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Object-based Inhibition of Return: Evidence from Overlapping Objects

Wei-Lun Chou and Su-Ling Yeh

Department of Psychology, National Taiwan University

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Correspondence Author: Su-Ling Yeh, Department of Psychology, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, 106, Taiwan（E-mail：suling@ntu.edu.tw）

Inhibition of return (IOR) refers to the delayed response to a location or an object that has recently been cued. Previous studies showing object-based IOR in either dynamic or static displays have used spatially separate stimuli that unavoidably involved spatial representation. It thus remains unclear whether the object-based IOR is a special case limited to the condition in which objects are separated in a 2-dimensional space. To rule out confounding with location-based IOR, we used two overlapping triangles constituting a "Star of David" in this study to examine whether and under what conditions object-based IOR can be observed. An object cuing paradigm was used in which one of the two triangles was brightened as the cued object. The target was a luminance change in one of the three disks connected to the vertexes of the cued or the uncued triangle. The participants judged whether the target brightened or dimmed. Results show that object-based IOR can occur for spatially overlapping object under two necessary conditions: A long enough cue-to-target SOA and the existence of an attractor that is presented after the cue and before the target.

Keywords: ***visual attention, representation, cuing paradigm, attractor***

When you search your desktop for a pen, the best strategy is to remember where you have already searched and not to search there again; looking in new places rather than the old ones makes your search more efficient. Human performance observed in psychological experiments indeed reveals a phenomenon similar to this search strategy: The reaction time (RT) increases when a target appears at a location that has recently been cued, an effect called "inhibition of return" (IOR; Posner, Rafal, Choate, & Vaughan, 1985). Posner and Cohen (1984) are the first to demonstrate the IOR effect. They used three outline boxes presented on a horizontal axis, with the central box as fixation and the right or the left box being brightened briefly as a peripheral cue. The target was a small filled square within the box, and the participants were instructed to respond to the target as quickly as possible. The target was usually in the central box ($p = .6$), but it could occur in either peripheral box ($p = .1$ on each side). They found, on the one hand, a facili-

* This research was supported by a grant from the National Science Council of Taiwan (NSC90-2413-H-002-021). Correspondence concerning this paper should be addressed to Su-Ling Yeh, Department of Psychology, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei, 106, Taiwan. E-mail: suling@ntu.edu.tw. Fax: 886-2-23629909. Tel: 886-2-33663097.

tatory effect in which RT to detect the target was shorter at the cued box than at the uncued box when the cue-to-target stimulus onset asynchrony (SOA) was shorter than 150 msec (i.e., 0, 50, and 100 msec). On the other hand, RT was longer at the cued box than at the uncued box when the SOA was longer than 300 msec (i.e., 300 and 500 msec).

Posner and Cohen (1984) argued that the initial RT benefit to the cued box is due to the summoning of attention by the cue. However, this early facilitatory effect is replaced by a subsequent inhibition to the previously cued location after attention had presumably shifted back to the central fixation (as targets occurred mainly in the central box). Although Posner and Cohen (1984) concluded that the cued *location* in visual space is facilitated early and inhibited later, such an account of space-based attention may be confounded with the possibility that their participants viewed these boxes as objects, rather than, or in addition to, viewing them as locations. Indeed, the three boxes used in their displays can be considered as either locations or objects, or both (Tipper, Weaver, Jerreat, & Burak, 1994; Jordan & Tipper, 1998). Nevertheless, Posner and Cohen's (1984) original paradigm is used by many follow-up studies, and the existence of location-based IOR has been well established (see review of Klein, 2000).

To distinguish location-based IOR from object-based IOR is important, as illustrated by the following example. Ecologically, it may be helpful to inhibit *places* that have just been searched before; say, for a sheep to search for fresh grass that has not been eaten already, assuming that the target (fresh grass) of a sheep in this example is more or less in a 2-dimensional space. However, it is unlikely that inhibiting previously searched *places* can also be helpful, as in the case of a lion looking for a running rabbit in the forest. Just as for lions, for humans, there are always multiple objects that may change locations, and one object may overlap the other in the environment. In such an environment that is dynamic, 3-dimensional, and full of multiple objects, inhibiting an already searched or attended *location* may in fact turn out to be inefficient for searching.

