# Past rejections lead to future misses: Selection-related inhibition produces blink-like misses of future (easily detectable) events

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Our recent experiences can have substantial effects on our future behavior. Here we show influences of prior visual experiences on the future workings of selective attention. Selective attention uses inhibitory processes to suppress distracting information on a given trial. We show that, once in place, this selective inhibition persists across trials and leads to misses of future targets when they belong to the previously distracting category of stimuli. This effect is documented using a single-target RSVP task, in which participants are asked to report the case (or color) of an oddball target. Furthermore, we show that selective inhibition is not present when observers are merely asked to detect the presence or absence of the oddball target. We argue that selective inhibition is a mechanism aimed at facilitating the access to secondary (non-target defining) features of the target stimuli, and that our results provide further evidence that visual stimuli are processed in a hierarchical, non-holistic manner.

Keywords: inter-trial effects, selective attention, inhibition, feature-based attention, attentional blink

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## Introduction

Most of the extant work on visual attention has focused on understanding the "amnesic" mechanisms of the visual system that govern how we deploy attention in a scene and what we see in that scene. For example, most theories and computational models of visual attention use something akin to a saliency map to compute processing priority, the order in which stimuli and different parts of the scene will be attended (e.g., Itti & Koch, 2000; Koch & Ullman, 1985; Li, 2002; Theeuwes, 2005; Wolfe, 1994). The computation of the saliency map gives high priority scores to regions of the image that are locally salient (with respect to the background), and lower priority scores to regions that are less visually distinct from the background. Most current models also incorporate memory-dependent information (i.e., top-down knowledge), which typically describe information about the task (e.g., instructions, response mappings, etc.) and characteristics of the target (e.g., shape and color). This memory-dependent information is typically constant for the duration of the experiment. However, recent advances in visual attention research have demonstrated how critically important past experience can be in determining how we attend to a visual scene (e.g., Chun & Jiang, 1998; Fecteau, 2007; Fecteau & Munoz, 2003; Maljkovic & Nakayama, 1994, 1996, 2000; Navalpakkam & Itti, 2007). In particular, this research has shown that the manner in which we processed a previous display or attended to a previous scene can have an enormous impact on how we attend to similar scenes in the future.

Another recent example of a history-dependent effect on visual attention is known as the distractor previewing effect (DPE) (see Ariga & Kawahara, 2004; Goolsby, Grabowecky, & Suzuki, 2005; Levinthal & Lleras, 2008; Lleras, Kawahara, Wan, & Ariga, 2008; Shin, Wan, Fabiani, Gratton, & Lleras, 2008). The DPE is observed in a surprisingly easy spatial search task, in which participants are asked to report some attribute of an oddball target in a scene. For example, in a color-oddball task, the display may contain a red target object among green distractor items, and in a gender-oddball task, the target might be a male target face among female distractor

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faces. Participants are asked to report a secondary attribute of the oddball target: the shape of the color-oddball in the color-oddball search task or the side of the face containing an earring in the gender-oddball task. Crucially, on half of all trials, no target is present in the display (i.e., all items belong to the same category of stimuli: they are all the same color or all the same gender, for instance). The DPE refers to the attentional modulation that is observed on target-present trials that immediately follow such target-absent trials. Specifically, it refers to the cost of selecting an object that belongs to the same category of stimuli as the distractors in the preceding target-absent trial. It is important to note that the search task itself is extremely easy, as the oddball target typically pops out of the display. Nevertheless, attentional allocation to the target can be delayed by as much as 100 ms in this scenario. The magnitude of this attentional modulation stands in sharp contrast to other well-known within-trial modulations of attention, such as spatial cueing (typically in the order of 10–20 ms; see Posner, Snyder, & Davidson, 1980), inhibition of return (in the order of 20–30 ms; see Posner & Cohen, 1984), and attentional capture (about 30–40 ms in the capture paradigm of Theeuwes, 1992). In sum, recent visual experiences can dramatically impact the manner in which we attend to a scene.

Here, we show for the first time that a between-trial modulation of attention can be observed in the realm of temporal selection, and furthermore, that the magnitude of that modulation, in the form of perceptual inhibition, is substantial as well (i.e., performance drops by more than 30%). Further, we show that this inhibition is only observed when participants are asked to report a secondary feature of the oddball target (i.e., not the feature that defines the oddball): the inter-trial effect is not observed when participants view identical displays and simply report the presence or absence of a target. In sum, whereas seeing a visual oddball is a fairly easy task (as indexed by the detection task), reporting something about that oddball can be quite demanding and our ability to do so is heavily impacted by our recent experience.

We asked observers to do a simple task: detect the oddball item in a sequence of rapidly presented characters at fixation (RSVP task). In Experiments 1a and 2a, participants simply reported the presence or absence of this oddball, and in Experiments 1b and 2b, participants reported some other attribute of the oddball (its case or color).

# General methods

## Participants

Fifteen different undergraduates (age range 18–23) at the University of Illinois at Urbana-Champaign participated in each of the experiments in exchange for course credit in an introductory psychology class. Participants had normal or corrected-to-normal vision, and none were colorblind.

