottom-up capturing effect can be quickly overridden by the top-down control[24]. In line with these attentional capture studies, we hypothesize that a cue with a color not matching the attentional set but salient enough to capture attention would open attentional window and produce cuing effect on T2 performance, but this cuing effect would be smaller than the cue with a color matching the attentional set for the target.

Results from studies on the cuing effect or attentional capture in the AB seem to be inconsistent. In Experiment 2 of Nieuwenstein et al.[16] and Experiment 1 of Nieuwenstein[17], the targets were colored digits and the distractors were uppercase letters in grey. The cues used in both experiments were two successive distractors preceding T2. These cues had a color which was different from (or the same as) the targets but which was always different from other distractors in the RSVP stream. In the Experiment 2 of Nieuwenstein et al.[16], the cuing effect of cues sharing the same color with the targets (i.e., the same-color cuing) was larger than the effect of cues possessing a different color from the targets (i.e., the different-color cuing). The interaction between the cue condition (cued vs. uncued) and the TOA condition (short vs. long) was significant for the same-color cue, but not for the different-color cue. In Experiment 1A of Nieuwenstein[17], the cue with a color different from the color of the targets also resulted in a marginally significant cue × TOA interaction ($p = 0.06$). In Experiments 1 and 2 of Wee and Chua[25], the RSVP stream consisted of uppercase letters with targets being marked in a different color from distractors, and the presentation rate was 100 ms per item. In half of trials, a square frame was presented together with the distractor preceding the T2. The other half of trials without the square frame served as the baseline. The color of the frame was different from the color of the targets but was the same as the distractors. The interval between the frame and the T2 could have 1, 2 or 3 lags. For the 1 lag condition, a significant cue (with frame vs. without frame) × TOA (short vs. long) interaction was observed. But there was no such an interaction for the 2- and 3-lag conditions.

One reason for the inconsistent findings in the above studies could be the difference in the cue-target onset asynchrony (CTOA) across experiments. Previous studies on attentional cuing have demonstrated that the SOA between the cue and the target is crucial to the pattern of cueing effects[26]. In Experiment 2 of Nieuwenstein et al.[16], the presentation rate of RSVP was 70.5 ms per item and the CTOA was 141 ms. In Experiment 1 of Nieuwenstein[17], the presentation rate of RSVP was 53.3 ms and the CTOA was 106.6 ms. In Wee and Chua[25], whether the putative interaction was observed depended on the frame-T2 CTOA. Thus, it seems that a shorter CTOA would result in an interaction while a longer CTOA would not. This observation is consistent with the notion of opening the attentional window by the singleton cue. Previous studies have demonstrated that this automatic attentional window lasts about

100—150 ms[9,13,27,28]. It is possible that for the cue to work in the AB, it should be presented not long before the presentation of T2.

Moreover, there might be a confounding in Nieuwenstein et al.[16] and Nieuwenstein[17]. That is, the larger cuing effect and the more significant cue and TOA interaction for the same-color cue than for the different-color cue could be due to the possibility that the same-color cue is viewed as a potential target, which extends the attentional episode from T1 and strengthens the cuing effect of the cue on T2. In these two experiments, the stimuli occurred within a single RSVP stream, and the two targets possessed the same color. When the TOA was short, the interval between T1 and the cue was also very short. Thus it was possible that the same-color cue was detected as a potential target and halted the attentional disengagement from T1[25]. The attentional episode for T1 and the episode for the cue were then combined, and the combined episode was more likely to extend over time until the presentation of T2. The performance on T2 could then be benefited from the extended attentional episode. A different-color cue, on the other hand, could not be viewed as a potential target, and its attentional episode must be different from the T1's. Consequently the cue could not produce the beneficial effect on the T2 performance as large as the same-color cue (Of course, when the TOA is long and the interval between T1 and the cue exceeds the possible span of attentional episode, the episode evoked by T1 could not have impact upon the T2 performance. Thus the interaction between the cue and TOA conditions for the same-color cue might be observed in Nieuwenstein et al.[16] and Nieuwenstein[17]).