Indeed, several studies have shown some IOR phenomena to be object-based. Tipper, Driver, and Weaver (1991) first demonstrate object-based IOR in a dynamic display in which the cued object rotates 90° from its original location after being cued, and the inhibition associated with it also moves with the object. However, the objects used in their experiment retain their relative locations when rotating around the fixation point. Thus, the objects may help set up a frame of reference in which attentional orienting operates on relative locations, but not on objects (Schendel, Robertson, & Treisman, 2001). Such a dynamic display, as that used by Tipper et al. (1991), has also been criticized as being confounded with left-to-right attentive tracking, and dynamic object-based IOR has been demonstrated only under certain experimental conditions (Müller & von Muhlenen, 1996).

There are also studies that have shown object-based IOR in static displays. Jordan and Tipper (1998), for example, found that the magnitude of IOR in the apparent-object-present condition (i.e., an illusory object induced by four "pacmen" had been cued) is significantly larger than that from the apparent-object-absent condition (i.e., only a location had been cued). They interpreted their results in the view that when objects are cued there are both location- and object-based IOR effects, while when only locations are cued, there is only location-based IOR. In this case, assuming the two kinds of IOR are additive, the object-based effect is inferred indirectly by the comparison of the magnitude of presumably location- plus object-based IOR and that of location-based IOR alone. Again, the results seem to be obtained only under certain circumstances (McAuliffe, Pratt, & O'Donnell, 2001). In a subsequent study, Jordan and Tipper (1999) used two spatially separate rectangles with a peripheral cue appearing at one end of a rectangle (see also Egly, Driver, & Rafal, 1994). They found longer detection RT at the uncued end of the cued object relative to the uncued end of the uncued object, demonstrating more directly object-based IOR in static displays.

Note that for the studies showing object-based IOR in either dynamic or static displays, spatially separate stimuli are used (e.g., McAuliffe et al., 2001; Tipper et al., 1991; Tipper, Jordan, & Weaver, 1999; Jordan & Tipper, 1998; 1999). This raises the question whether object-based IOR is a special case limited to the condition where objects are separated in 2-dimensional space. This is an important question because if only the objects which occupy different 2-dimentional spaces can reveal the object-based IOR, the effect is unavoidably associated with not only object representation, but also space representation. In other words, if the object-based IOR can only be found when objects are spatially separate, it means that the *space* representation is crucial to the *object-based* effect.

In this study, overlapping objects were used to avoid confounding from location-based effects (e.g., Duncan, 1984; Haimson & Behrmann, 2001) and to see whether object-based IOR occurs for spatially overlapping objects. This arrangement of stimuli is justifiable on ecological grounds: The retinal images of many real-world objects are usually overlapped.

The stimuli used in the present study (Figure 1) are similar to those in Brawn and Snowden (2000). One of the objects was brightened as a cue, but this exogenous object cue was uninformative as to which object the target will appear. Using this display, they find an object-based facilitatory effect: Shorter RT when the target appears at the cued object than at the uncued object. More importantly, they demonstrate that attention can select one of the two overlapping objects (see also Stuart, McAnally, & Meehan, 2003). The cue-to-target SOA was less than 300 msec in their study, and curiously, they did not manipulate longer SOAs to see whether an IOR effect can also be found with overlapping objects. Adopting the object cuing paradigm used by Brawn and Snowden (2000), we examine whether object-based IOR occurs for a long enough SOA.

In fact, in a similar display using overlapping objects, Schendel et al. (2001) do not find object-based IOR even when the SOA is extended to 725 msec. Likewise, Theeuwes and Pratt (2003) also fail to find depth-specific IOR when the SOA is 883 msec, and they term it "depth-blind" IOR. In Theeuwes and Pratt (2003), after a specific object in the x-y-z coordinate was cued, the effect of IOR spread across the z-dimension: Namely, IOR occurs for the depth planes in front and behind the cued object. Although two objects at different depth planes are different from two overlapping objects at the same depth plane, it is reasonable to infer from this result that no object-specific IOR for overlapping objects can be observed at this SOA (883 msec).

It has been shown that the more complex the object is, the longer the SOA it requires for obtaining the object-based effect (Ho & Atchley, in press). The stimulus displays used in Schendel et al. (2001) and in Theeuwes and Pratt (2003) are more complex than those of Jordan and Tipper (1998; 1999). While the former two studies fail to find object-based IOR, the latter successfully demonstrate its existence. We suspect that it may be due to the shorter SOAs (725 and 883 msec) used in the former two studies than those in Jordan and Tipper (1998; 1999; 1186 and 1166 msec). Hence, there is reason to believe that their experiments (Schendel et al., 2001; Theeuwes & Pratt, 2003) did not provide a strong test of the possible existence of object-based IOR and their designs are not fair to answer whether object-based IOR can be observed from overlapping objects. We are thus curious whether the object-based IOR for spatially overlapping objects can be observed if the cue-to-target SOA is extended to an even longer duration.