## Apparatus and stimuli

Stimuli were presented on 17-inch Samsung monitors, at a refresh rate of 60 Hz, at a resolution of 1280 × 1024, driven by 3.4 GHz Pentium-4 Dell Optiplex GX620 PCs with 3.5 gb RAM. The experiments were programmed using the Psychophysics Toolbox for Matlab (Brainard, 1997; Pelli, 1997). The RSVP streams consisted of 12 characters, in 34 pt Times New Roman font. Each character was presented for two refreshes (~33 ms), followed by a five-refresh blank screen (~83 ms). In Experiments 1a, 1b, and 3, a color-oddball procedure was used. The characters were English letters presented randomly in either upper or lower case. On target absent trials, all the letters would be the same color (red, green, or white). On target-present trials, one letter (the target) would be of a different color from the distractors (e.g., the only red letter among green distractor letters), and participants were asked to report whether this color oddball was an uppercase or lowercase letter. In Experiments 2a and 2b, a letter/number category-oddball procedure was used. On target-absent trials, all characters belonged to the same category (e.g., they were all letters). On target-present trials, one character (the target) belonged to a different category from the distractors (e.g., the target was the only number character among letter distractors). The color of the character was randomly assigned for each character in the stream (either red or green), and participants were asked to report the color of the category-oddball target in the stream (if one was present). See Figure 1A or 1B for details.

In sum, on target-absent trials in all experiments, all characters belonged to the same visual category. On target-present trials, the target belonged to one visual category and all other distractors to a second category, producing a category oddball or pop-out effect. The target letter was presented randomly in positions 3 through 11, and never appeared in positions 1 or 2, nor last in the stream. A 1000-ms blank inter-trial interval followed each target-absent trial. Target-present trials were followed by a blank interval that lasted until a response was made or 2500 ms had elapsed, followed by an additional blank interval of 1000 ms.

## Procedure and data collection

The experiments consisted of five blocks of 102 trials each. The trial sequence was determined by trial pairs, such that 82% of trial pairs consisted of a target-absent trial followed by a target-present trial, 9% of pairs were two consecutive target-absent trials, and the remaining 9%

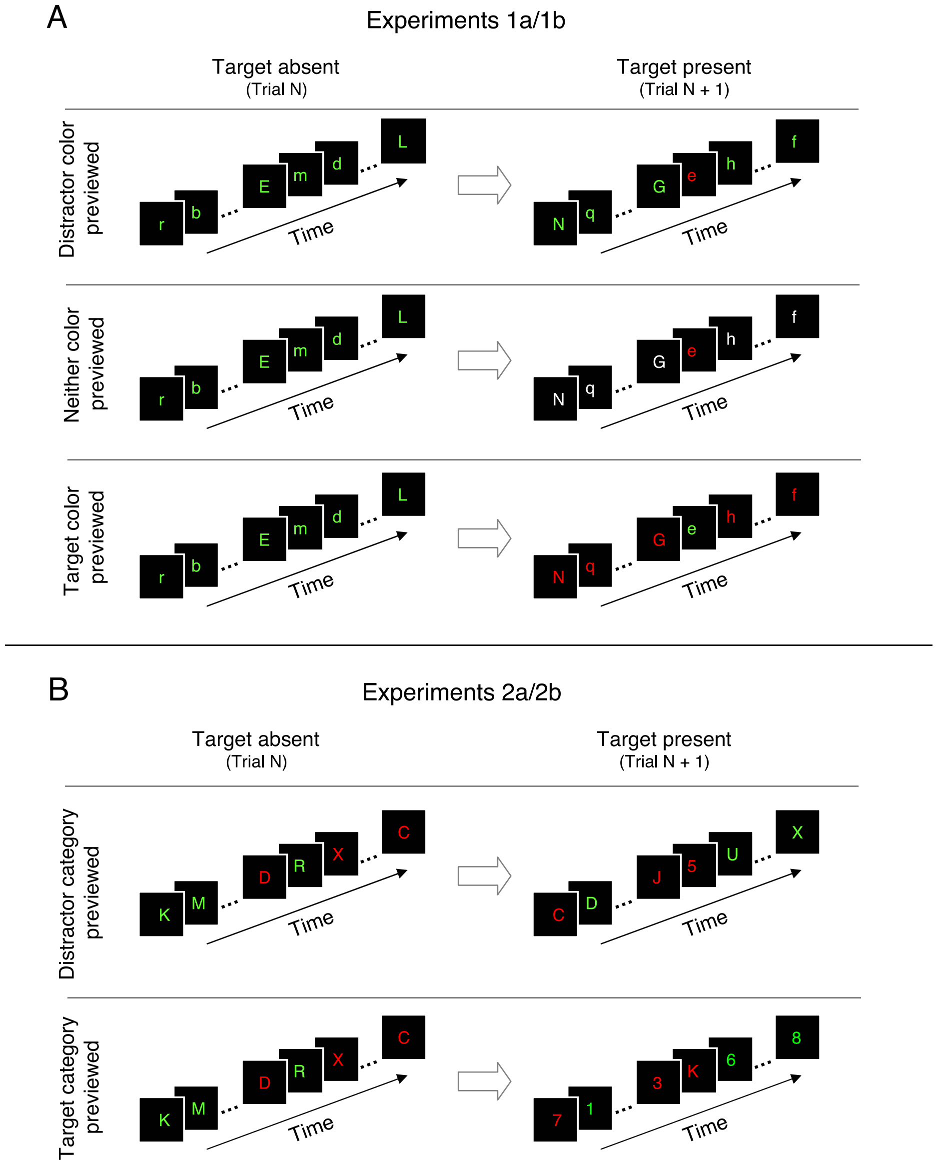


Figure 1. (A) Schematic of different trial sequences in Experiments 1a/1b. In Experiment 1a, the participants' task is to report the presence of an odd-colored letter in the RSVP stream, while in Experiment 1b participants are required to report its case (upper vs. lower). *Top*: distractor-color previewed condition; *middle*: neither-color previewed condition; *bottom*: target-color previewed condition. (B) Schematic of different trial sequences in Experiments 2a/2b. Participants were required to either indicate the presence (Experiment 2a) or color (Experiment 2b) of an odd-category item in the RSVP stream. *Top*: distractor-category previewed; *bottom*: target-category previewed condition.