To avoid these potential confoundings and to examine whether the pattern of cuing effects on T2 performance in the AB is contingent upon the top-down attentional set adopted for the targets, we used triple RSVP streams (cf. Peterson and Juola[29]) in which the cue, T1 and T2 were presented either in the same or in different streams. The cue could be in the same color as the targets or in a different color. Having the cue and T1 presented in different streams would reduce the possibility that the attentional windows for the cue and T1 are combined to give stronger facilitation to the T2 performance, especially when the cue and the targets are in the same color[30]. We also hypothesized that since the task defined T1 and T2 to a specific color, participants would form a top-down attentional set for that color. Thus if the cue had the same color as the targets, it would match the attentional set. The attentional window opened by the cue would be more likely to extend over time and T2 would be more likely to be included into this window, hence producing a facilitatory cueing effect. If the cue was in a different color, although it would not match the attentional set, it might capture attention by its salience and open the attentional window anyway. However, the time course of the attentional window opened by the different-color cue would be briefer and T2 would be less likely to be included into this window when the interval between the onsets of the cue and T2 was long. Therefore, we manipulated the SOA between the cue and T2 (CTOA). Thus, half of the trials in the experiment had a cue, half not. For the cued trials, the experiment had a factorial design with the cue (the same-color cue vs. the different-cue), cue-T1 location (in the same stream vs. different streams), TOA (short vs. long), and CTOA (90 ms vs. 180 ms vs. 270 ms) as four within-participant factors. We hypothesized that T2 was likely to be included into the attentional window opened by the cue if it was close in time to the cue (i. e., having a short CTOA). Furthermore, we hypothesized that having the cue (and T2) in a stream different from the stream for T1 would reduce the possibility of "contamination" from T1 on T2 performance, especially when the cue and the targets had the same color. Therefore, the crucial questions for this study were, firstly, whether the cue not matching the attentional set for the targets could enhance T2 performance, and secondly, whether this cuing effect was affected by the CTOA between the cue and T2, and thirdly, whether the spatial relationship between the cue and T1 influenced the pattern of cuing effects.

1 Method

1.1 Participants

Twenty one right-handed students (10 males and 11 females) from Peking University were recruited for the experiment in return for monetary compensation. Their ages ranged from 19—27, and averaged 21 ± 2. 5 years. All the participants reported having normal color vision and normal or corrected-to-normal eyesight.

1.2 Apparatus and stimuli

The experiment was run in a dimly illuminated room, with stimuli presented on a 17″ (43 cm) CRT monitor running at a resolution of 1024×768 pixels. Stimulus presentation and recording of participants' responses were controlled by Presentation software (http://nbs.neuro-bs.com/). The targets were digits drawn from the set ranging from 2 to 9. The distractors (and the cue) were uppercase letters drawn from the alphabet (excluding "D", "I", "O", "P" and "Q"), and were presented in three simultaneous letter RSVP streams placed in an up equilateral triangular arrangement along an imaginary circle with a 1.4° diameter (cf. Peterson and Juola[29], see Fig. 1). The imaginary diameter was small enough so that participants could identify items in any of the three locations without resorting to eye movements. Each stream consisted of 21 items, with the restriction that no letters or digits were repeated within a stream or appeared in more than one stream during the same frame. The presentation rate of RSVP was 11.1 items per second. That is, the onset asynchrony between each item was 90 ms, without blank interval between items. For 11 participants, the targets were in red (with the RGB value of [130, 0, 0]). For the other 10 participants, the targets were in green ([0, 100, 0]). T1 and T2 occurred in any stream with equal possibility. The distractor letters were in grey ([125, 125, 125]). For half of the trials, the cue was a red or green letter preceding the upcoming of T2, and was always in the same stream as T2. For another half of trials, there was no cue.

