Notes and Comment

Inhibition of return to color: A replication and nonextension of Law, Pratt, and Abrams (1995)

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We presented subjects with an unpredictable cue that was followed after a 150- to 900-msec interstimulus interval (ISI) by a detection target. Cue and target were blue or red squares that appeared at fixation and in an otherwise uniform black field. In a filler condition, a task-irrelevant filler stimulus (magenta square) was presented during the ISI; in a no-filler condition, no stimulus appeared during the ISI. Using only a 900-msec ISI, Law, Pratt, and Abrams (1995) reported slower reaction times (RTs) when cue and target were the same color, but only when the task-irrelevant filler was presented during the ISI. They argued that attention is first drawn to the cue color and that inhibition of return (IOR; see Posner & Cohen, 1984) is established when attention is drawn away from that cue color representation by the task-irrelevant filler. Critical to their view is the assumption that IOR occurs only after attention is drawn away from the cue color by the filler. Assuming a time course for the withdrawal of attention from the cue color representation, Law et al.'s view predicts growth of the inhibitory effect as a function of ISI in the filler condition as well as facilitation at early ISIs in the no-filler condition (because there is no filler to withdraw attention from the cue color). Contrary to these predictions, we found that the inhibitory effect observed by Law et al. at the 900-msec ISI was present at—and did not vary in magnitude across—the range of ISIs tested. And there was never facilitation in the no-filler condition. These results challenge Law et al.'s inference that IOR for foveally presented colors was operating in their paradigm.

When attention is oriented to a location in space via an uninformative peripheral cue, reaction times (RTs) to targets appearing at cued relative to uncued locations are fast at relatively short cue–target intervals and slow at long ones (Posner & Cohen, 1984). To determine whether the inhibitory consequence of attentional orienting (inhibition of return; IOR) occurs for attributes other than spatial location, Law, Pratt, and Abrams (1995) presented subjects with a nonspatial color detection task. A magenta fixation square was followed in the same spatial lo-

cation by a 900-msec blue or red cue. Following a 900-msec interstimulus interval (ISI), a blue or red target appeared to which subjects made a speeded detection response. In separate experiments, the duration of the ISI was marked by the presentation of another magenta square (magenta filler) or by the absence of any stimuli (i.e., the screen reverted to a uniform background, no filler). When cue and target were the same color, RTs were longer than when the cue and target were different colors, but only when the magenta filler was presented.

The authors argued that this repeated-color inhibition represented IOR that was established by the presence of the task-irrelevant filler. In particular, they suggested that IOR occurred because attention was first drawn to the color representation of the cue and that the task-irrelevant filler served to withdraw attention from—and to consequently inhibit attention from returning to—the cue color representation. Under this view, withdrawal of attention from the cue color representation to that of the task-irrelevant filler is *necessary* for establishing IOR. As such, Law et al. (1995) argued that previous failures to observe IOR in the color domain (e.g., Kwak & Egeth, 1992) were due to the lack of a neutral attentional “attractor” (i.e., a filler).

We thought it necessary to replicate the work of Law et al. (1995) in an extension that allowed for an evaluation of the time course of the effect. If the effect that Law et al. reported for same-color trials does reflect inhibition to return attention to the cue color representation, then, according to their account, establishing this inhibitory effect should depend on the initial capture of attention by the cue color and—critically—on the time available for the filler to withdraw attention away from that attended cue color representation. When the filler is presented for only a short duration, a same-color advantage might be expected on the grounds that attention is still focused on the cue color representation at the time of target presentation; however, when the filler is presented for a relatively long duration, attention should be withdrawn fully from the cue color representation, and a full-blown same-color inhibitory effect should be observed. In the absence of a facilitatory component—or at least a dependence of the inhibitory effect on the duration of the filler—disadvantage for same-color trials cannot be confidently attributed to IOR.