of pairs were two consecutive target-present trials. Responses were marked as incorrect if no response was made following a target-present trial.

## Experiments 1a and 1b

In these two experiments, the oddball status was determined by color: the target was the uniquely colored letter in a stream of otherwise homogeneously colored distractor letters. In Experiment 1a, participants reported whether a color-oddball letter was present or not in the RSVP stream, whereas in Experiment 1b, participants viewed identical displays but were asked to report the case of the oddball-color letter. We used three different colors, which allowed us to define three different types of inter-trial relations. In the target-color previewed condition (25% of target-present trials), the target in a target-present trial was of the same color as the items in the immediately preceding target-absent trial (and the color of the distractors was randomly selected among the two remaining colors). In the distractor-color previewed condition

(25% of target-present trials), the distractors in a target-present trial were of the same color as the items in the immediately preceding target-absent trial (and the color of the target was randomly selected among the two remaining colors). In the neither-color previewed condition (50% of target-present trials), neither the color of the target nor of the distractors in the target present trial were viewed on the preceding target-absent trial.

Our initial hypotheses were (1) given the attentional demands of the discrimination task (which requires detection of the oddball on one feature dimension as well as discrimination of a different set of features for the response), participants will try to inhibit the processing of distracting stimuli as a means to improve the likelihood of selecting and isolating the target (should one appear) from the other items in the stream (for similar ideas, see also Kawahara, Enns, & Di Lollo, 2006; Olivers & Watson, 2006 ); (2) following our work on inter-trial effects in spatial search tasks, we expected that this inhibition would not be automatically reset from one trial to the next (e.g., Levinthal & Lleras, 2008; Lleras et al., 2008; Shin et al., 2008). If so, then one should observe a cost in selecting a target on trial N that belongs to the category (or shares the color of) recently inhibited information (the color of distractors on trial $N - 1$). This cost should here be observed in terms of a drop in target identification accuracy; (3) this inhibition ought to dissipate as participants start to appropriately inhibit the distractors on the current trial; (4) if this inhibition is uniquely related to the selection of the target, as a means to preserve it for further processing, no inhibition will be observed in the detection task where the identity of the target itself is not required for response. Note that this dissociation between detection and discrimination was documented in the case of the spatial oddball search in Lleras et al. (2008). In contrast, if the inter-trial cost is related to a low-level decrease in the saliency of the color (or category) that is repeatedly viewed from one trial to the next, the cost ought to be observed in the detection task as well.

## Methods

Participants used the "up" arrow key to report uppercase targets and the "down" arrow key for lowercase targets. If no target was present, participants were instructed to withhold from responding. Because of the relatively low number of observations per [position × preview] cell in the design (on average 11.6 observations per cell), the statistical analyses were performed in two ways. First, analyses were performed on the full design with each position (3 through 11) by preview condition (target, neither and distractor-color previewed) considered separately. To confirm that the results were not due to unstable observations, we pooled data into three larger position categories: early, pooled data from positions 3, 4, and 5; intermediate, pooled data from positions 6, 7, and 8; and late, pooled data from positions 9, 10, and 11. Both analyses revealed the same patterns in the data. For brevity sake, we only report the individual position analysis.

## Results

The data showing accuracy[1] as a function of task, preview condition, and position in RSVP stream are shown in Figures 2A and 2B. As can be clearly seen, trial history played no role in Experiment 1a, when participants simply had to detect the presence or absence of a color-oddball letter in an RSVP stream. There was no effect of preview condition ($F(2,28) = 2.74$, $p > .08$, $p$-rep $< 0.84$) nor of position in the RSVP stream ($F(8,112) = 1.39$, $p > .21$, $p$-rep $< 0.71$). In contrast, trial history played a dramatic effect in Experiment 1b, when participants had to report the case of the oddball target, and this effect was constrained to the target-color previewed condition: accuracy at position 3 (56.2%) dropped nearly 30% compared to latter positions, where accuracy increased to approximately 85% (the same asymptote as the other two preview conditions). Statistical analysis confirmed this visual trend, both at the level of independent positions in the stream and with pooled data. When considering the data from independent positions, an ANOVA with factors position and preview condition revealed significant main effects for position, $F(8,112) = 8.59$, $p < 0.001$, $p$-rep $> 0.99$, and preview condition, $F(2,28) = 18.98$, $p < 0.001$, $p$-rep $>$ 0.99. More importantly, the two-way interaction was also significant, $F(16,224) = 5.52$, $p < 0.001$, $p$-rep $> 0.99$.