Another hint of using long enough SOA to obtain the object-based IOR can be found in Law, Pratt, and Abrams (1995). Using a cuing paradigm with 1800 msec cue-to-target SOA, they show that participants are slower to detect a color patch (i.e., the target) if the color matches that of a patch presented earlier at the same location (i.e., the cue). This is interpreted as an IOR effect based on the nonspatial attribute of color (but see Fox & de Fockert, 2001). Although it is unclear whether such feature-based IOR is applicable to the object-based IOR, it is nonetheless a case that shows an object-related IOR in a long (1800 msec) cue-to-target SOA condition.

To examine the effect of SOA on object-based IOR, we first use a long enough SOA to see whether IOR with overlapping objects can be obtained, and then compare it with a shorter SOA to test our first hypothesis in this study: A long enough SOA is necessary for object-based IOR. As noted, our object display is more complex than that in Jordan and Tipper (1998), who successfully demonstrated the object-based IOR from spatially separate objects. Thus we chose a slightly longer cue-to-target SOA (1360 msec) than the SOA used by them (1186 msec). As a comparison, we also used a short cue-to-target SOA, which was 884 msec, similar to that in Theeuwes and Pratt (2003; 883 msec). We predict that only the long SOA can lead to the object-based IOR, but not the short one, if a long enough SOA is necessary for obtaining the object-base IOR for spatially overlapping objects.

Another concern regards the nature of IOR. As implied in the name "inhibition of return," Posner and Cohen (1984) remarked, "...if attention is not drawn away from the cued location, no net inhibition is found," (p. 541). Without manipulating the probability that the target appeared in the central box, Posner and Cohen (1984) replicated the IOR effect with a simpler method. In the aforementioned three-box displays, after the brightening of one of the boxes on the two sides (which serves as a peripheral cue), the central box was brightened briefly (as a neutral cue) before the onset of the target. It is assumed that on each trial, the participant's attention is first summoned by the peripheral cue and then by the central cue before the onset of the target display. This is why the IOR effect is attributed to the participant's attention being inhibited from returning to the previously cued location (but see Danziger & Kingstone, 1999). We call a stimulus such as the central cue in Posner and Cohen (1984) the "attractor" because it occurs after the offset of the peripheral cue and captures the participant's attention, taking it away from the previously cued location.

Recently, the role of attractor in location-based IOR has been carefully examined by Pratt and Fischer (2002). They found that the attractor is needed *only* at a short SOA (200 msec). At longer SOAs (400 and 800 msec), the location-based IOR can be observed regardless of whether an attractor is present (see also McAuliffe et al., 2001), indicating that attractor is not necessary for location-based IOR. However, in their design, although the presence or absence of an attractor does not seem to affect location-based IOR at longer SOAs, such a result cannot exclude the possibility that participants' attention had still returned to the central fixation from the cued location. Note that their participants knew that the cue was uninformative and thus to stay on fixation was the best strategy for the task at hand. Thus the participants may *endogenously* shift their attention from the cued location to the fixation location even without an attractor, especially in the long cue-to-target SOA conditions. It is hitherto unclear whether "the removal of attention" from the cued location is crucial for location-based IOR.

Adopting the original notion of Posner and Cohen (1984), the paradigm that reveals object-based IOR used by Tipper and his colleagues (1991; 1994) always contains an attractor following the peripheral cue (see also Abrams & Dobkin, 1994; McAuliffe et al., 2001; Jordan & Tipper, 1998; 1999). However, it has not been directly tested whether an attractor in object-based IOR is necessary, and so comes our second hypothesis: An attractor presented in between the sequential presentation of the cue and the target is necessary for object-based IOR with overlapping objects.

Because we aim to examine the object-based IOR without confounding from the location-based IOR, the attractor we use is meant to be another object that can attract participants' attention from the originally cued object. This is quite different from the brightening of the central fixation used in previous studies that demonstrate location-based IOR (Abrams & Pratt, 1996; Pratt & Abrams, 1995; Pratt & Fischer, 2002; Pratt, Spalek, & Bradshaw, 1999; Snyder, Schmidt, & Kingstone, 2001; Tipper, Weaver, & Watson, 1996). The use of different kinds of attractor involves the relationship between object-based representation and location-based representation, which is beyond the scope of this study. What is emphasized here is that assuming object-based IOR occurs in object-based representation, the attractor used should be more like an object rather than a symbol that signifies a particular location (such as the fixation dot or cross used in previous studies). For this purpose, we use a long line that is also overlapped with the two overlapping objects as an attractor.

