中　華　心　理　學　刊
民96，49卷，2期，145-158

Chinese Journal of Psychology
2007, Vol. 49, No. 2, 145-158

# Involuntary Orienting Caused by Salient Stimuli Outside Focal Attention: Comparison of Two Paradigms

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MS No.: 06031; Received: July 28, 2006; 1st revision: April 13, 2007; 2nd revision: May 22, 2007; Accepted: May 23, 2007
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A peripheral red distractor hampers central target identification when the target is defined by red (Folk, Leber, & Egeth, 2002). On the other hand, a peripheral onset distractor fails to affect task performance when the target location is pre-cued by a 100%-valid central cue (Theeuwes, 1991; Yantis & Jonides, 1990). Different paradigms were used in these two sets of studies (RSVP in the former and spatial cueing in the later studies) and this may affect the deployment of attention and the results differently. We asked the participants to search for a *red* target as in Folk et al. (2002) and compared attentional capture by *red* distractor (i.e., contingent on the target-defining feature) and *onset* distractor (i.e., not contingent on the target-defining feature), using the RSVP paradigm (Experiment 1) and the spatial cueing paradigm (Experiment 2 and 3). Results showed that, regardless of which paradigm is used, attentional capture occurs only by the red distractor but not by the onset distractor, suggesting that the different results obtained in previous studies were not caused by different paradigms used. Outside focal attention a salient stimulus that is contingent on the target-defining feature has the highest possibility to capture attention.

**Keywords:** ***rapid serial visual presentation, spatial cueing paradigm, color, onset***

## Introduction

The visual world is full of stimuli, and not all of them can be processed simultaneously. Under most circumstances, our attention is directed to the location or the object which is important for the current behavioral goal. Occasionally, however, one's attention can be captured by task-irrelevant stimuli. Past studies have demonstrated two kinds of attentional capture phenomena by task-irrelevant distractors: one by the stimuli that share the same feature as the defining characteristic of the target (e.g., Atchley, Kramer, & Hillstrom, 2000; Bacon & Egeth, 1994; Folk & Remington, 1998; Folk & Remington, 1999; Folk, Remington, & Johnston, 1992; Folk, Remington, & Wright, 1994; Gibson &

This study is supported by NSC91-2413-H-002-013 and NSC94-2752-H-002-008-PAE.

Kelsey, 1998; Johnson, Hutchison, & Trammell, 2001), and the other by the stimuli *per se* without any contingency on top-down control settings (e.g., Gellatly, Cole, & Blurton, 1999; Jonides & Yantis, 1988; Theeuwes, 1991, 1992, 1994; Turatto & Galfano, 2000, 2001; Yantis, 1993; Yantis & Hillstrom, 1994; Yantis & Jonides, 1984, 1990). We call the first kind of phenomenon *contingent capture* and the second kind *stimulus-driven capture* for short.

Folk, Remington, and Johnston (1992) proposed *the contingent involuntary orienting hypothesis* and first demonstrated the effect of contingent capture. They presented two kinds of cues preceding the target: a red cue or an onset one. Participants identified the target letter when it was the only red letter among other white ones, or a single onset letter in a blank field. In the former case, the *target-defining feature* was "red" and in the latter case it was "onset". The cue was uninformative as to the target location, because it appeared randomly in one of the four possible target locations. In order to identify the target as quickly as possible, the best strategy for the participants was to ignore the cue. Their results showed that when the target was defined by red, response latency was shorter when a red cue appeared at the target location than when it appeared at a different location. When the target was defined by an onset, on the other hand, an onset cue led to such a location effect instead. That is, the uninformative cue that is task-irrelevant (we call it *distractor* hereafter) still captures attention when it shares the same feature as the defining characteristic of the target. An often mentioned daily-life example of contingent capture is the left-turn arrow in the cross road when drivers wait for the green "go" light. Although the goal is to go straight, drivers usually unavoidably respond to the left-turn light when it turns on. The left-turn light which should be ignored nevertheless captures attention because it shares the same feature (i.e., green) as the defining characteristic of the green "go" light.

Yantis and Jonides (1984), on the other hand, first demonstrated the effect of stimulus-driven capture. Participants in their study were required to search for a target letter among other letters. Different from the contingent capture as mentioned above, the target was not defined by any specific color or feature. The target letter can be either an onset or a non-onset which emerges from a placeholder, such as removing two segments in a figure-eight pattern to reveal the letter E, U, P, H, or S. They found that when the target happened to be an onset letter, the search slope was near to zero. Based on this, they suggested that the onset letter captures attention and is processed earlier than other non-onset letters.

Although stimulus-driven capture occurs, it does not fulfill the criteria of automaticity (Jonides, 1981; Jonides, Naveh-Benjamin, & Palmer, 1985), since it is modulated by top-down control settings. Yantis and Jonides (1990), for example, found in a spatial cueing paradigm that when a central symbolic cue with a 100% validity indicating the target location was presented 200 msec before the target, there was no difference in response latency, regardless of whether the target was an onset or not. There was always an onset letter in their target display, thus, if the target was a no-onset letter, then the onset stimulus became a distractor. However, this onset distractor did not slow down the response to the target when the target location was known beforehand for sure.