Post hoc comparisons revealed significantly lower accuracy in the target-color previewed condition than in distractor-color previewed conditions at positions 3, 4, and 5, with the largest difference being 28.3% at position 3, followed by 12.2% at position 4 and 9.1% at position 5 ($t(14) = 6.68$, $p < 0.001$, $p$-rep $> 0.99$, $t(14) = 3.38$, $p < 0.004$, $p$-rep $<$ 0.98, and $t(14) = 3.81$, $p < 0.002$, $p$-rep $< 0.99$, respectively). At position 6, the 6.2% difference approached significance, $t(14) = 1.82$, $p > 0.09$, $p$-rep $<$ 0.83, and none of the comparisons at later positions approached significance. Although the neither-color previewed condition was consistently lower than the distractor-color previewed, the differences between these conditions did not reach significance at any of these positions, $t(14) =$ 1.17, $t(14) = 0.90$, $t(14) = 0.29$, $t(14) = 1.05$, respectively, for positions 3, 4, 5, and 6 (all $p$s $> 0.05$, all $p$-rep $< 0.88$). Finally, it should also be noted that the small drop in accuracy at early positions in the distractor- and neither-color previewed conditions reflects the presence of an attentional awakening effect in the data (Ambinder & Lleras, 2009; Ariga & Yokosawa, 2008).

## Discussion

Experiments 1a and 1b show that trial history has a strong effect on temporal selection, but only when

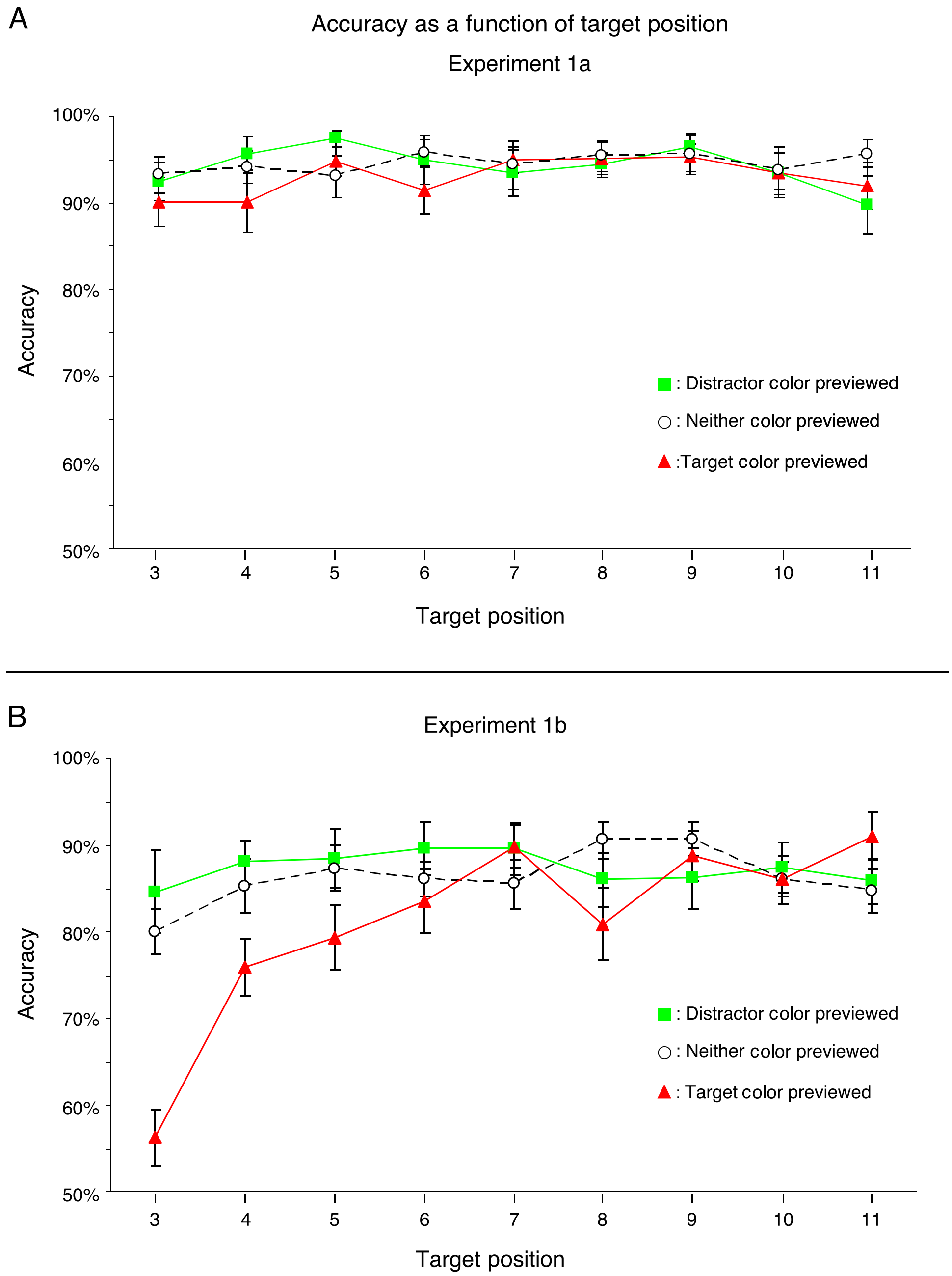


Figure 2. (A) Results of Experiment 1a (color-oddball detection task). Participants were quite good at this task, and oddball-detection accuracy did not differ across experimental conditions or target position. (B) Results of Experiment 1b (color-oddball discrimination task). Overall accuracy was slightly worse than in the detection task, and a substantial inter-trial effect can be observed between the distractor-color previewed condition and the target-color previewed condition at target positions 3, 4, and 5.

