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Li Jingling^a; Su-Ling Yeh^a

^a National Taiwan University, Taipei, Taiwan

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New objects do not capture attention without a top-down setting: Evidence from an inattentive blindness task

Li Jingling and Su-Ling Yeh

National Taiwan University, Taipei, Taiwan

Past studies have suggested that a new object can involuntarily capture attention in a visual search task (Yantis & Jonides, 1984). However, trials in these experiments usually begin with abrupt onsets that are considered to signal new objects; thus, there may be a bias toward paying attention to new objects. We examine whether new objects can still capture attention when this bias is excluded, using an inattentive blindness task. Our results showed that when the trials began with new objects, a new object captured attention. When new objects were totally irrelevant and all top-down settings for new objects were prevented, a new object did not capture attention. Our findings argue against the view that new objects capture attention in a purely stimulus-driven fashion.

In our visual field, some items could be more easily attended to than could others. This priority of attentional selection can be determined by top-down processes, such as task relevance, or can be more dominated by bottom-up processes, such as stimulus salience (Serences & Yantis, 2006). Among various stimulus properties, an abrupt onset is considered the most effective attractor of attention. Yantis and his colleagues (Enns, Austen, Di Lollo, Rauschenberger, & Yantis, 2001; Hillstrom & Yantis, 1994; Yantis & Hillstrom, 1994) suggest that an onset signals a new object, and new objects can receive higher attentional priority irrespective of top-down processes. In this study, however, we argue that an overlooked top-down effect, the trial-wide attentional control setting for new objects, contributes to the capture effect by new objects. By using the inattentive blindness (IB) task, we show

Please address all correspondence to Su-Ling Yeh, Professor, Department of Psychology, National Taiwan University, No. 1, Section 4, Roosevelt Road, Taipei 106, Taiwan.
E-mail: suling@ntu.edu.tw

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that a new object captures attention only when new objects are contingent on a top-down setting, rather than in a purely stimulus-driven manner.

Past studies of attentional capture by new objects have mostly used visual search tasks. In the experiments of Yantis and Jonides (1984), for example, a “placeholder” display containing several figures of eight precedes the target display. Subsequently, some segments of each figure of eight disappear and reveal letters. Since these letters have been generated by offsets, they are usually referred to as “no-onset” letters. In addition to these, there is one letter that is presented abruptly in an empty position without a placeholder. This is called an “onset” letter. In this design, the onset letter happens to be the target only at a chance level; thus, paying attention to the onset letter is not beneficial to target identification. That is, stimulus onset is irrelevant to the task. Yantis and Jonides showed that when the target is one of the no-onset letters, response time increases with the number of distracting letters, showing a limitation of attentional resource in finding the target. When the target happens to be the onset letter, however, response time does not elevate with the number of distracting letters, suggesting that detecting an onset target is effortless; namely, onset captures attention.

Yantis and his colleagues suggested that the difference between the onset and the no-onset letters is that the former is a new object, and the latter is an old one. First, they showed that an abrupt onset is different from a salient item in luminance, colour, or motion dimensions in that an abrupt onset can capture attention while the other salient features cannot (Hillstrom & Yantis, 1994; Jonides & Yantis, 1988; Yantis & Egeth, 1999). Second, when a stimulus signals a new object, regardless of the feature dimension (e.g., luminance, texture, or binocular disparity), all abruptly presented items can capture attention equally well (Yantis & Hillstrom, 1994). Finally, the capture effect by an abrupt onset cannot be explained by the luminance increment of the onset item, because equal-luminance new objects still have higher attentional priority than old objects (Gellatly, Cole, & Blurton, 1999; Yantis & Hillstrom, 1994). With the same amount of luminance increment, a new object attracts attention more easily than does an old one (Enns et al., 2001). Altogether, an abrupt onset seems to be special because it signals a new object, and a new object can capture attention while the other salient features cannot.

Nevertheless, luminance change can indeed create a new object and then capture attention. Rauschenberger (2003), for example, reports that increasing the stimulus luminance by a factor of 2.5–3.3 is sufficient for it to capture attention, presumably due to its producing a new object. In the other feature dimensions, however, the condition to create a new object is not yet clearly defined. It seems that pure colour changes (without luminance changes) of an old object do not lead to the creation of a new object (Cole, Kentridge, & Heywood, 2005; Theeuwes, 1995; but see Lu, 2006), although

colour change can reveal a new object and thus capture attention if the change removes camouflage (Cole et al., 2005). For example, we will perceive a new chameleon only when the colour change of its surface makes it stand out from the background. If a chameleon has already been clearly perceived and then it changes its colour, we will not consider it as another chameleon. Based on these findings, in this study we created a new object by increasing luminance and presenting it at a previously empty location, and presented an old object by changing its colour without luminance increment or transformation.

Although attentional capture by new objects can be modulated by intensions (Yantis & Jonides, 1990), it is often considered involuntary, or stimulus-driven (Yantis, 1993). In Yantis and Jonides (1984), for example, the participants should not have expected the target to be an onset item, but only an onset target was found to capture attention. Moreover, in other attention tasks, a new object seems to have a special advantage over old objects in attracting attention (Cole, Kentridge, Gellatly, & Heywood, 2003; Cole, Kentridge, & Heywood, 2004; Donk & Theeuwes, 2003). However, we suspect that the special role of a new object might not be due to involuntary attentional capture; rather, it might be caused by an overlooked top-down process: The trial-wide attentional control setting for new objects. We argue that the trial-wide setting for new objects is developed in the above studies and a new object matches this setting; due to this, the new object always receives higher priority than old objects.