Our experiment was modeled after Law et al. (1995). We examined simple detection RT to color targets that followed 900-msec color cues by ISIs of 150–900 msec. In the filler condition, the ISI was marked by the presentation of a magenta square; in the no-filler condition, the ISI was marked by the absence of the magenta square and the screen reverted to the uniform black of the back-

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ground screen. According to Law et al., in the no-filler condition, the absence of a task-irrelevant color stimulus should result in the failure to withdraw attention from the cue color representation in such a way that no IOR should be established. Indeed, to the extent that the cue color is capable of attracting attention to the representation of the cue color, the no-filler condition should reveal a time course of facilitation for same- versus different-color target RT. In the filler condition, if the repeated-target inhibition results from attentional allocation to the cue color representation followed by subsequent withdrawal due to presentation of the task-irrelevant filler, there should be a time course of inhibition for same-versus different-color target RT.

METHOD

Participants

Thirty-six Dalhousie University undergraduates received credit toward their introductory psychology grade or were paid \$6 in exchange for participation. Subjects had normal or corrected-to-normal vision and were naive to the purpose of the experiment.

Stimuli and Apparatus

Stimuli were magenta, blue, and red squares presented in the center of a black field on a 13-in. VGA monitor. At a 47-cm viewing distance, each stimulus subtended 4° visual angle on a side. Stimulus presentation and data collection were controlled by a 486 IBM-compatible microcomputer.

Procedure

Each trial began with a 500-msec warning tone that was accompanied by a 900-msec presentation of a magenta square at fixation. Following the fixation square in the same location was a 900-msec blue or red square (cue). In the filler condition, the cue was replaced by another magenta square (filler) that remained visible for the duration of the cue–target ISI for the trial; in the no-filler condition, the screen reverted to a uniform black during the ISI and no stimulus was presented. On noncatch trials, a blue or red target square was presented at fixation; subjects responded to this target by making a speeded detection response (pressing the space bar of the computer keyboard). On catch trials, no target appeared and subjects were required to withhold a response.

At the beginning of the experimental session, subjects were informed of the trial stimulus sequence and variable cue–target ISI. Subjects were told to respond as quickly as possible without making

catch trial errors. Apart from being informed of the nonpredictive relation between cue and target colors, subjects were not given explicit instructions with respect to either the cue or, where applicable, the magenta filler.

Subjects received performance feedback in the form of error messages that appeared in the center of the screen. On noncatch trials, if subjects responded in under 80 msec (anticipation), a tone sounded twice and the words “too soon” were presented for 700 msec; if subjects failed to respond within 1,000 msec, a 200-Hz tone sounded for 100 msec and the word “miss” was presented for 600 msec. On catch trials, if subjects responded, a tone sounded three times and the words “catch error!!!” were presented for 1,200 msec. In the absence of error feedback, the intertrial interval was 1,500 msec; with error feedback, the 1,500-msec interval was increased by the duration of the feedback. Mean RT for each subject in each experimental cell was based on trials that were not in error (i.e., those that had RTs between 80 and 1,000 msec).

Design

Filler versus no filler was run between subjects. The 18 subjects serving in each of these conditions performed one block of 480 trials. Of these, 360 were noncatch trials: 15 replications of the factorial combination of cue color (blue, red), target color (blue, red), and ISI (150, 300, 450, 600, 750, 900 msec). The remaining 120 trials were catch trials: 10 replications of the factorial combination of cue color (blue, red) and ISI (150, 300, 450, 600, 750, 900 msec). Prior to performing in the experimental block proper, subjects performed a practice block that was composed of the random presentation of 12 trials that resulted from the factorial combination of cue color (blue, red), target color (blue, red), and four ISIs (150, 450, 750 msec) and 6 catch trials that resulted from the factorial combination of cue color (blue, red) and ISI (150, 450, 750 msec).