participants are required to access information about the target that is not directly conveyed by the target-defining feature (here, color). Because the target is defined as a visual pop-out, its presence is easy to detect in the RSVP. However, observers have difficulty reporting anything about this target (other than its presence). It is likely then, that as a means to increase the successful access to the target's "secondary" features (such as the feature observers are asked to report), the visual system actively inhibits the processing of visual information associated with distractor status (as it has been proposed in the Attentional Blink literature; see Di Lollo, Kawahara, Shahab Ghorashi, & Enns, 2005; Olivers, 2007; Olivers & Watson, 2006). In other words, once a trial starts with the presentation of a few green letters, the visual system will start inhibiting the processing of "green" items, as a way of increasing its chances of successfully selecting non-green targets. Note that this idea is not new and has been proposed as an important mechanism in both spatial and temporal search paradigm (see the work of Olivers for example: in spatial search Olivers & Humphreys, 2003; Olivers, Humphreys, & Braithwaite, 2006; in temporal search: Olivers & Watson, 2006). What is remarkable about our findings is that this inhibitory state against processing green items remains active across trials, affecting the selection of green targets on subsequent trials. It should also be noted that our data suggest that it may take up as long as 500 ms to eliminate an inappropriate inhibitory state (there are no differences by preview condition past position 6 in the stream). Thus, our results add to this prior literature in two important ways: they illustrate the cross-trial persistence of these inhibitory effects, and they provide us a window into the temporal dynamics of the "resetting" of this inhibition (i.e., how long it takes for the inhibitory effect to subside).

Finally, the current results also allow us to address a potential alternative account for our results. It could be argued that our results reflect task-switching costs rather than attentional inhibition. Indeed, task-switching costs are very pervasive and have been previously observed in RSVP experiments (e.g., Allport, Stylkes, & Hsieh, 1994; Potter, Chun, Banks, & Muckenhoupt, 1998). One could argue that the cost of switching "distractor" filters from one trial to the next could be responsible for the drop in performance observed in the target-color previewed condition, compared to the relatively spared performance (or benefit to performance) from using the same "distractor" filter from one trial to the next in the distractor-color previewed condition. That said, such a task-switching account would then predict that performance on the neither-color previewed condition should be just as impaired as performance on the target-color previewed condition: in both cases, participants have to reject distractors from a different color than the distractors on the previous trial. Yet, performance in the neither-previewed condition was in fact identical to that in the distractor-previewed condition. We take this as strong evidence that the observed inter-trial effect is not being driven by the repetition/alternation of the type of distractors that have to be rejected on every trial. Rather, the effect is uniquely driven by the color of the target on the current trial: if it matches the color of the recently rejected distractors (the color of items on the preceding target-absent trial), participants will have a difficult time selecting it, early on in the stream; if the target is presented on a color that has not been recently rejected (as is the case in both distractor-color and neither-color previewed conditions), participants will show no difficulty in selecting it.

# Experiments 2a and 2b

Experiments 1a and 1b first documented what we call selection-related inhibition, in the context of a color-oddball task. We argue that this inhibition is uniquely related to selection processes insofar as it was not observed in the context of the oddball detection task, which did not require the target to be selected for further processing (i.e., merely detecting the feature oddball's presence is sufficient for completing the task). Our goal for Experiments 2a and 2b was to demonstrate the generality of our finding by extending it to a more complex visual discrimination by using the categories of letters and numbers. That is, rather than using oddballs along the visual dimension of color (a discrimination that could arguably be accomplished pre-attentively), we used oddballs defined by category membership: on target-absent trials, all items belonged to the same category (all letters or all numbers), and on target-present trials, all but one item belonged to one category (e.g., numbers) and the target belonged to the alternate category (e.g., letters). Once again, we ran two tasks: in Experiment 2a, observers had to report the presence or absence of a category oddball; in Experiment 2b, observers had to report the color (red or green) of the category oddball (using identical displays as in Experiment 2a). The goal of these experiments was to demonstrate that this selection-related inhibition works at a high cognitive level and therefore is unlikely a result of low-level gain modulations (for similar accounts of inter-trial effects, see Navalpakkam & Itti, 2007; Wolfe, Butcher, Lee, & Hyle, 2003). That is, we believe that the effect does not arise because the weight of a basic feature map is decreased.

## Methods

Methods were identical to those of Experiments 1a and 1b, except for the following: in Experiments 2a and 2b, all stimuli were letters or numbers, each presented randomly in either red or green; to avoid an asymmetry in the number of exemplars of each stimulus category, we displayed the numbers between one and nine, and nine upper-case letters; we only presented targets at positions 3, 7, and 11 in the stream.

## Results

The data showing accuracy[2] as a function of task, preview condition, and position in RSVP stream are shown in Figures 3A and 3B. As it can be readily seen, the results of Experiments 2a and 2b are formally equivalent to those of Experiments 1a and 1b, even though participants' performance depended on a much more complex visual discrimination. Still, participants were able to detect the presence of an oddball category item in the RSVP stream at near-ceiling levels (91.3%), and no inter-trial effect was observed (Figure 2A).