It is proposed that when the target is defined by a specific feature, participants will give this feature high priority and develop an attentional control setting for the feature during the task (Folk, Remington, & Johnston, 1992). For example, when the participants are asked to distinguish a red letter among several white letters, the colour red is set into the attentional control setting during that task. In this case, a red cue preceding the target can attract attention, even though this red cue does not predict the target location (Folk et al., 1992). This is because the red cue is contingent on the attentional control setting, so it receives higher attentional priority and captures attention. Gibson and Kelsey (1998) further proposed that not only the defining feature of the target, but also all the properties associated with the target, can be configured into the attentional control setting. They called this last kind of setting a display-wide attentional control setting. They showed that when the target was a red E or H and the distractors were red Fs and Ss, and all the items were presented abruptly, both "red" and "onset" cues could capture attention because both were included in the display-wide attentional control settings. Note that, in this example, neither red nor onset can facilitate the distinction between target and distractors; however, they belong to features that the target possesses, hence they can receive higher priority than other features that the target does not possess.

Similar to the display-wide setting, we suggest that there may be a trial-wide attentional control setting for new objects developed in tasks such as visual search. In Yantis and Jonides (1984), for example, all the stimuli were presented abruptly on the screen at the beginning of each trial, as in almost all conventional visual search tasks. The participants were required to perform a certain task, i.e., discrimination of a target letter; however, the task was performed after new objects had been shown on the screen, which made the participants pay attention to these new objects because they signalled the upcoming target. Thus, "new objects" (appearing from an empty position) are events associated with the task. Although the presence of new objects cannot be used to distinguish the target from distractors, as the target could also be an old object emerging from figure of eight patterns, it is still possible that new objects become a part of the trial-wide attentional control setting, as in the condition of the display-wide attentional control setting (Gibson & Kelsey, 1998). In this case, the onset letter (a new object) matches this setting, while the no-onset letters (old objects) do not, leading to a stronger capture effect by the former than the latter. This view can explain the absence of attentional capture by a salient colour (Hillstrom & Yantis, 1994; Jonides & Yantis, 1988; Yantis & Egeth, 1999), because specific colour will not match a trial-wide attentional control setting for new objects. On the other hand, new objects defined along any feature dimension can capture attention equally well (Yantis & Hillstrom, 1994) because they all match this trial-wide attentional control setting for new objects. According to this view, a new object captures attention because it is contingent on the trial-wide attentional control setting, rather than because it induces a stimulus-driven capture effect. We suspect that if there were no trial-wide setting for new objects, new objects might not be able to capture attention.

To test this hypothesis, we should examine and compare the capture effect by new objects in two different conditions: with and without the trial-wide setting. The design of the task needs to match three requirements for a fair comparison. First, the task should be performed either *with*, or *without*, seeing a change of the stimuli on the screen that would induce a trial-wide setting for new objects. For the former condition, to encourage the trial-wide setting, new objects should be presented on each trial, as in a conventional visual search task. For the latter condition, on the other hand, to avoid the trial-wide setting, the participants should not see any new objects in each trial. Second, the target per se should not be defined by a new object, so that the participants would not aim to search for a new object. This would exclude the possibility of a direct top-down setting for new objects, and any capture effect by new objects should be revealed in the absence of any top-down processes. If a new object can capture attention in both conditions, that is, with and without a trial-wide setting, then the capture effect can be supposed to be stimulus-driven. If, however, a new object captures attention

only when there is a trial-wide setting, then this suggests that the capture effect is influenced by top-down processes. Finally, a new object should be presented in the task (though it should not be the target) to test the possibility of attention capture. To fulfil all the requirements, we adopted an inattentional blindness (IB) task (Mack & Rock, 1998).

In an IB task, participants are asked to perform a certain task for several trials. Subsequently, there is a critical trial in which a critical item (CI) is presented on the screen for the first time and, after responding to the task, the participants are asked to report whether they observed any other changes in this first critical trial (CT1). The response to the CI in CT1 is assumed to reflect performance under the condition of inattention, since the participants neither expect, nor have been told to pay attention to, the CI. The response to the CI in the second critical trial (CT2), on the other hand, is assumed to reflect performance under the condition of divided attention because the participants may anticipate the appearance of the CI, and divide their attention to include it. Finally, in the third critical trial (CT3), the participants are asked to ignore the task and respond to the CI, when performance is assumed to be under the control of focal attention. When the CI reporting rate in CT3 is significantly higher than the expected rate based on guessing, the possibility that the CI in CT1 could potentially be insufficiently visible can be ruled out.

The IB phenomenon (Mack & Rock, 1998; Mack, Tang, Tuma, Kahn, & Rock, 1992; Rock, Linnett, Grant, & Mack, 1992) refers to the circumstance that the CI is not reported in CT1, but is reported in CT2 and CT3. That is, when IB occurs, the participants seem to be “blind” to the CI because they do not pay attention to it. IB is negatively correlated with the salience of the CI (Mack & Rock, 1998; Most, Scholl, Clifford, & Simons, 2005; Most et al., 2001; Rock et al., 1992). In addition, the participants are more likely to report the CI when it is presented at an odd corner of a textured background, and also when it is a large or a bright item. Moreover, when the CI is one’s own name, IB is seldom obtained. Based on these results, Mack and Rock (1998) argue that the probability of observing IB can be reduced when the CI captures attention, and Simons and his colleagues (Most et al., 2005; Simons, 2000) further suggest that IB can be considered an explicit measure of attentional capture.