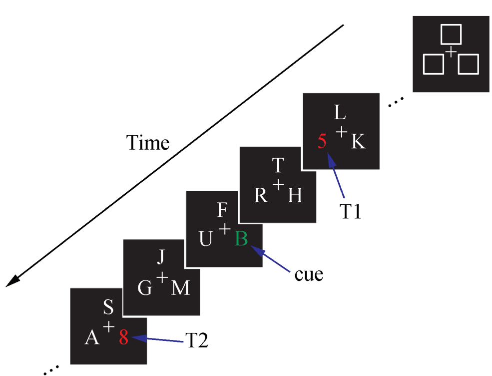

Fig. 1. A schematic representation of trial procedure. In this schematic trial, the TOA is 360 ms, and the cue is the different-color cue with 180 ms of CTOA, and it appears in a different stream from T1.

1.3 Design and procedure

This was a within-participant factorial design. Half of the trials had a cue, half not. The TOA had two levels, 360 and 720 ms. The spatial relationship between T1 and the T2 had two levels, in the same stream and in different streams. When a trial had the cue, the CTOA between the cue and T2 had three levels, 90, 180 and 270 ms, although they were always in the same stream. The color of the cue (cue color) had two levels, having the same color as the targets or having a different color from the targets.

There were 27 cued trials for each combination of cue color, CTOA and TOA when the T1 and T2 occurred within a stream, and 54 trials when the T1 and T2 were in different streams. Thus there were 972 trials having the cue and equal number of trials without the cue. Among the trials without the cue, there were 162 trials for each TOA when the T1 and T2 occurred within the same stream, and 324 trials for each TOA when the T1 and T2 occurred in different streams. Because there were a total of 1944 trials, the testing of participants was divided into 3 testing sessions, conducted in three different days within a week. Each session had 6 testing blocks with 108 trials in each block. Trials from different experimental conditions were equally distributed into the different testing blocks and there was an interval of 1—2 minutes between the blocks. Participants received 40 practice trials before they were tested for the experiment.

Each trial was initiated by the participant pressing the space bar. A fixation display consisted of a central fixation cross and 3 grey outline frames was presented for 1000 ms (see Fig. 1). The frames marked the locations where the RSVP streams would occur. Then the 3 outline frames disappeared but the fixation cross was kept until the end of the trial. The three streams of letters (and digits) were presented simultaneously at the three locations. Participants were instructed to keep fixating on the fixation cross and avoid eye movement during a trial. Their task was to monitor the streams and identify the targets which were digits in red for 11 participants or in green for other participants. At the end of the trial, participants reported the targets by typing them into the computer. They were required to enter the targets in the order of appearance, and were encouraged to guess if they were unsure what the targets were.

2 Results

2.1 T1 performance

The main effects or interactions involving T1 accuracy (mean = 93%) or T1 accuracy conditionalized upon correct reporting of T2 (i.e., T1|T2) were not significant ($p > 0.1$), indicating that the T1 performance was not influenced by any experimental manipulations.

2.2 T2 performance

The trials with T1 error were not included in the calculation of T2 accuracies. That is, T2 accuracies were conditionalized upon correct reporting of T1 (i.e., T2|T1). The T2|T1 collapsing over CTOA (see Fig. 2) were put into a 3 (cue condition: uncued, same-color cue, and different-color cue) × 2 (TOA: 360 and 720 ms) × 2 (spatial relationship: the same stream vs. in different streams) ANOVA. The main effect of TOA was significant, $F(1,20) = 184.07$, $p < 0.001$, with lower T2 performance for short TOA (mean = 72.0%) than that for long TOA (mean = 82.9%), manifesting the typical AB effect. The main effect of cue condition was significant, $F(2,40) = 12.53$, $p < 0.001$, with the lowest T2|T1 for the uncued condition (mean = 75.4%), the highest for the same-color cue condition (mean = 80.3%), and the medium for the different-color cue condition (mean = 76.6%). The main effect of spatial relationship was significant, $F(1,20) = 4.66$, $p < 0.05$, with higher T2 performance for the same stream condition (mean = 78.1%) than for the different stream condition (mean = 76.8%). The interaction between cue condition and TOA was significant, $F(2,40) = 11.58$, $p < 0.001$. Other interactions were not significant, $p > 0.1$. Thus, although the main effect of spatial relationship was significant, it did not interact with other factors, indicating that the spatial relationship was not the cause of differences between cue conditions.