However, when it came time to report something more than the mere presence or absence of those oddball items,

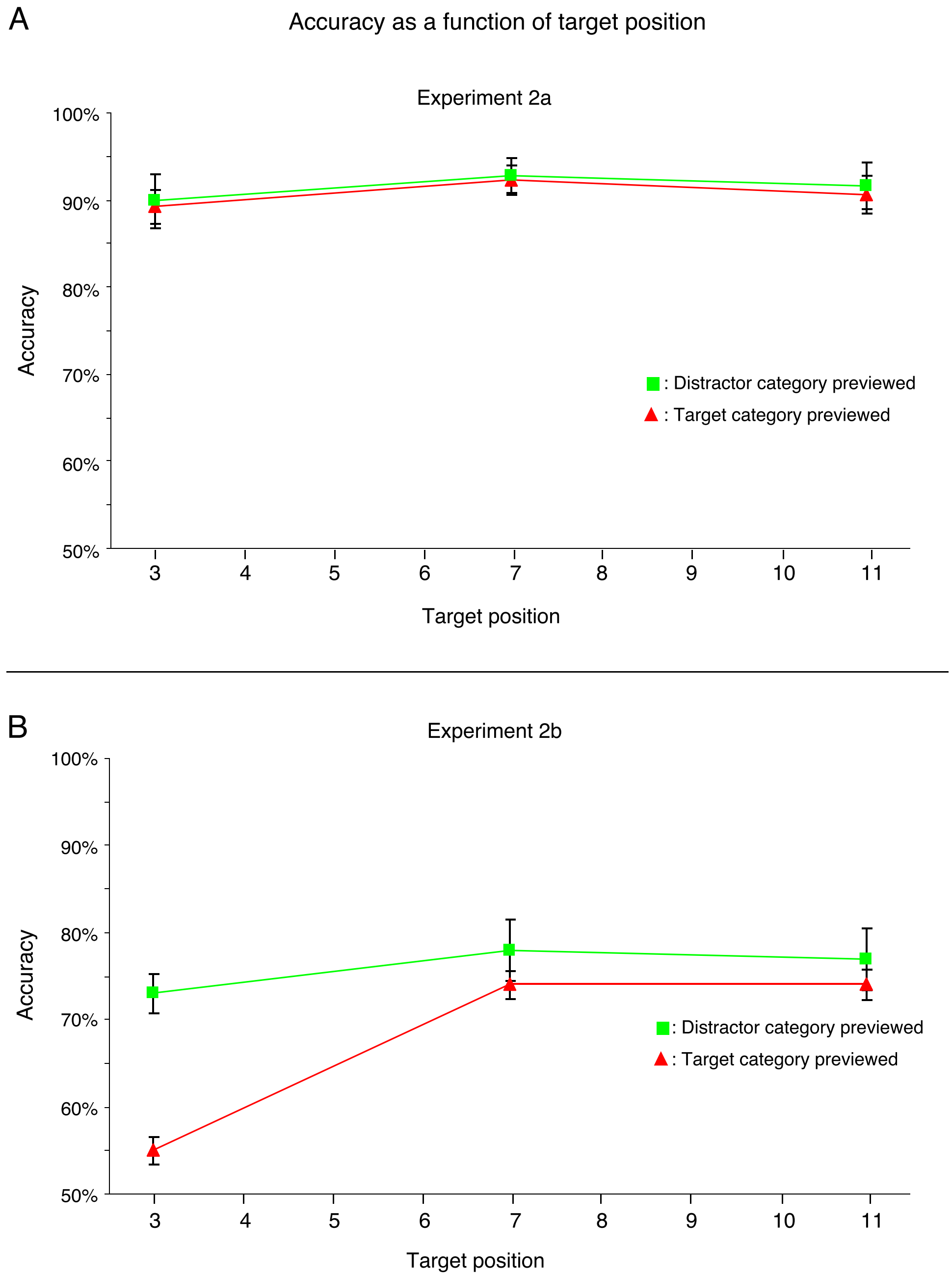


Figure 3. (A) Results of Experiment 2a (category-oddball detection task). Overall oddball detection accuracy was high and did not differ across experimental conditions or target position. (B) Results of Experiment 2b (category-oddball discrimination task). Overall accuracy was worse than in the detection task, and we observed a substantial inter-trial effect between the distractor category previewed condition and the target category previewed condition at target position 3.

participants found the task much more difficult to complete (Figure 2B). In particular, we found once again a dramatic inter-trial effect at the early positions in the RSVP stream: when the current item belonged to the category of items that had been recently rejected as distractors on the preceding trial, participants' performance dropped to 55%. This inter-trial effect was not visible when the current distractors belonged to the same category of items that had been rejected on the previous trial (73.4%). Furthermore, this difference in performance between target-category previewed and distractor-category previewed was only visible at the early positions in the RSVP stream ($t(14) = 5.81$, $p < .001$, $p$-rep $> 0.99$) and was absent at later positions (at position 7: $t(14) = 1.93$, $p > .07$, $p$-rep $< 0.85$; at position 11: $t(14) = 0.98$, $p > .34$, $p$-rep $< 0.61$). Finally, we also ran analysis to test for illusory conjunctions. On trials where participants misreported the target (target-category previewed condition, early position in stream), participants may have been reporting the color of a distractor that was presented one, two, three, or four positions after the target stimulus (Botella, Garcia, & Barriopedro, 1992). We found no evidence of such effects in our data: correlations between response and the color of later distractors were zero at all positions in the stream (all *t*s < 2.05, all *p*s > .05, all *p*-rep < 0.87).