There is, however, some debate about whether this is indeed inattentional “blindness”, or whether it could be inattentional “amnesia” instead. An absence of the CI report in CT1 may indicate a “blindness”: The CI is not seen or is only processed up to a certain level (Humphreys, 2000; Mack, 2001; Mack & Rock, 1998; Noë & O’Regan, 2000; Rees, Russell, Firth & Driver, 1999), or it may be an “amnesia”: The CI is seen but subsequently forgotten (Moore & Egeth, 1997; Wolfe, 2000). Although whether it is blindness or amnesia is not an issue that needs to be resolved here, we should

also avoid the insensitivity of subjective reports and the possibility of a memory failure in the IB task. To avoid an overestimation of IB, and thus an underestimation of attentional capture in this study, we encoded a *correct* response if any *identity* or *location* of the CI could be reported. It has been shown that when the location of the CI is accepted as a correct response, the IB effect is seldom obtained (Newby & Rock, 1998, 2001; Rock et al., 1992). Furthermore, our conclusions are based on a comparison of performance across otherwise similar conditions, and a lack of CI reports due to a memory failure should therefore be expected to be similar across the conditions (Most, Simons, Scholl, & Chabris, 2000; Most et al., 2001; Rensink, 2000). Thus, variation in the CI reporting rate across conditions in this study cannot be attributed to memory problems.

Simons (2000) and Most et al. (2005) suggest that the IB task provides an explicit measure of attentional capture, which is different from the implicit measure provided by reaction times (e.g., in visual search tasks; cf. Yantis & Jonides, 1984). In particular, attentional capture effect in the IB task can be noticed, whereas in search it may go unnoticed. They further suggest that the explicit capture effect can be dominated by a top-down process because the participants detect the CI more frequently if the CI matches the current attentional control setting. One may therefore consider that using an IB task in this study would overestimate the top-down effect and could not reveal a stimulus-driven capture effect by new objects. Two counterarguments can be provided to this point. First, an IB task can indeed reveal the bottom-up aspect of attentional capture, such as stimulus salience (Mack & Rock, 1998; Most et al., 2001, 2005; Rock et al., 1992). Second, in an IB task, a sudden onset in a static display can always be detected (Mack et al., 1992; Rock et al., 1992), similar to the findings in the visual search tasks that an onset target in a static visual search task can always capture attention (Yantis & Jonides, 1984). Although it has been shown that an onset cannot capture attention in a dynamic display of a sustained IB task (Most et al., 2005), this is also true in a visual search task because a new object does not capture attention if it is presented in conjunction with a large moving event on the screen (Franconeri, Hollingworth, & Simons, 2005). Thus, if a new object captures attention in a stimulus-driven manner, it should be able to capture attention in the IB task as well.

Four experiments were carried out to test the capture effect by new objects. The CI was designed to be a new object, which would be presented either as an onset or as an onset-then-offset stimulus. Ideally, the mere presentation of a new object should be sufficient to test the capture effect by new objects. However, because there would be no removal of stimuli on the screen in some of our experiments, the new object CI in this case would then stay on the screen during the participants' response. This may introduce another confounding factor to which the participants may respond

according to their impression of the increment of the total number of lines, which is not distinguishable from attentional capture by the new object CI. Therefore, in addition to merely being defined by an onset, we also presented the CI in onset-then-offset synchrony with the target. These two types of presentation were investigated with (Experiment 1) and without (Experiment 2) the trial-wide attentional control setting for new objects. In Experiments 3 and 4, we dealt with possible confounding factors associated with the onset-then-offset presentation of the CI. In summary, the results support our conjecture that a new object captures attention only when it matches the top-down settings of participants.

GENERAL METHOD

Participants

A total of 248 naïve undergraduates of the National Taiwan University participated in this study in return for a course credit. The participants had never heard of or performed similar experiments before. There were 25, 25, 18, 24, 27, and 21 participants in Experiments 1A, 1B, 2A, 2B, 3, and 4, respectively. Three additional groups of participants were recruited to provide guessing controls for Experiment 1 ($N=30$), Experiments 2 and 3 ($N=30$), and Experiment 4 ($N=26$).

Equipment and stimuli

The stimuli were presented on a 20-inch EIZO monitor at a viewing distance of 45 cm, controlled by a Visual Stimulus Generator graphic card (VSG 2/3, Cambridge Research System). Each trial consisted of a target display sandwiched between two fixation displays (see Figure 1). In each display, eight disks ($0.74^\circ \times 0.63^\circ$ in visual angle) were located on an imaginary circle with a diameter of 13° . These disks were white in the fixation display, one of them was green in the target display, and an additional one was pink (in Experiment 4). A white fixation cross at the centre and several randomly distributed white lines surrounding the fixation cross were presented inside the imaginary circle. Each line was 0.04° in length, and 0.003° in width. The CI was an additional horizontal white line, and its position was randomly selected within the imaginary circle across trials, but, in other respects, it was the same as the other lines that were already present on the screen. All stimuli, including the white lines, the white disks, the green disk, and the additional pink disk used in Experiment 4, had the same luminance level (13.8 cd/m^2) as measured with a photometer, and hence were equal-luminance to the average observer. The luminance of the black background was 0.2 cd/m^2 .

Figure 1. Examples of procedures used in the critical trials in Experiments 1A, 2A, and 4. The target was a green disk (shown in grey in the figure). A critical item (CI, indicated by the arrow) was shown in the target display. (A) In Experiment 1A, a blank display was shown for 500 ms, followed by a fixation display for 1000 ms, and then a beep for 250 ms. Subsequently, the target display appeared, and the fixation display was shown in the intertrial interval (ITI). The CI was presented without removal. (B) In Experiment 2A, the fixation display was shown with a beep for 250 ms. After that the procedure was the same as in Experiment 1A. (C) In Experiment 4, the CI was presented and removed, and an additional disk changed its colour to pink (denoted by the hatched pattern). Note that stimuli shown here are not to scale.