To reiterate, the two goals of the present study are: First, whether there exists object-based IOR for overlapping objects. The object-based facilitatory effect has been found, but the inhibition, the object-based IOR, does not seem to have been demonstrated consistently, especially for overlapping objects (e.g., Brawn & Snowden, 2000; Theeuwes & Pratt, 2003; Schendel et al., 2001). Second, we test, with overlapping objects, whether a long enough SOA and/or an attractor are necessary for object-based IOR.

Experiment 1

Method

Participants. Sixteen undergraduates of National Taiwan University participated in the experiment to fulfill course requirements. All reported normal or corrected-to-normal vision and were naïve as to the purpose of this experiment.

Stimulus materials. Stimulus displays were controlled by an IBM 486 personal computer and presented on a 14' ViewSonic monitor. A computer program, DMDX (Forster & Forster, 2003), was executed to present the stimuli and collect the RT data. Participants sat at a viewing distance of 60 cm in a dimly lit chamber, with their heads supported by a chinrest.

Each trial consisted of four kinds of display, including the fixation, the cue, the attractor, and the target display. In the fixation display, the fixation was a central white cross ($.67^\circ \times .67^\circ$) against a gray background, and two outline ($.29^\circ$ in width) triangles (one inverted and one upright triangle, with each side extended 9.46°) were presented, one overlapping the other. One of the triangles (randomly chosen) was green and the other red. Three disks of $.95^\circ$ in diameter, centered 5.71° from the fixation cross, were connected to the three ends of each triangle and painted with the same color as the connecting triangle. In the cue display, one of the triangles was brightened and defined as the cued object. In the attractor display, a black dotted line ($9.46^\circ \times .29^\circ$) that was slightly longer than the sides of the triangles was presented on fixation at orientations –45, 0, or 45 degrees (randomly chosen) from vertical. The line was centered on the same central location as the two overlapping triangles. In the target display, one of the six disks connected to the two triangles was either brightened or dimmed, and the other five disks remained unchanged.

Design. The relation between the cue and the target was manipulated in an object cuing paradigm. In the *valid* condition, the target was located on one of the three disks connected to the *cued* triangle. In the *invalid* condition, the target was located on one of the three disks connected to the *uncued* triangle. If there is object-based IOR, RT to the target in the valid condition should be longer than that in the invalid condition. In addition, the role of attractor is examined by comparing the *with-attractor* condition with the *without-attractor* condition. If an attractor is necessary, the object-based IOR should be found only in the *with-attractor* condition, but not in the *without-attractor* condition.

The four conditions (valid/invalid × with-attractor/without-attractor) were repeated 12 times within a block of 48 trials, with their orders randomized. There were four blocks of these trials in total, with an effort to balance the possible combinations of target locations. Sixteen practice trials preceded the formal 192 trials, and the participants could take short self-paced breaks between blocks.

Procedure. The stimulus sequence is illustrated in Figure 1. The participants began each block of trials by pressing the space bar. At the beginning of each trial, an auditory tone was sounded for 100 msec, and at the same time, a fixation display was shown for 1020 msec. After the fixation display, the cue display was presented for 255 msec and replaced by the fixation display again. In the *without-attractor* condition, following the cue display, the fixation display was shown for 1105 msec. The target display appeared at 1360 msec SOA after the onset of the cue and stayed for 1000 msec or until the participants responded, whichever happened first. The whole display turned blank for an ISI of 500 msec, and then the next trial began. In the *with-attractor* condition, the cue-to-target SOA was