### Discussion

The results of Experiments 2a and 2b are important in two ways. First, they replicated the dissociation found in Experiments 1a and 1b showing that this inter-trial effect is clearly related to attentional selection: participants may very well be able to setup a perceptual filter able to detect the presence or absence of a brief stimulus in a rapid series of visual events (e.g., Di Lollo et al., 2005; Olivers, 2007), and that filter may be quite refined, insofar as it can be made to discriminate between two categories of stimuli with nearly overlapping low-level visual features (letters and numbers). Yet, the filter seems to be passive and limited in its scope: it does not "pass on" a whole stimulus (say an object file with a full list of the object's features), but rather merely signals the presence of an "item of interest" in the stream. Such output is sufficient for the detection task but vastly insufficient for the discrimination task. Second, the results are also important because they show that in order to *access* information regarding the detected target the visual system must suppress the processing of distractor-related information. Once this suppression is put in place, it persists, passively, from one trial to the next. Furthermore, removing this suppression seems to be a time-consuming task: performance in the target-category previewed conditions did not recover until 600 ms after the beginning of the RSVP stream.

## Experiment 3

We ran one final experiment to investigate whether the magnitude of the inter-trial effect was at all related to the length of the RSVP stream. To do so, we re-ran Experiment 1b, with much shorter streams containing only 6 items. This also allowed us to gather more observations per condition at each one of the critical positions in the RSVP stream (positions 3, 4, and 5) for which the effect appeared to be strongest. A new group of seventeen subjects participated in this second experiment. Every other aspect of the design was identical to the initial experiment. Overall, performance improved with position in the stream from 63.0% at position 3 to 67.4% at position 4 and 67.9% at position 5, $F(2,28) = 5.81$, $p < 0.008$, *p*-rep < 0.96. More importantly, preview condition had once again a significant effect on accuracy, $F(2,28) = 14.21$, $p < 0.001$, *p*-rep > 0.99. Post hoc analyses at positions 3, 4, and 5 revealed that accuracy in the target-color previewed condition (55%, 61%, and 65%, respectively) was significantly lower than in the distractor-color previewed condition (69%, 73%, and 70%, respectively) at each temporal position, $t(14) = 3.77$, $t(14) = 3.66$, $t(14) = 2.25$, respectively, all *p*s < 0.05, all *p*-rep > 0.87. As in Experiments 1b and 2b, participants were close to 50% at reporting the case of the target letter in the target-previewed condition at position 3 in the stream (accuracy 55%). Furthermore, accuracy was significantly higher in the distractor-color previewed condition than in the neither-color previewed at positions 3 (64%) and 4 (67%), $t(14) = 2.74$, $p < 0.02$, *p*-rep < 0.93, $t(14) = 4.56$, $p < 0.001$, *p*-rep > 0.99, revealing a relative benefit to starting a trial with an appropriate inhibitory setting when two consecutive trials have the same color distractors.

## General discussion

Overall, the present data provide three important results. First, history matters in temporal selection tasks: selection-related inhibition setup to reject distractors on one trial remains active and influences selection on subsequent trials. This persistent attentional state can have a devastating effect on performance: it is very difficult to report any information regarding targets that belong to the recently inhibited category. Second, it takes about 600 ms to de-activate this selection-related inhibitory state: after position 6 in the RSVP stream, accuracy asymptotes and trial history no longer affects performance. Third, selection-related inhibition applies to complex visual categories just as much as to simple visual features, indicating that the effects observed here must be mediated at higher levels of information processing dealing with goals and outcomes of behavior (Fecteau, 2007). In this manner, the results stand in sharp contrast with some current theories of inter-trial priming effects that, which suggest a more low-level and automatic source of priming (e.g., Goolsby et al., 2005; Navalpakkam & Itti, 2007; Wolfe et al., 2003). At a more general level, our results further support the view that selection and inhibition are intimately related processes in vision. Whenever we seek to select information from the environment, inhibition also seems to occur, as demonstrated in the context of spatial selection in such phenomena as localized attentional inhibition (Mounts, 2000a, 2000b), inhibition of return (Posner & Cohen, 1984), negative priming (Tipper, 1985), multiple-object tracking (Pylyshyn, 2006), as well as in other temporal selection tasks as in the attentional blink (Olivers & Meeter, 2008; Raymond, Shapiro, & Arnell, 1992). Indeed, some have argued that inhibition is a necessary function of selection processes in vision (e.g., Tsotsos, 1990).

One issue that remains open is the relationship between the cross-trial inhibition observed in the present study and the type of experimental task (detection vs. discrimination) performed on a given trial. It is possible that detection tasks are uniquely capable of circumventing inhibitory biases. On the other hand, it is possible that detection tasks are as susceptible to inhibitory biases as discrimination tasks, but that these biases are simply not formed during detection tasks (i.e., biases are not automatically formed following every target-absent trial). Based on our results, we cannot distinguish between these two possibilities. This question could be addressed in an experiment in which prior to any given trial participants were directed to either detect or discriminate. Would a target-absent/discrimination trial create inhibition that would be observed in a subsequent target-present/detection task? Or would detection trials always be unaffected by trial history? We are currently investigating this issue in our lab. Note that detection tasks are generally understood to be performed without the need of selective attention. Thus, the results of this investigation will be an important contribution to our understanding of the factors that control inhibitory states in the discrimination tasks and perhaps of the inhibition that accompanies selective attention operations in general.