Design

There were eight trials in total in each experiment. In all experiments, the target was a disk that changed its colour from white to green, and the task was to point out its location. The participants performed the localization task for five trials, and then a CI was presented in the sixth trial. In the sixth trial, after localization of the colour-changed disk, the participants were asked about any spontaneous detection of the CI, and the response was recorded in CT1. Followed by the same procedure in the sixth trial, the report of the CI in the seventh trial was recorded in CT2. Finally, in the eighth trial, CT3, the same display was shown, and the participants were asked to search for the CI, rather than localize the target. In total, each participant performed seven localization trials (Trials 1–7), and responded to three critical trials of the CI (Trials 6–8 as CT1 to CT3).

To test the trial-wide attentional control setting for new objects, our IB task was designed to match the three requirements mentioned in the introduction. First, the task can be performed with and without presenting new objects in each trial. Our task was to localize a green disk, which can be performed with a blank display at the beginning of each trial (Experiment 1, Figure 1A) or without a blank display (Experiments 2, 3, and 4, Figure 1B and 1C). Second, the target is not considered a new object because it changed only in the colour dimension with a very restricted luminance variation (Cole et al., 2005; Jonides & Yantis, 1988; Rauschenberger, 2003). Hence, new objects are not relevant to the task. Finally, the CI is a new object because it is a white line presented abruptly from the background with a large luminance change (from 0.2 cd/m^2 to 13.8 cd/m^2), which matches the conditions previously found necessary to form a new object (Rauschenberger, 2003).

The CI reporting rate is taken as an index of attentional capture by new objects. If the CI reporting rate is not higher than that obtained from the guessing rate in CT1, and yet is higher than the guessing rate in both CT2 and CT3, no attentional capture by the CI is obtained. If, on the other hand, the CI reporting rate is higher than the guessing rate in all critical trials, the CI is considered to capture attention. The guessing rate was estimated in a control experiment in which no CI was presented in CT1, but participants were nevertheless asked to respond. An identical guessing rate was used for the experiments with the same display and procedure.

Procedure

Each trial was initiated by the experimenter. The instructions in the first five trials (not the critical trials) were as follows: “After I press a key, one of the

eight disks will change its colour to green. This is the target. Please indicate its location. Because the target location varies from trial to trial, please fixate at the central cross and pay attention to the whole field." After recording the response, the experimenter reminded the participants to return fixation to the cross, and the next trial began.

A CI was presented in the critical trial. In the sixth trial, after the participants had already pointed out the target location, they were asked to report any other changes on the screen. The instruction was, "Please tell me if, in this trial, there was any change other than the disk changing its colour." If they reported a change, the experimenter recorded their response, and asked if they could point out the location. If they did not report any changes, a confirmation was requested: "That is to say, in this trial, nothing changed on the screen except the colour of the disk, right?" To avoid underestimation of the CI reporting rate, any response other than a confirmation would replace the first report. The procedure during the seventh trial was the same as that in the sixth trial. In the last trial, the participants were required to search for changes in the background, while ignoring the colour change of the disk.

In the guessing control task, the responses were still double-checked if the participants failed to give a report about the CI in the critical trials, despite the fact that there really was no CI at all. This was done to keep the guessing control and the experimental trials as similar as possible.

Recording. Four types of responses for the CI are shown in Table 1: identity, location, none, and correct. A response of "identity" was coded if the participant reported a line, and a response of "location" was coded if they pointed to the quadrant where the CI had appeared. The experimenter then pointed to the location on the screen, following the directions of the participant, to confirm the reported location. Note that a report could be coded in both types if it matched both criteria. The "none" response was recorded in the trials in which the participants could not successfully detect a nontarget change, or if they reported both its identity and location incorrectly. Finally, the percentages of "correct" detection of a CI were given by the remaining response of "none", that is, including either correct localization or identification. All comparisons across conditions shown later were based on the data in the "correct" column.

Guessing control. To evaluate at which level the CI reporting rate exceeds the guessing rate, and thus should be considered significant statistically, several control experiments were carried out for each of the different experimental procedures. Since no CI was presented in CT1 in the control conditions, the guessing response was recorded upon the report of a specific feature or location. In the guessing control task for Experiment 1,

TABLE 1
Reporting rate (%) in the critical trials

<i>Trials</i>	<i>Identity</i>	<i>Location</i>	<i>None</i>	<i>Correct</i>
<i>With blank in the beginning of each trial</i>				
Experiment 1A				
Target localization, CI onset				
CT1	44	24	56	44*
CT2	72	60	20	80*
CT3	100	84	0	100*
Experiment 1B				
Target localization, CI onset and offset				
CT1	40	40	60	40*
CT2	64	72	28	72*
CT3	100	100	0	100*
<i>Without blank in the beginning of each trial</i>				
Experiment 2A				
Target localization, CI onset				
CT1	4	25	75	25
CT2	46	79	21	79*
CT3	83	96	4	96*
Experiment 2B				
Target localization, CI onset and offset				
CT1	50	50	39	61*
CT2	50	83	17	83*
CT3	89	100	0	100*
Experiment 3				
Target localization, CI offset				
CT1	7	22	78	22
CT2	52	70	30	70*
CT3	70	89	11	89*
Experiment 4				
Target discrimination, CI onset and offset				
CT1	14	24	71	29
CT2	28	57	43	57*
CT3	71	100	0	100*

Note: * reporting rate is higher than its guess rates; CI: the critical item.

three out of thirty participants gave such reports in CT1, so the estimated guessing rate was 3/30 (10%). In the guessing control for Experiments 2 and 3, again three participants responded, making the guessing rate 3/30 (10%). In the control for Experiment 4, three participants responded and the guessing rate was 3/26 (12%).