RESULTS AND DISCUSSION

The mean percent target misses, anticipations, and RT (for error-free trials) are shown in Table 1 for the filler condition and in Table 2 for the no-filler condition. Misses and anticipations were not analyzed due to lack of variance in several cells. Percent false alarms (catch trial errors) were collapsed over cue color and analyzed in a repeated measures analysis of variance (ANOVA), with condition (filler, no filler) and cue–target ISI (150, 300, 450, 600, 750, 900 msec) as factors. The effect of experimental condition was significant [$F(1,34) = 12.71, p < .00$], with 5.0% catch errors in the filler condition and 0.7% catch errors in

Table 1
Filler Condition—Percent Target Misses (M), Percent Anticipations (A), and Reaction Times (RTs) as a Function of Cue–Target Color Relation and Interstimulus Interval (ISI); Percent False Alarms as a Function of Cue Color and ISI

Cue–Target ISI	Cue–Target Color Relation												False Alarms	
	Same						Different							
	Blue Cue			Red Cue			Blue Cue			Red Cue				
	M	A	RT	M	A	RT	M	A	RT	M	A	RT	Blue Cue	Red Cue
150	0.74	0.00	488	0.74	0.37	492	1.85	0.00	472	1.85	0.00	465	16.11	12.78
300	0.74	0.74	450	0.74	0.37	452	0.00	0.00	446	0.37	0.74	439	7.22	9.44
450	0.74	0.37	447	1.48	0.37	436	0.37	0.74	421	0.00	0.37	423	5.56	8.33
600	0.00	0.74	441	1.11	0.00	430	0.00	0.37	430	0.74	1.11	426	2.22	4.44
750	1.48	0.37	436	1.48	0.74	426	0.37	0.00	410	0.74	1.11	422	7.22	3.89
900	0.74	1.11	442	0.00	1.48	430	0.74	0.74	418	0.00	1.85	430	4.44	4.44

Table 2
No Filler Condition—Percent Target Misses (M), Percent Anticipations (A), and Reaction Times (RTs, in Milliseconds)
as a Function of Cue–Target Color Relation and ISI; Percent False Alarms as a Function of Cue Color and ISI

Cue–Target ISI	Cue–Target Color Relation												False Alarms	
	Same						Different							
	Blue Cue			Red Cue			Blue Cue			Red Cue				
	M	A	RT	M	A	RT	M	A	RT	M	A	RT	Blue Cue	Red Cue
150	0.00	0.74	406	0.00	0.37	403	0.74	1.48	390	1.11	0.00	375	2.22	2.22
300	0.74	2.22	358	0.37	1.11	361	1.11	0.37	369	0.37	1.85	359	1.11	1.67
450	1.11	1.48	350	0.74	0.37	341	0.74	0.37	352	0.00	1.85	336	3.33	1.67
600	0.74	1.85	348	0.37	1.85	349	0.37	2.22	348	0.74	0.74	343	2.22	3.89
750	0.37	2.59	359	0.00	2.59	365	0.37	1.85	364	0.74	2.22	360	2.22	3.33
900	0.00	1.85	370	0.00	2.22	364	0.37	2.96	372	0.37	1.85	370	1.11	1.67

the no-filler condition. The effect of ISI was significant [$F(5,170) = 45.12, p < .03$] and likely due to the high percentage of false alarms at the shortest ISI. The interaction of condition and ISI was also significant [$F(1,170) = 3.40, p < .01$]. This interaction of condition and ISI was parceled by analyzing the filler and no-filler conditions separately. For the filler condition, this analysis revealed a significant effect of ISI [$F(5,85) = 3.07, p < .01$], due to the greater overall catch trial errors at ISIs of 150 and 750 msec (see Table 1). For the no-filler condition (see Table 2), the effect of ISI was not significant [$F(5,85) = 2.02, p < .08$].