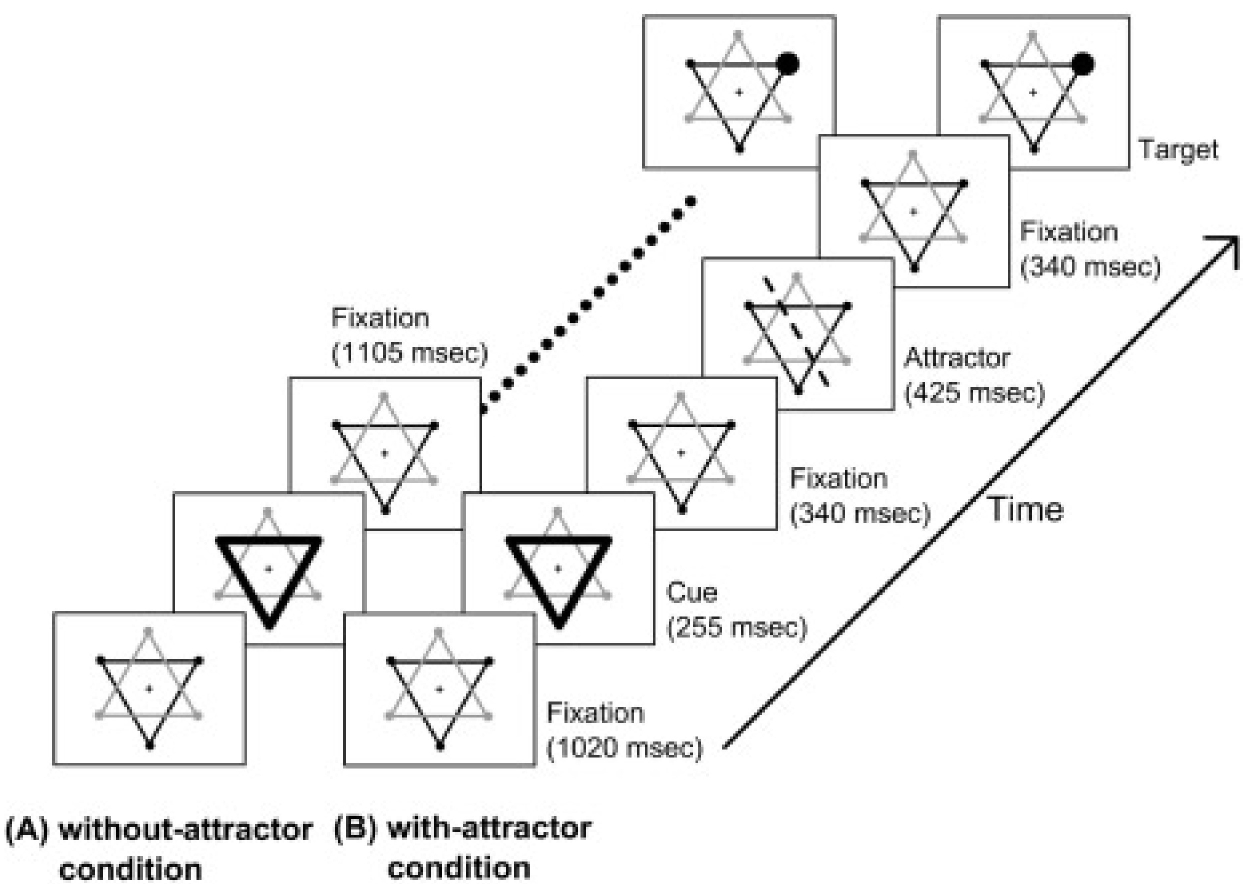

Figure 1. Illustration of the display sequence used in this study (not to scale). In the actual experiment, the background was gray and one of the triangles and its connecting disks were green, while the other triangle and its connecting disks were red. (A) The without-attractor condition. (B) The with-attractor condition. The attractor was a black dotted line shown on the 4th frame and was presented at 45˚, 0˚, or -45˚. The cue and the target were equally likely to occur for the two triangles.

still 1360 msec, but an attractor display was added in between the cue display and the target display. The attractor display was shown 595 msec after the onset of the cue display and stayed for 425 msec. Two fixation displays, one before and one after the attractor display, were each presented for 340 msec.

In the experiment, the participant judged whether the target was brightened or dimmed by pressing the "F" key on the computer keyboard with the left index finger if it was brightened and pressing the "J" key with the right index finger if it was dimmed. The participants were informed that the brightened triangle (the cued object) was not predictive of the subsequent target and targets were equally likely to appear on cued vs. uncued objects. They were instructed to respond as quickly and accurately as possible. Before the practice trials and before each block of the experiment, the participants were informed of the necessity of maintaining fixation throughout the trial.