EXPERIMENT 1

In Experiment 1, we first designed the IB task in a way that would induce a trial-wide attentional control setting for new objects. To induce such a trial-wide setting, each trial began with a blank display. In this case, the stimuli of the previous trial needed to be removed from the screen, and then be redisplayed in the following trial. That is, on each trial all the stimuli were shown in previously empty locations, making them new objects. Since trials began with plenty of new objects, a trial-wide attentional control setting for new objects could be developed.

Note that the target item (the colour-changed disk) remained an old object in Experiment 1, rather than being a new one. Similar to the procedure used in the visual search tasks (Yantis & Jonides, 1984), the display of several new objects was presented before the target was shown (Figure 1A). The duration for this display was 1250 ms, designed to stabilize the new objects, since it has been shown that after such a long duration new objects are not perceptually new anymore (Yantis & Gibson, 1994; Yantis & Jonides, 1984). Since the target was not a new object, the participants should not have tried to search for a new object. Nevertheless, a trial-wide setting for new objects was developed because each trial began with new objects and the participants needed to pay attention to the stimuli from the beginning of each trial.

With the encouragement of the trial-wide setting for new objects, a CI should be detectable if it is a new object. With an abrupt presentation and a large luminance change, the CI (a new line) in this experiment was a new object and was expected to capture attention. Two types of CI, the onset-only CI (Experiment 1A) and the onset-then-offset CI (Experiment 1B) as described in the introduction, were used in this experiment. In Experiment 1A, the CI was a line abruptly presented when the target disk changed colour; after that, this line stayed on the screen without being removed. The CI in CT1 was presented on the screen again from the beginning of the trial in CT2 and CT3, and the CI in CT2 was also presented in CT3. As a result, there were nine lines in the background at the end of Experiment 1A, consisting of the six lines shown from the beginning of the experiment and the three lines subsequently presented in the three critical trials. In Experiment 1B, the CI was first onset and then offset, in synchrony with the colour change of the target in the critical trials. With the removal of the CI, the participants would not be exposed to the additional line during the response period. This could prevent the participants from reporting an additional line due to the impression given by the increasing number of lines in the background, rather than attention being captured by the additional line.

Method

The procedure of the critical trial in Experiment 1A is shown in Figure 1A. A blank display was first shown for 500 ms, followed by a fixation display for 1000 ms. After that an 800 Hz tone was presented for 250 ms with the fixation display, followed by the target for 200 ms, and then the fixation display was shown again and remained on the screen during the intertrial interval (ITI). Other details were as described in the General Method section.

Results

Few errors were made in the localization tasks, presumably because the localization of a changed-colour disk was a simple task. In Experiment 1A, only one participant mislocalized the target in one trial. That is, in a total of 175 reports (7 localization trials $\times$ 25 participants) the error rate was 0.6%. In Experiment 1B, there were six error localizations of the target, making the error rate 3.4%.

The CI reporting rates (Table 1) confirmed our prediction that the participants detected the new object CI well above chance in both experiments. Compared with the guessing rate (10%), in Experiment 1A the CI reporting rates were significantly higher in CT1, $\chi^2_{(1)} = 8.31$, $p < .01$, CT2, $\chi^2_{(1)} = 27.46$, $p < .001$, and CT3, $\chi^2_{(1)} = 44.19$, $p < .001$; and in Experiment 1B they were also significantly higher in CT1, $\chi^2_{(1)} = 6.80$, $p < .01$, CT2, $\chi^2_{(1)} = 22.21$, $p < .001$, and CT3, $\chi^2_{(1)} = 44.19$, $p < .001$. Since the CI could be detected in all three critical trials, the CI captured attention in both experiments.

Discussion

In this experiment, we found that a new object CI, presented as either onset-only (Experiment 1A) or onset-then-offset (Experiment 1B), could capture attention in the condition with a blank at the beginning of each trial. A top-down factor, such as the imposition of a trial-wide setting for new objects, could explain these results. Before reaching this conclusion, however, we need to see whether this effect disappears when no such trial-wide setting for new objects is possible. We tested this in Experiment 2. If our hypothesis of the trial-wide setting is correct, no attentional capture should be observed when the trial-wide setting for new objects is prevented.

EXPERIMENT 2

The same design as in Experiment 1 was applied, except that there was no blank between trials. All the stimuli (except the CI in Experiment 2B) remained on the screen throughout the experiment. In this case, before the CI was shown, the participants should not have seen any new object on the screen, and therefore the trial-wide attentional control setting for new objects should not develop. As in Experiment 1, the CI was onset only (without any offset as they remained on the screen) in Experiment 2A, and it was onset and then offset in Experiment 2B.

Method

The procedure of the critical trials in Experiment 2A is shown in Figure 1B. Each trial began with an 800 Hz beep with the fixation display for 250 ms, followed by the target display for 200 ms. Then the fixation display was shown again, until the next trial. Because the fixation display remained on the screen, no stimulus appeared or disappeared during the experiment before the critical trials. The CI was presented without removal. The procedure of Experiment 2B was the same as that in Experiment 2A, except that the CI was removed after its presentation in the critical trials.