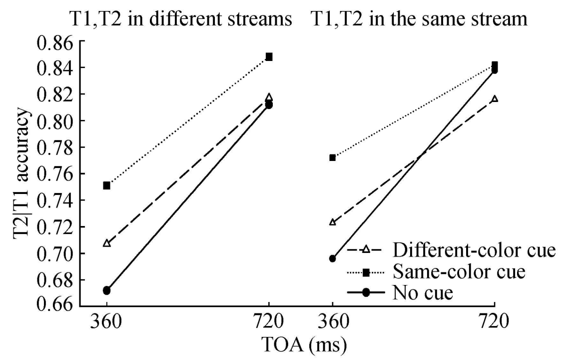

Fig. 2. T2|T1 accuracies collapsing across CTOA, illustrated as a function of TOA and in separate columns for each T1-T2 spatial relationship.

Table 1. The cuing effect and standard error (Mean ± SE) for each condition

T1 & T2 location	Color of cue	CTOA (ms)	Cuing effect for the short TOA (%)	Cuing effect for the long TOA (%)	Significance of difference
Different stream	Different-color cue	90	11.9±2.4**	1.0±2.4	**
		180	−0.2±2.2	−2.0±1.9	
		270	−1.1±2.1	2.7±1.5*	
	Same-color cue	90	13.0±2.1**	5.8±1.5*	**
		180	4.1±1.7*	1.0±1.2	
		270	6.8±1.3**	4.0±1.4*	
The same stream	Different-color cue	90	13.9±2.3**	2.0±2.6	**
		180	2.7±1.7	−1.1±3.0	
		270	−8.3±3.0*	−7.6±2.7*	
	Same-color cue	90	17.6±1.9**	5.2±1.7*	**
		180	6.3±1.8*	0.9±2.3	***
		270	−0.9±2.1	−5.0±2.0*	

The T2|T1 accuracies for the uncued conditions were subtracted from the accuracies for the cued condition, and obtained cuing effects. Asterisks in the right three columns denote the significant level for each t-test comparing with zero or between short and long TOA. * $p < 0.05$, ** $p < 0.001$, *** $p = 0.08$.

To assess the cuing effects and to avoid the difficulty in interpreting higher level interactions, we subtracted the T2|T1 accuracies for the cued conditions from the accuracies for the uncued condition (Table 1) and entered the resulting values into a 2 (spatial relationship) × 2 (TOA) × 2 (cue color) × 3 (CTOA) ANOVA. The main effect of spatial relationship was significant, $F(1,20) = 4.66$, $p < 0.05$, with a larger cuing effect when the targets were in the same stream (mean = 3.9%) than when they were in different streams (mean = 2.1%). The main effect of TOA was significant, $F(1,20) =$

24.81, $p<0.001$, with a larger cuing effect for the short TAO (mean = 5.5%) than for the long TOA (mean = 0.6%). The main effect of cue color was significant, $F(1,20) = 19.38$, $p < 0.001$, with smaller cuing effects for the different-color cue (mean = 1.1%) than for the same-color cue (mean = 4.9%). The main effect of CTOA was significant, $F(2,40) = 24.21$, $p<0.001$, with the highest cuing effects for CTOA of 90 ms (mean = 8.8%), the lowest for CTOA of 270 ms (mean = −1.2%), and medium for CTOA of 180 ms (mean = 1.5%). The interaction between spatial relationship and CTOA was significant, $F(2,40) = 49.75$, $p<0.001$. The interaction between TOA and CTOA was also significant, $F(2,40) = 17.65$, $p<0.001$, indicating that the patterns of cuing effect differed inside or outside of the AB period. Other interactions were not significant, $p>0.1$. The absence of interaction between spatial relationship and cue color confirmed further that the spatial relationship did not influence the patterns of cueing effects for the same-color or different-color cue.