Results and Discussion

In all experiments of this study, trials with an incorrect response or a RT less than 200 or longer than 1,000 msec are excluded as error trials, and less than 1% of trials are removed in each experiment. Figure 2A illustrates the mean RTs in this experiment. A repeated measure of the analysis of variance (ANOVA, a software provided by Chen & Cheng, 1999) was conducted with the attractor (with-attractor, without-attractor) and the cuing (valid, invalid) as the within-subjects factors. Neither the main effect of attractor nor the main effect of cuing is significant, *p*s > .05. However, the two-way interaction is significant [$F(1, 15) = 7.07$, $MS_e = 94.13$, $p < .05$]. Planned comparisons showed that the effect of cuing is significant only in the with-attractor condition [$F(1, 30) = 8.30$, $MS_e = 144.20$, $p < .01$], and the effect of attractor is significant only when the cue is valid [$F(1, 30) = 9.17$, $MS_e = 231.86$, $p < .01$]. In the with-attractor condition, RT is significantly longer when the cue is valid (M = 493 msec) than when it is invalid (M = 480 msec). In the without-attractor condition, however, no difference in RT is found between valid cue (M = 476 msec) and invalid cue (M = 477 msec).

The percentage of errors for each condition is shown in Table 1. Analysis of error rates indicates that the speed-accuracy trade-off for differences in the effect can be ruled out. Neither the main effect of attractor nor the main effect of cuing is significant, *F*s < 1. The two-way interaction does not reach the significance level, either [$F(1, 15) = 1.45$, $p > .05$].

Therefore, this experiment yields two important results. First, we found that participants responded slower to targets at cued objects than at uncued objects, demonstrating object-based

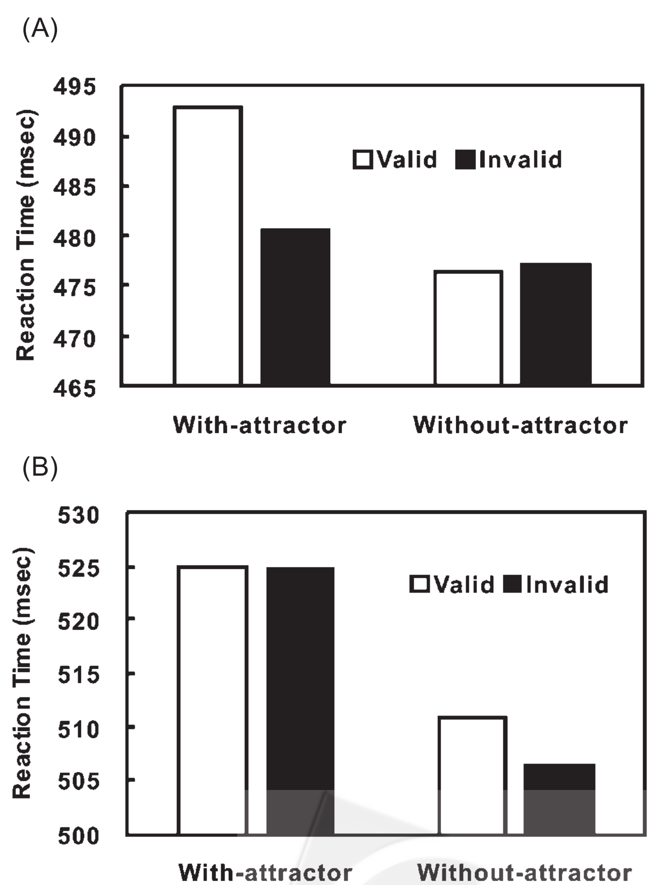

Figure 2. (A) The results of Experiment 1. (B) The results of Experiment 2.

Table 1
Percentage of errors in Experiment 1 and 2

	With-attractor		Without-attractor	
	Valid	Invalid	Valid	Invalid
Experiment 1	5.3	4.4	4.3	5.3
Experiment 2	5.6	5.0	3.4	5.0

IOR by cuing attention to one of the two overlapping objects. Previous studies showing object-based IOR used spatially separate stimuli that unavoidably involved spatial representation. By using spatially overlapping objects to avoid such confounding in this experiment, we demonstrate that object-based IOR can also occur for spatially overlapping objects. Thus, the object-based IOR is not a special case limited to the condition in which objects are separated in a 2-dimensional space. Second, the object-based IOR is found in the with-attractor condition, but not in the without-attractor condition, thus indicating the necessity of an attractor in demonstrating object-based IOR.

Experiment 2

With displays of overlapping-objects similar to that in our Experiment 1, Theeuwes and Pratt (2003) and Schendel et al. (2001) do not find any object-based IOR effects when the cue-to-target SOA are 883 and 725 msec respectively. We are thus curious whether the object-based IOR observed in our Experiment 1 is due to the long SOA used in that experiment. In Experiment 2, we used the same displays and procedure as those in Experiment 1 but changed the cue-to-target SOA to 884 msec to see whether a long SOA is necessary for object-based IOR in the overlapping-object display. If it is, changing the SOA close to that used by Theeuwes and Pratt (2003) and Schendel et al. (2001) should then make the object-based IOR we observed in Experiment 1 disappear.