Results

In these two experiments, the localization of the target was perfect; that is, no error was found. The CI reporting rates in Experiment 2A were significantly higher than the guessing rate (10%) in CT2, $\chi^2_{(1)} = 26.42$, $p < .001$, and CT3, $\chi^2_{(1)} = 39.37$, $p < .001$, but not in CT1, $\chi^2_{(1)} = 2.16$, $p = .14$. Thus, IB was obtained in this condition. In Experiment 2B, however, they were significantly higher than the guessing rate in CT1, $\chi^2_{(1)} = 14.23$, $p < .001$, CT2, $\chi^2_{(1)} = 25.81$, $p < .001$, and CT3, $\chi^2_{(1)} = 36.72$, $p < .001$. Thus, the CI captured attention in Experiment 2B but not in Experiment 2A.

Discussion

Since IB was obtained in Experiment 2A, and the CI was a new object, it seems that a new object is not able to capture attention. The design in this experiment was the same as that in Experiment 1A, except that the blank display inserted before each trial in Experiment 1A was removed in this

experiment. That is, a trial-wide attentional control setting for new objects could be developed in Experiment 1A, but not in Experiment 2A. Thus, the result of the lack of attentional capture in Experiment 2A can be explained by the lack of a trial-wide attentional control setting for new objects. In other words, new objects do not capture attention in a purely stimulus-driven manner; rather, the ability of capturing attention by new objects is determined by the existence of the trial-wide setting for new objects.

However, this cannot explain why a new object CI can still capture attention in Experiment 2B, even though there was no trial-wide setting for new objects either. One possibility is that the offset of the CI is crucial in attentional capture. This can be inferred from our Experiments 1 and 2, which showed that the CI with an offset could always capture attention, regardless of whether it was presented in a condition with or without a trial-wide setting for new objects. Therefore, it may be that an offset rather than a new object captures attention. If this is the case, an offset alone should be able to capture attention. We tested this possibility in Experiment 3.

EXPERIMENT 3

In this experiment, the same design as in Experiment 2 was applied, and an offset-only CI was used to test whether the lack of capture effect in Experiment 2A was due to lack of offset of the CI. At the beginning of the experiment, there were nine lines in the background, rather than six lines. These lines remained on the screen, and, in the critical trials, one of these lines was removed as the CI. Other details were the same as in Experiment 2. If the CI captured attention in Experiment 2B but not in Experiment 2A because it had an offset in Experiment 2B, then the offset CI should be able to capture attention, and no IB should be obtained. On the other hand, if an offset is not critical in determining the capture effect in Experiment 2B, the offset CI should not capture attention in this experiment.

Results

In the localization task, one participant mislocalized the target in the first trial, but apart from this error, performance was perfect. The CI reporting rates were significantly higher than the guessing rate (10%) in CT2, $\chi^2_{(1)} = 21.85$, $p < .001$, and CT3, $\chi^2_{(1)} = 35.47$, $p < .001$, but not in CT1, $\chi^2_{(1)} = 1.60$, $p = .21$. Thus, the IB was obtained, showing that an offset *per se* cannot capture attention.

Discussion

We found that an offset-CI could not capture attention in the IB task. That is, the capture effect by the CI in Experiment 2B should not be due to the offset of the CI. One may argue that an offset-only sequence is less effective than an onset-then-offset sequence, but this does not lead to the conclusion that an offset cannot contribute to the capture effect. It is possible that an offset contributes to the capture effect only when it follows an onset. In other words, an onset-then-offset sequence matters. Note that the target disk changes its colour from white to green and then from green back to white, and one may search for a change-stay-change event, rather than the colour green, in the localization task. In this case, an onset-then-offset CI is synchronous with this sort of transient change. Thus, it is possible that in Experiment 2B the presentation of CI is consistent with this setting, leading to the attentional capture by the CI. Nevertheless, an onset-only CI does not match this setting, so it did not capture attention in Experiment 2A. We tested this possibility in Experiment 4.

EXPERIMENT 4

In this experiment, we modified the task so that the target was no longer defined by a change-stay-change transient event; rather, colour discrimination is required to localize the target. In the target display, there were two transient events: one from white to green then back to white, the other from white to pink then back to white. The task remained the same, that is, to localize the green disk. Since both transient events were in a sequence of change-stay-change, the participants needed to distinguish colours between them, rather than just paying attention to the transient events. In this case, an onset-then-offset CI would not be associated with the task at hand. If the CI captured attention in Experiment 2B because it matched the pace of change-stay-change target presentation, then it should not be able to capture attention once this pace was not predictive of targets from nontargets (as in this experiment).

Method

In the beginning of the experiment, a green patch was presented on the screen to demonstrate the target colour to the participants. In each trial, as shown in Figure 1C, two disks changed colour in the target display. Otherwise, the procedure was the same as in Experiment 2B.

Results

In this experiment, the error rate in the localization task was 5.4%. That is, of the total of 147 reports (7 localizations $\times$ 21 participants), eight were incorrect. These errors were all made in the first and second trials, and none of them were in the critical trials. The CI reporting rate was significantly higher than the guessing rate (12%) in CT2, $\chi^2_{(1)} = 11.12$, $p < .001$, and CT3, $\chi^2_{(1)} = 36.35$, $p < .001$, but not in CT1, $\chi^2_{(1)} = 2.18$, $p = .14$. Thus, IB was obtained. We conclude that the onset-then-offset CI cannot capture attention in the IB task when the target cannot be located by searching for a change-stay-change event.

Discussion

We showed in this experiment that when the onset-then-offset presentation of the CI does not match the setting of the task, the CI (though still a new object) can no longer capture attention. The design of Experiments 2B and 4 were the same, except that the target could be localized by transient events in Experiment 2B, while it could only be localized by recognizing its colour in this experiment. The change of the task can eliminate the capture effect by the new object CI, showing that the capture effect by the CI is not determined by stimulus-driven factors. Note that in both cases the trial-wide attentional control setting for new objects were avoided. In summary, our data suggest that a new object is not able to capture attention when it does not match any one of the current top-down settings, including the trial-wide setting and a task-relevant setting.