RTs were collapsed over cue color and analyzed in a three-way repeated measures ANOVA, with condition (filler, no filler), cue–target color relation (same, different), and cue–target ISI (150, 300, 450, 600, 750, 900 msec) as factors. There was a main effect of condition [$F(1,34) = 8.15, p < .01$], with overall slower RTs in the filler than in the no-filler condition (Figure 1). The main effect for ISI was also significant [$F(5,170) = 23.54, p < .00$] and interacted with condition [$F(5,170) = 2.83, p < .02$]. The main effect of cue–target relation was significant [$F(1,34) = 12.35, p < .00$] and interacted with condition [$F(1,34) = 4.90, p < .03$]. The interaction of ISI and cue–target relation was not significant [$F(5,170) = 1.85, p < .11$], nor was the critical predicted interaction of condition, ISI, and cue–target relation ($F < 1$).

Determining whether the effect of cue–target relation varies as a function of ISI in the filler condition is central to evaluating Law et al.'s (1995) claims for color IOR. Thus, despite the nonsignificance of the three-way interaction in the omnibus analysis, the filler and no-filler conditions were analyzed in separate within-subjects ANOVAs (see Keppel, 1982), with ISI and cue–target relation as factors. For the filler condition, this analysis revealed a significant effect of ISI [$F(5,85) = 17.88, p < .00$; see Figure 1]. This effect likely represents increasing preparation due to decreasing temporal uncertainty regarding target onset. Consistent with Law et al.'s findings, there was also a significant effect of cue–target relation [$F(1,17) = 13.14, p < .00$], wherein RTs were slower when the cue and target were the same ($M = 447$ msec) than when they were different ($M = 433$ msec) colors.

However, indicating that this same-color inhibition did not depend on the duration of the filler, this effect of cue–target relation failed to interact with ISI ($F < 1$).

For the no-filler condition, the same analysis revealed a significant effect of ISI [$F(5,85) = 9.76, p < .00$; shown in Figure 1 as a nonlinear change in RT across ISI]. In contrast to the filler condition, there was no main effect of cue–target relation [$F(1,17) = 1.13, p < .30$]. There was also no interaction of ISI and cue–target relation [$F(5,85) = 1.63, p < .16$].

Law et al.'s (1995) IOR account of the slower same-versus different-color RTs predicts that cue–target relation should interact with ISI in the filler condition. As noted, this did not occur. In concert with Law et al., we did find slower responses associated with repeating a color. However, this disadvantage for same- versus different-color trials was observed at the shortest and longest ISIs, with no change in the magnitude of the effect across ISI.

Figure 1. Simple detection reaction times (RTs) to targets that follow same-color and different-color cues, as a function of cue–target interstimulus intervals (ISIs) during which a colored filler is presented or during which no filler is presented and the screen reverts to the background.

In an effort to salvage the IOR interpretation, it might be suggested that the colored filler stimulus attracted attention away from the cue color so rapidly that facilitation was not observed at the shortest ISIs in the filler condition. However, if the colored filler was drawing attention away from the cued color across all ISIs, then when the filler was eliminated in the no-filler condition, facilitation should have been observed—at least at the shortest ISIs. The lack of a main effect for cue–target relation and the failure of this effect to interact with ISI in the analysis of the no-filler condition, however, denies this possibility. Moreover, as seen in Figure 1, rather than there being an early facilitatory effect in the no-filler condition, there was tendency toward same-color inhibition [$F(1,17) = 4.09, p < .06$].

CONCLUSION

The present study confirms the findings of Law et al. (1995) for a 900-msec cue–target ISI: RTs on same-color trials were longer than those on different-color trials but only when cue and target were separated by a task-irrelevant colored filler. However, our extension of the Law et al. study did not show the predicted crossover interaction. Law et al.'s IOR hypothesis for their same-color inhibition requires that attention be allocated to and then withdrawn from the cue color representation to that of the neutral attentional "attractor" (i.e., the colored filler). Law et al.'s IOR claim therefore predicts that same-color inhibition should vary with the interval over which the filler can operate in the reallocation of attentional resources. Our failure to find a three-way interaction of condition (filler, no filler), cue–target relation (same, different), and ISI contradicts this claim. Moreover, the failure to show facilitation at early ISIs for the no-filler condition (or for the filler condition) argues against requisite attentional orienting to the cue color representation in the first place. Indeed, contrary to the prediction of facilitation in the no-filler condition, there was a tendency for there to be a same-color inhibition at the earliest ISI. On the basis of these findings, we suggest that IOR for color is an unlikely mechanism for the same-color inhibition that was observed in the filler condition, and, instead, we favor an alternative explanation that was proposed by Law et al. but rejected on the basis of the time course of their inhibitory effects: repetition blindness (RB).