Method

Participants. Another group of twenty undergraduates with the same characteristics as described in Experiment 1 participated in this experiment.

Stimuli, Design, and Procedure. The stimuli, design, and procedure were the same as those in Experiment 1 except for the following: The cue-to-target SOA was shortened to be 884 ms in this experiment. In the without-attractor condition, following the cue display, the fixation display remained unchanged for 629 msec. The target display appeared at 884 msec SOA after the onset of the cue, and stayed for 1000 msec or until the participants responded, whichever happened first. In the with-attractor condition, the cue-to-target SOA was still 884 msec, but an attractor display was added in between the cue display and the target display. The attractor display was shown 357 msec after the onset of the cue display and stayed for 425 msec. Two fixation displays, one before and one after the attractor display, were each presented for 102 msec.

Results and Discussion.

Figure 2B shows the mean RTs for valid and invalid trials of the with-attractor and without-attractor conditions. Only the main effect of attractor is significant [$F(1, 19) = 18.32$, $MS_e = 283.26$, $p < .01$]. RT is significantly longer in the with-attractor condition ($M = 525$ msec) than the without-attractor condition ($M = 509$ msec). However, the effect of cuing is not significant [$F(1, 19) = 0.29$, $MS_e = 364.65$, $p > .1$].

The mean error rate for each condition is shown in Table 1. Analysis of error rates indicates that the speed-accuracy trade-off for differences in the effect can be ruled out. Neither the main effect of attractor nor the main effect of cuing is significant, $ps > .1$. The two-way interaction is not significant, either [$F(1, 19) = 2.20$, $p > .1$].

As predicted, no object-based IOR is

observed when the cue-to-target SOA is shortened to be 884 msec in this experiment. Examining the results of Experiments 1 and 2 together indicates that both an attractor and a long cue-to-target SOA are necessary for object-based IOR. In Experiment 1, with an SOA of 1360 msec, object-based IOR is observed only when an attractor is presented in the time sequence between the cue and the target. In Experiment 2, with an SOA of 884 msec, even when an attractor is presented, still no object-based IOR is found. Although both the attractor and the long SOA are necessary for the object-based IOR, they are not inevitably two independent and additive factors. It is possible that the presence or absence of the attractor may modify the SOA for observing the object-based IOR. The patterns of results in Figure 2A and 2B seem to suggest that this might be the case.

Because the display in the with-attractor condition is more complex than that in the without-attractor condition, it is not surprising that participants need longer time to respond in the former condition (M = 525 msec) than in the latter (M = 509 msec). We also observe the same trend in Experiment 1, although the effect is not statistically significant in that experiment.

General Discussion

We obtained several important results in this study. First, participants responded slower to targets at cued objects than at uncued objects, demonstrating object-based IOR by cuing attention to one of two overlapping objects (Experiment 1). Second, the object-based IOR was found in the *with-attractor* condition, but not in the *without-attractor* condition, thus indicating the necessity of an attractor in demonstrating object-based IOR (Experiment 1). Third, when the cue-to-target SOA was not sufficiently long, the object-based IOR observed in Experiment 1 disappeared even when an attractor was present (Experiment 2).

As mentioned in the Introduction, the findings of object-based IOR in past studies used spatially separate stimuli that involved spatial representation (e.g., Jordan & Tipper, 1998; 1999; Tipper et al., 1994), which raises the question whether object-based IOR is limited to objects that do not overlap. We used overlapping objects in this study and demonstrated object-based IOR. The overlapping objects we used are similar to those in Brawn and Snowden (2000). Nevertheless, by prolonging the cue-to-target SOA to 1360 msec (as compared to the 200-300 msec used in their study), we have extended their finding of a facilitatory effect to an inhibitory effect and showed that object-based IOR can occur for overlapping objects. This major result provides an answer to the unsolved question in previous studies: Object-based IOR is *not* a special case limited to the condition where objects are spatially separate.