GENERAL DISCUSSION

In this study, we used the IB task to examine the contribution of attentional control settings to the attentional capture effect by new objects. In particular, we proposed that a trial-wide attentional control setting for new objects might be developed in a task in which new objects are presented to signal the beginning of a trial. Therefore, the capture effect by new objects in that task may be due to the fact that new objects match this trial-wide setting, rather than capture attention in a stimulus-driven fashion. The trial-wide setting was introduced in Experiment 1A and avoided in Experiment 2A; our results showed that an onset CI (a new object) captured attention in Experiment 1A but not in Experiment 2A. Thus, the trial-wide setting for new objects indeed plays a role in affecting the capture effect by new objects.

With the same design in Experiments 1B and 2B but using an onset-then-offset CI (a new object), however, the CI could still capture attention without

the trial-wide setting (Experiment 2B). We showed that the reason that this onset-then-offset CI could capture attention was not because it had an offset (Experiment 3); rather, it was because the CI was presented and removed synchronously with the target. When the participants could not locate the target by searching for a change-stay-change event, this onset-then-offset CI did not capture attention (Experiment 4). In other words, there was a “searching for a change-stay-change stimulus” attentional control setting being developed in Experiment 2B, so that the onset-then-offset CI could capture attention without the contribution of the trial-wide attentional control setting for new objects. Altogether, our data suggest that new objects cannot capture attention without the contingency of top-down settings in an IB task.

The relative strength of the settings

In this study, we showed that the trial-wide attentional control setting for new objects can affect the capture effect of the CI in the IB task. Note that this setting is actually not directly related to the target since the target was always an old object in our IB tasks. However, new objects signal the upcoming display in each trial, thus the setting of paying attention to new objects can be developed. The effect of the trial-wide attentional control setting for new objects is revealed by the results that the CI reporting rate in CT1 is not higher than the guessing rate without this setting (Experiment 2A), while it is higher than the guessing rate with this setting (Experiment 1A).

Apart from the trial-wide setting for new objects, some other attentional control settings may also be developed in the IB task. More specifically, the participants may have developed some settings directly associated with the target since they were requested to localize this item. For example, in Experiment 2, the participants may have searched for a change-stay-change event, while in Experiment 4 this setting was avoided. Since this kind of setting can help target localization, it can directly affect the capture effect of the CI. Therefore, an onset-then-offset CI, which matches the change-stay-change setting, has a higher than guessing reporting rate in Experiment 2B but not in Experiment 4.

Therefore, we suspect that at least two types of attentional control settings affected the CI reporting rates in our IB task: one was the setting for change-stay-change events in Experiment 2, and the other was a trial-wide setting for new objects in Experiment 1. The relative contributions of these settings to attentional capture were considered to be adjusted according to their relevance to the task. The more relevant setting (the one that can help to locate the target) should affect the attentional priority more than a remotely

related setting. Thus, the stimuli that are contingent on the former setting may capture attention more easily than the stimuli that match the latter one. In our study, the change-stay-change setting is more relevant, and the trial-wide setting for new objects is remotely related to the localization task. Accordingly, a CI that matches the former setting should be able to capture attention more easily than one that matches the latter one. This is consistent with what we have observed. In fact, with the contribution of the change-stay-change setting, the CI reporting rate increases from 29% (Experiment 4) to 61% (Experiment 2B), while with the trial-wide setting, it increases from 25% (Experiment 2A) to 44% (Experiment 1A). The increment of the CI reporting rate in the former condition is larger than that in the latter condition, showing the former setting has a stronger influence than the latter.

Expectation versus attention

One might argue that IB is due to a lack of expectations about the target (Braun, 2001), but not due to a lack of attention (Mack, 2001). For example, Braun argues against the attentional view because, as demonstrated in his earlier works, some salient stimuli could be processed at a pre-attentive stage, while this kind of stimuli was subject to the IB. Mack, on the other hand, although not denying the possibility of expectation involved in the IB task, argues that the IB phenomenon cannot be completely explained by expectation. Mack argues, for example, that at least the finding that there is more IB for the CI at fixation than at periphery (Mack & Rock, 1998) cannot be explained by expectation. Moreover, the IB phenomenon is very similar to both neglect (Humphreys, 2000) and to change blindness (Noë & O'Regan, 2000), which are usually considered to be attentional problems, rather than expectation problems. Moore and her colleagues actually suggest that IB can be used as an operational definition of inattention (Moore, Grosjean, & Lleras, 2003; Moore, Lleras, Grosjean, & Marrara, 2004). Altogether, we tend to think that IB cannot be explained merely by a lack of expectation, and attention should play a role in this phenomenon.

Even if IB were caused by the lack of an expectation in our study, our conclusion of a top-down dependence of the capture effect by new objects should still hold. One consequence of the lack of an expectation is the surprise effect (see Horstmann, 2002). That is, an unexpected item may elicit surprise, and attention would then be directed to it to promote further processing of the unexpected item. In this case, our CI can be considered as such an unexpected item, and our results show that a new object does not necessarily lead to surprise. Only when a new object matches the attentional control setting can it elicit surprise and receive attention.