Since the factor CTOA interacted with spatial relationship as well as with TOA, separate analyses for the cuing effects in each CTOA condition were conducted. When the CTOA was 90 and 180 ms, the main effects of spatial relationship were not significant, $F(1,20) = 2.99$ and $F(1,20) = 1.57$ respectively, $p>0.1$. But the main effects of TOA were significant, $F(1,20) = 110.59$ and $F(1,20) = 6.44$ respectively, $p<0.05$, with larger cuing effects for the short than for the long TOA. When the CTOA was long (270 ms), the main effect of spatial relationship was significant, $F(1,20) = 72.1$, $p < 0.001$, with inhibitory cuing effects when the cues occurred in the same stream as T1 (mean = −5.4%) and facilitatory cuing effects when the cues occurred in a different stream from T1 (mean = 3.1%; see also Table 1). The main effect of TOA was not significant, $F(1,20) < 1$. For all the CTOA conditions, the main effects of cue color were significant, $F(1,20) = 3.80$, $p = 0.065$, $F(1,20) = 5.44$, $p<0.05$ and $F(1,20) = 13.81$, $p<0.01$ respectively for the short, medium and long CTOAs. None of interaction was significant, $p>0.1$, except a marginally significant three-way interaction from the analysis for the short CTOA, $F(1,20) = 3.92$, $p = 0.062$.

Because of the marginally significant three way interaction for the short CTOA, further separate analyses for the short and long TOA were conducted. Analysis for the short TOA found only a significant main effect of spatial relationship, $F(1,20) = 6.18$, $p<0.05$, with a smaller cuing effect for the cue occurring in a different stream from T1 than that for the cue in the same stream as T1. Analysis for the long TOA showed only a marginally significant main effect of cue color, $F(1,20) = 4.18$, $p = 0.054$, with a smaller cuing effect for the different-color cue than the effect for the same-color cue.

To examine the cuing effects in detail, separate analyses were also conducted for all the smallest combinations of experimental manipulations. The cuing effects were compared between the short and the long TOA conditions for different manipulations. To save space, Table 1 summarizes the statistical findings of these analyses. It is clear from the table that only when the CTOA was 90 ms were the cuing effects at the short TOA significantly larger than the cuing effects at the long TOA. This pattern did not vary according to whether the cue and T1 was in the same or different streams or whether the cue shared the same color or not with the targets.

3 Discussion

The main findings can be summarized as follows. The performance on T1 was not influenced by any experimental manipulation, while the T2 performance showed robust AB effects. Importantly, we observed significantly larger cuing effects for the same-color cue than for the different-color cue, no matter the cue and T1 were in the same stream or in different streams. This was so irrespective of the CTOA or TOA, even thought the sizes of cuing effects were the largest at the short CTOA. Moreover, when the CTOA was relatively short (i.e. 90 and 180 ms), the cuing effects were equivalent for cues occurred in different streams from T1 and for cues in the same stream as T1. This was so for both the same-color and the different-color cues and at both the short and the long TOAs. When the CTOA was the longest (i.e. 270 ms), the cue occurring in the same stream as T1 impaired the T2 performance while the cue occurring in a different stream from T1 enhanced the T2 performance, irrespectively of the TOA and the cue color. Most importantly, we obtained a significant interaction between the cuing effect and TOA, but only when the CTOA was short. At the short CTOA, larger cuing effects were obtained when the cue and T2 were inside the AB period than when they were outside of the AB, irrespective of the spatial relationship between the cue and T1 and the matching of color between the cue and T2.