Furthermore, when a long SOA is used versus a short SOA (Experiment 1 vs. Experiment 2), object-based IOR is obtained only in the *with-attractor* condition, but not in the *without-attractor* condition. The attractor used in our experiments is a long onset line, which is considered an object and has been used to examine the object-based attention in several studies (e.g., Duncan, 1984; Lavie & Driver, 1996). Since abrupt onset object or new object can capture attention (Theeuwes, 1991; Yantis & Jonides, 1984), the onset line pulls participants' attention away from the attended object (i.e., the cued triangle). The necessity of attractor in IOR found in this study thus indicates that withdrawing attention from the attended object is crucial for object-based IOR to be observed. The conclusion is consistent with the long-held notion of IOR which assumes that RT is delayed because attention is inhibited from *returning* to a cued location (or object) and that where attention resides determines whether the facilitation or the inhibition will be found (Posner & Cohen, 1984).

Our results are also consistent with Ro and Rafal (1999). They used two moving objects, similar to Tipper et al. (1991), while manipulating the salience of the attractor (a neutral cue) and found that the likelihood of producing object-based IOR increases with the salience of the attractor. They emphasize, nonetheless, that the object-based facilitatory effect is found at long SOAs (600 and 900 msec) when no attractor is used. We do not find the sustained object-based facilitatory effect in the without-attractor condition at 884 msec SOA in Experiment 2, however. This discrepancy may be due to differences between Ro and Rafal's (1999) study and our study, such as detection vs. discrimination tasks, dynamic vs. static displays, and spatially separate objects vs. overlapping objects.

As mentioned, the role of the attractor in location-based IOR has been examined by Pratt and Fischer (2002). Their results indicate that the attractor is not necessary for location-based IOR in long-SOA conditions. We do not think their results are irreconcilable with the notion that "withdrawing attention from the attended location is critical to IOR". Spatial representation may be a special case regarding the role of attractor. In the space domain, the central fixation, usually also the medial position between possible target sites, naturally indicates a neutral location of the display. And that is also usually the most likely location at which the participants maintain their attention. Thus, during the interval between the peripheral cue and the target, especially in long-SOA conditions, participants may shift their attention from the cued location to the fixation location endogenously, even without an attractor. In other words, if the cue-to-target SOA is long enough, participants can actively withdraw attention from the attended location without being triggered by an attractor. This may explain why in Pratt and Fischer (2002) the attractor seems irrelevant only in long-SOA conditions. However, for the overlapping objects used here and the color target used in Law et al. (1995), alternative non-target objects or colors (i.e., neutral objects or colors) are not typically available to relocate the participant's attention, and thus a presented attractor becomes necessary. Our results are consistent with Law et al.'s (1995) notion that in order to demonstrate IOR, it is necessary to direct attention to a value of a specific stimulus dimension, and then to shift attention from that particular value of the cued stimulus dimension to another value.

In addition to an attractor, an adequately long cue-to-target SOA is also necessary for object-based IOR in overlapping-object display. In Experiment 2, we used the same display and procedure as those in Experiment 1 but changed the cue-to-target SOA from 1360 msec to 884 msec, an SOA similar to that in Theeuwes and Pratt (2003). The absence of IOR in this short SOA condition is consistent with Theeuwes and Pratt's (2003) study: Their results of "depth-blind" IOR suggest that IOR cannot be restricted to one of the overlapping objects at 883 msec SOA.

To sum up, we have shown that object-based IOR can occur with overlapping objects, but only when an attractor is sandwiched between the cue and the target display, and when the cue-to-target SOA is long enough. Object-based IOR is not a special case limited to the condition where objects are spatially separate.

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以重疊物體探討物體為基礎的回向抑制及其產生要件

周蔚倫　葉素玲

國立台灣大學心理學系暨研究所

回向抑制（Inhibition of return, IOR）指的是：對於出現在剛被提示過的位置或物體上的目標物，反應時間會增加。過去顯示回向抑制也能以物體為基礎的研究皆使用空間上分開的物體作為刺激，因而留下一個重要而未解決的問題：「物體為基礎的回向抑制是否需仰賴物體間不同的二度空間表徵才得以展現？」。我們使用物體提示派典（object cuing paradigm）和可排除空間表徵混淆變項的設計來探討這個問題。兩個三角形重疊於畫面中，其中一個三角形會先亮一下，接著目標物出現在任一三角形的任一端點，觀察者必須判斷目標物是變亮或變暗。實驗結果發現，當線索到目標物的時距夠長以及有注意力擷取物的情況下，以物體為基礎的回向抑制現象得以在二度空間重疊的物體上展現。

關鍵詞：視覺注意力，表徵，線索派典，注意力擷取物