Task differences in the attentional capture effect

Our finding of the top-down dependence of the capture effect by new objects in the IB task does not agree with the conclusions drawn from the visual search tasks that a new object could receive attentional priority in a stimulus-driven fashion (Hillstrom & Yantis, 1994; Jonides & Yantis, 1988; Yantis & Egeth, 1999). In particular, the IB task used in this study requires localization of the target, which is easier than the identification task that is often required in visual search. Thus, a stronger capture effect by irrelevant distractors should be expected in the IB task given a lower perceptual load (Lavie & Tsai, 1994); nevertheless, this is not what we discovered. In the IB task, we found that a new object CI could not capture attention in two of our five conditions (including Experiments 1A, 1B, 2A, 2B, and 4, see Table 1). In contrast, new objects usually capture attention in the visual search tasks. Thus, there must be some other differences between these two tasks so that a new object can always capture attention in visual search, while it cannot capture attention without a setting in the IB task.

Our IB task and the visual search task are different in several aspects. For example, a small new object (0.04° in visual angle) was used in our IB task, while it was about 1° in the visual search task used by Yantis and Jonides (1984). Since the new object is larger in the visual search task, it is possible that the lack of the capture effect in our IB task is due to the small size we used for the CI (Mack & Rock, 1998). Nevertheless, CI of the same size can capture attention in one condition (e.g., Experiment 1A) but not in another (e.g., Experiment 2A), and this cannot be explained solely by the factor of stimulus size. Among the several differences between our IB task and the visual search task used by Yantis and colleagues, we suggest that the most critical difference lies in the strength of the attentional control setting for new objects. More specifically, we suspect that new objects are more relevant to the task in visual search than to the task in IB. For instance, the onset item (a new object) could be a target in some of the trials in visual search, whereas it is entirely irrelevant to the task in CT1 in our IB task. Moreover, in visual search each trial was accompanied by onsets and offsets, that is, the participants must have perceived and have expected to perceive new objects in each trial, and a trial-wide attentional control setting for new objects may have existed. In our IB task (e.g., Experiment 2A) this trial-wide setting for new objects could be avoided so the CI was the first new object the participant perceived. These factors may enhance a top-down setting for new objects in visual search, but not in our IB task, leading to attentional capture by new objects in the former, but not in the latter. As a result, a stronger capture effect for a new object in visual search (Enns et al., 2001; Gellatly et al., 1999; Yantis & Hillstrom, 1994) and in the other tasks (Cole et al., 2003, 2004; Donk & Theeuwes, 2003) may partially be due to the fact that a new

object matches the trial-wide setting for new objects while other features do not. If such a setting can be avoided, then a new object may not have any special role compared to the other features.

The influence of a trial-wide attentional control setting for new objects can not only be observed in this study, but can also be inferred from the comparisons between the IB task used in this study and in other studies. For example, the IB task in this study was modified to include location report, in order to increase the sensitivity of the subjective report data. The idea that this would increase sensitivity was based on the results of previous studies (Newby & Rock, 1998, 2001) in which no IB was found with the location report. In our experiments, more location responses (rather than identity responses) were also obtained for CT2 or CT3 (e.g., Table 1); however, this is not the case for CT1. With this more sensitive measure, IB was still observed in our Experiments 2, 3, and 4. One of the crucial differences is that in those previous studies, unlike in ours, new objects were presented on each trial, and a trial-wide attentional control setting for new objects was not avoided. The correct reports of the CI in previous studies can thus partially be attributed to the expectation that new objects were about to appear.

Although our experiment was designed by using an explicit task as to attentional capture (i.e., the IB task) rather than an implicit task (e.g., the visual search task in which reaction time is measured and attentional capture is inferred from it), we believe our findings of the contribution of the trial-wide setting to attentional capture by new objects can be applied in an implicit task as well. Actually, by the nature of the implicit tasks, the trial-wide setting for new objects must have been involved. This is because stimuli are repeatedly presented in each trial to cumulate the response in the same condition in the implicit tasks; thus, onset and offset must accompany the trials and/or the target, leading to a trial-wide setting for new objects. With this trial-wide setting, a new object will receive higher attentional priority than the other stimuli. In other words, by adopting the implicit task, the chance that the new objects are capable of capturing attention is high, as long as the trial-wide setting is not actively avoided.

Franconeri, Simons, and Junge (2004) tried to avoid the involvement of transient events in each trial to explore the capture effect by abrupt onsets in the visual search task. They found that after the removal of visual transients on each trial an onset could still capture attention. Although they tried to avoid the occurrence of transient events trial-by-trial, they did not successfully avoid presenting new objects on each trial. In their Experiment 1, the search set did not change across trials, which is similar to the design in our Experiment 2. The task was to discriminate whether the target was presented in the search set, while the target letter was given in each trial by an auditory cue. Since visual and auditory stimuli may share attention resource and can be integrated into the same event (Shimojo & Shams,

2001), this trial-by-trial auditory cue may induce a setting for new objects. In their Experiment 2, the participants were requested to saccade to a fixation away from the screen during the ITI, and a new search set was presented on the screen during saccade. They assumed that the participants would not perceive changes because of saccadic suppression. Nevertheless, the participants must have perceived new objects, since their fixation changed. Moreover, in both experiments, four onset dots were presented around a letter in every trial before the target was presented, which could also induce a setting for new objects. Altogether, the implicit task relies on repeated measures of the capture effect, which by its nature cannot avoid the repeated exposure of new objects. Thus, we suspect that the trial-wide setting for new objects may contribute to the capture effect by onsets in the implicit tasks, making a new object appear special in attentional capture.

CONCLUSION

We tested the effects of trial-wide attentional control settings on attentional capture by new objects. In the absence of a control setting for a new object, there was no evidence for attentional capture. Previous studies showing attentional capture by new objects in visual search tasks might have inflated any capture effect by encouraging a setting for new objects across trials. The results indicate the need to reconsider the issue of whether a new object can truly capture attention in a stimulus-driven manner.

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