The significant interactions between the cue (cued vs. uncued) and TOA (short vs. long) conditions replicated what was observed in Nieuwenstein et al.[16], Nieuwenstein[17] and our another study (Zhang et al., submitted manuscript). This interaction suggests that the cue opens an attentional window and truncates the delay of engagement to T2 within the AB period. The opening of attentional window in advance of T2 enhances the stage II of T2 processing. But outside of the AB period, there is no space for the enhancing of T2 performance because the engagement to T2 is not delayed. However, this interaction was observed only when the CTOA was short. This was consistent with Wee and Chua[25] and the Experiment 1 of Nieuwenstein[17], but inconsistent with the Experiment 2 of Nieuwenstein et al.[16] which used a relatively long CTOA. Thus, across the studies, the patterns of cueing effects are in support of the hypothesis that the cue enhances T2 performance via the mechanism of attentional window which lasts a relatively short time i.e., about 100—150 ms[9,13,27,28].

For the short CTOA conditions, the cuing effects, relative to the uncued condition, and the interaction between the cue (cued vs. uncued) and TOA (short vs. long) were all significant regardless of whether the color of the cue being the same as the target. This finding is inconsistent with the contingent cuing hypothesis of delay engagement model, which assumes that the necessary condition for a cue to open the attentional window for T2 is that it should be incorrectly viewed as a target, and, therefore, the feature of cue must match the attentional control setting programmed for the target[19,31]. However, a possible escape route for this model is that the top-down attentional set is not defined specifically to the color value (e.g., red) of the target, but simply to the color discontinuity. Thus whether the cue and the target have the same color or different colors, the cue still fits the attentional set for the target. Alternatively, one might argue that, no matter the cue has the same color as the target or has a different color, as long as it is perceptually salient enough it will capture attention in a bottom-up manner and open the attentional window anyway. The latter would enhance T2 performance within the AB period. Either way, the delayed engagement model has to be amended. It should noted, however, although a different-color cue could open the attentional window and enhance the T2 performance, its effect is smaller and briefer than the effect of the same-color cue, indicating that the top-down control can quickly override the cuing effect if there is a mismatch between the critical feature of the cue (e.g., color or brightness) that captures attention and the feature of T2. Therefore, the present study did not deny the sustained top-down control in the AB, but rather, revealed the fact that the bottom-up attentional capture is possible even when the top-down control is in power.

Results from this experiment also showed that whether T1 and T2 occurring in the same stream or not, the patterns of cuing effects for the same- and the different-color cue were similar. In the short CTOA (i.e. 90 and 180 ms) conditions, the cuing effects did not vary as a function of the spatial relationship between the cue and T1. Consequently the finding that the larger cuing effects for the same-color cue than for the different-color cue in this experiment as well as in Nieuwenstein et al.[16] and Nieuwenstein[17] could not be accounted for by the combination of attentional windows for T1 and the cue and its impact upon the T2 performance for the same-color cue condition.

It is intriguing that the cuing effects for both the same- and the different-color cues, whether inside or outside of the AB, turned to be inhibitory at the long CTOA (i.e. 270 ms) when the cue and the targets occurred in the same stream while it remained to be facilitatory when T1 and the cue (and T2) were in different streams (see Table 1). We are currently at lost as to why it should be so. One speculation is that because of the long CTOA between the cue and T2, the attentional window for the cue has to be closed before the window for T2 is opened. This re-opening process may have negative impact upon the T2 performance. However, due to the attentional shift over different streams, the opening of the attentional window for the cue is delayed, making T2 more likely to be included into this window, thus enhancing the T2 performance. Obviously this inhibitory cueing effect in the AB paradigm merits further investigation.

In summary, by using the same- or different-color cue and by presenting the cue (and T2) and T1 in the same RSVP stream or in different streams, the present study observed cuing effects for the T2 performance, compared with the uncued condition.

However, the effect induced by the different-color cue was smaller and lasted for a shorter period than the effect induced by the same-color cue. Moreover, the cuing effect inside the attentional blink period was in general significantly larger than the effect outside of the AB when the CTOA between the cue and T2 was short. These findings suggest that the cue could capture attention and open the attentional window for T2, not matter it matches the attentional set defined for the targets or not. However, the top-down control, which is not lost during the AB, could quickly override the effect of attentional capture by the cue when the cue and T2 are not matching in terms of attentional set, suggesting that both the top-down attentional control setting and the bottom-up attentional capture function during the attentional blink.

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