RB is the failure to report the second occurrence of attended letters, words, or colors (see, e.g., Kanwisher, 1987, 1991). Law et al. (1995) argued for IOR and against RB by noting that "the similarity of Kanwisher's (1991) paradigm and results to those in the present study suggests that a common mechanism may underlie both effects. However, the interval between the repeated color stimuli used by Kanwisher (1991) was 117 msec, whereas intervals of at least 300 msec typically produce inhibition of return in covert orienting paradigms . . . [and] intervals of less than 300 msec usually produce facilitation" (pp. 406–407). In making this circular argument,

the authors have made the a priori assumption that their paradigm taps mechanisms of attentional orienting and not the mechanisms of RB; they argued against RB on the basis of an assumed early facilitation that they never measured. Clearly, our results challenge the view that the inhibitory effect measured by Law et al. was IOR and instead support the possibility that the separation of repeated colors by a task-irrelevant colored filler results in RB for the second occurrence of the color.¹

Recent demonstrations have revealed that color discriminations at peripheral locations may suffer from inhibition that is tagged to a previously cued *location* (e.g., Lupiáñez, Milán, Tornay, & Tudela, 1997). However, Law et al.'s (1995) study is the only one of which we are aware that argues for a purely nonspatial IOR in a strictly color domain. On the basis of our findings, we are forced to conclude that there has yet been no convincing evidence that IOR can be tagged to a color representation per se; the results that Law et al. reported are interesting, but do not demonstrate IOR for color.

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NOTE

1. Converging evidence for an RB account may be gleaned from a replication we conducted of the present experiment, in which the cue duration was 100 msec and the cue–target stimulus onset asynchrony (SOA) was manipulated instead of ISI. In neither the filler nor the no-filler conditions was the main effect of cue–target relationship, or its interaction with SOA, significant. There was, however, a trend for facilitation at the shortest SOA in the filler condition [with same-color 19 msec faster than different-color, $F(1,17) = 3.86, p < .07$]. This tendency for facilitation was not due to attentional allocation to the cue's color representation, because it was not observed in the no-filler condition [indeed, the pattern was reversed: Same-color was 14 msec slower than different-color, $F(1,17) = 2.50, p < .13$]. But, even if it were due to attention, the pattern contradicts Law et al.'s (1995) proposal, which entails inhibition at the longer intervals (i.e., IOR ensues following removal of attention from the cued color by the magenta attractor stimulus).

In contrast, because RB depends on the identifiability of the first token (Shapiro, Driver, Ward, & Sorensen, 1997), we think this pattern

may provide some—albeit indirect—support for the RB account rejected by Law et al. (1995). Shapiro et al. (Experiment 1) reported that targets presented during the “blink” period in a rapid serial visual presentation task yield RB when they are identified, whereas unidentified targets presented during the blink yield priming. In our experiments, when the cue is 900 msec and easily identified, there is inhibition for color repetitions at all intervals as long as a new color is interposed. However, when the cue is 100 msec long and unlikely to be identified (not only is it difficult to identify so brief a color stimulus, but also, because the cue color is task irrelevant, subjects would have no incentive

to allocate resources to assist with identification), there is an early facilitation and no inhibition at all.

It must be noted that the link between Shapiro et al.'s (1997) task and the one used here is entirely speculative. Certainly, further studies will be needed to confidently determine whether the slower responses we and Law et al. (1995) have observed for color repetition is an example of repetition blindness.

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