Finally, one remaining issue that warrants discussion is the relationship between the present findings and the phenomenon of Negative Priming (e.g., Tipper, 1985). Negative priming refers to the finding that responding on trial $N$ to a stimulus that was previously ignored on trial $N - 1$ is slower than to a previously attended or not ignored stimulus. On the surface, it appears that the spatial DPE and negative priming (NP) might indeed be related, if not the same phenomenon. But upon closer examination, several important differences between these two phenomena become apparent. First, the condition in which the suppression in NP is formed is quite different from the conditions that lead to the DPE and the current inter-trial effect on RSVP streams. In order for inhibition to be observed in an NP experiment, the to-be-ignored stimulus on trial $N - 1$ must be presented alongside a to-be-attended stimulus (Lowe, 1979; Milliken, Joordens, Merikle, & Seiffert, 1998; Moore, 1994; Tipper & Cranston, 1985). In contrast, in the DPE as well as in the current studies, the information that is suppressed is not presented alongside to-be-selected information: the inhibited information is always homogeneously presented on target-absent displays. A second difference is that NP arises according to top-down control settings that are held constant throughout the experiment: participants are, for instance, instructed to always ignore the red items. In the current studies, we observe suppression associated with a visual feature (or category) that changes from trial-to-trial in an event-driven fashion, not in an a priori fashion. Further, participants seem to have little-to-no control over the implementation of this inhibition (e.g., Ariga, Lleras, & Kawahara, 2004; Goolsby et al., 2005): the suppression is not eliminated when participants are instructed ahead of the trial whether the upcoming trial is a target-absent or a target-present trial. One last empirical difference between NP and the current effects is the magnitude of these two phenomena: whereas NP is in the order of 10–20 ms, the spatial DPE is typically around 60–80 ms, sometimes more, and the magnitude of the current effects was as large as 30% at the earliest positions in the RSVP stream.

At a theoretical level, one can also find differences between the negative priming and the DPE. There are two classes of theories regarding NP (as well as theories that combine elements of both classes; see Tipper, 2001). The first account, the active (or persistent) inhibition theory (as originally proposed by Tipper, 1985), argues that the color-based suppression of the "distractor" on trial $N - 1$ persists to trial $N$ and is associated with the current-target stimulus (i.e., a stimulus with the same identity as the previously ignored distractor, but presented in the to-be-attended color). According to this account, the inhibition is associated with the specific identity of the recently rejected stimulus (above and beyond the featural inhibition associated with the to-be-ignored color). In contrast, in the current study, the inhibition is constrained to the feature (or category) level. We have also previously demonstrated that the inhibition is constrained to the "search-relevant" feature dimensions of the task (Levinthal & Lleras, 2008): inhibition is only observed along feature dimensions that are used to define the oddball-status (such as stimulus identity or shape). In other words, the inhibition does not transfer to other dimensions of the "rejected" stimuli (e.g., response features). The second account of NP, the episodic retrieval theory (originally proposed by Neill, Valdes, Terry, & Gorfein, 1992) argues that NP arises because when selecting a target, there is automatic re-activation of previously response-related information associated with this stimulus. In the "previously ignored" condition of NP, this re-activation produces a response conflict that slows responses because the last action associated with this stimulus was a "no-go/no-response" action. Variants of this theory have gathered support lately (e.g., Rothermund, Wentura, & De Houwer, 2005; Stahl & Gibbons, 2007). According to this class of theories, the locus of inhibition is at the response-selection/preparation stage of processing. In contrast, various demonstrations have shown that the DPE is not a response-level effect (e.g., Lleras et al., 2008). In particular, using electrophysiological recordings of participants during a spatial DPE task, Shin et al. (2008) showed that the spatial DPE correlated with differences in the latency of the N2Pc (an attentional component) and found no differences in the LRP (a marker of response preparation that is sensitive to conflict during response-selection processing). In sum, the extant data on the DPE are inconsistent with current theories of NP. However, one could still argue that current theories of NP have failed to capture important aspects of the NP phenomenon and that paradigm-driven investigations of NP and the DPE are responsible for the apparent dissociation between these two effects. After all, these two effects are both examples of "transfer-inappropriate processing” (Neill & Mathis, 1998). Thus, it is possible that further investigations on these two phenomena might yet lead to a better understanding of this larger class of behavioral effects and possibly shed light on the role of inhibitory processing observed in experience-based effects.

In conclusion, the current experiments illustrate how our goals affect our perception: we constantly setup goals that determine what we want to see and examine in a scene. Yet, these control settings can sometimes inappropriately prevent us from seeing the very things we are looking for: an easily *detectable* color or category oddball can become hard to see when we need to *identify* it. Further, our results strongly support the notion that history is a powerful force in perception: the way we viewed the world a few seconds ago will greatly impact how we see the world now; and what we choose to ignore now might very well determine what we end up missing next.

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## Footnotes

[1]False alarm rates (approximately 2%) and miss rates (approximately 4%) did not differ across experimental conditions and are not discussed further.

[2]As in the previous experiments, false-alarm rates (6.9% of trials) and miss rates (8%) did not differ across experimental conditions and will not be discussed further.

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