Theeuwes (1991) also provided converging evidence consistent with this observation, using a spatial cueing paradigm as well. In his experiment, a 100%-valid central cue pointing to the target location was presented either before or after the target, and a peripheral onset was presented randomly in one of the four possible target locations before, after, or simultaneously with the target. He found that under the condition that when the cue was presented *after* the target, response times were faster when the target happened to appear near the onset location (i.e., the onset captured attention). But no capture occurred when the cue was presented *before* the target. Assuming that attention is either distributed over the entire display when the cue is presented *after* the target, or pre-focused to the target location when the cue is presented *before* the target, this finding suggests that a peripheral onset captures attention only when attention is distributed. In other words, pre-focusing attention to the target location seems to prevent stimulus-driven capture. It is inferred that advance knowledge of the target location with 100% certainty leads to a strong top-down control, and thus prevents stimulus-driven capture.

However, contingent capture does not seem to follow this rule. Folk, Leber, and Egeth (2002) presented stimuli in the central rapid serial visual presentation (RSVP) stream and participants had to identify a *red* letter there. Participants were assumed to focus their attention on the central stream because this was where the target always appeared. Interestingly, results showed that the appearance of a peripheral *red* distractor still produced a decrement in the identification of the central target. It implies that contingent capture can still occur even when it is presented outside focal attention. In contrast to stimulus-driven capture, contingent capture seems to occur inevitably without being affected by top-down control, and therefore fulfill the criteria of automaticity.

However, different paradigms have been used to prove the presence of contingent capture and the absence of stimulus-driven capture outside focal attention. Thus, in this study we aim to examine whether this is due to difference in the paradigms used. A fair comparison should be made with the same paradigm and the conclusion drawn by it could thus be more affirmative. Comparing the studies described above, note that contingent capture is still observed when focal attention is maintained at fixation in an RSVP paradigm, whereas no stimulus-driven capture is observed when attention shifts to the target location in a spatial cueing paradigm. Two reasons may have contributed to the differences in results.

It is possible that contingent capture and stimulus-driven capture might involve different mechanisms that cause the different results. Alternatively, it might be due to the difference in paradigms used. For example, one's attention may not necessarily focus on the central stream in an RSVP in a very precise way, and this "leakage" of attention could perhaps lead to the contingent capture that was observed. In fact, Folk et al. (2002) also mentioned that "it is possible that the act of focusing spatial attention on an RSVP stream involves a different process than the act of focusing attention in response to a spatial precue (p.752)." In accordance with this statement, we contrast the two paradigms in the following way.

We examine whether stimulus-driven capture *can* also occur in an RSVP paradigm, and whether contingent capture *cannot* occur in a spatial cueing paradigm. If so, it is the difference in the paradigms used that has caused the difference in results, and not the difference in the two kinds of capture. Moreover, if peripheral onsets are able to capture attention in an RSVP paradigm, it can be argued that the RSVP stream is not sufficient to maintain the focus of attention at fixation. In this case, the conclusion that contingent capture occurs outside focal attention by Folk et al. (2002) is challenged.

By using a spatial cueing paradigm to examine whether contingent capture occurs with an act of shifting attention to the pre-cued target location, we are able to examine whether it indeed involves a different mechanism from stimulus-driven capture. If contingent capture can still occur in a spatial cueing paradigm, the answer is affirmative. If not, it indicates that the spatial cueing paradigm invokes a different kind of attentional focusing than RSVP does, and that contingent capture may not differ from stimulus-driven capture in terms of attentional capture outside focal attention.

Note that the contingent involuntary orienting hypothesis does not preclude the possibility of attentional capture by onset, but it occurs only when the target-defining feature is also an onset (e.g., when the participants looked for the only onset in the display, the onset distractor captured attention as well, see Folk et al., 1992). Thus, the difference between the contingent capture and the stimulus-driven capture should not be misplaced as the difference between the distractor types. That is, according to the contingent involuntary orienting hypothesis, a red distractor will not capture attention if the target-defining feature is not red, and an onset distractor will be able to capture attention if the target-defining feature is onset. What really matters is the “match” between target and distractor. We use red as the target-defining feature as in Folk et al. (2002) and compare the two paradigms (RSVP vs. spatial cueing) that separately demonstrated contingent capture occurred outside focal attention on the one hand and stimulus-driven capture did not on the other hand. For the sake of parsimony, we will use red distractor and onset distractor to stand for the condition of contingent capture and non-contingent capture, respectively, following the previous two sets of studies introduced above. However, bear in mind that the stimulus dimension should not be confused with the two kinds of attentional capture.

## Experiment 1

In this experiment, the same paradigm as in Folk et al. (2002) was used and a distractor type of an onset which did not share the same defining feature as the target was added (Figure 1). The purpose of this experiment is to test whether this peripheral non-contingent onset distractor captures attention, just like a color distractor, when the participant is asked to search for a red target and to identify it in an RSVP paradigm. We expect to replicate the capture effect by the color distractor as in Folk et al. (2002), and aim at using this as an anchor point to estimate the effect caused by the onset distractor. A no-distractor condition was used as a baseline control.

Folk et al. (2002) have used four gray boxes appearing on the four peripheral locations as distractors and found that they could not capture attention. Although this can be considered a failure to find stimulus-driven capture by onsets, we suspect that four abrupt onsets appearing simultaneously could signal four different locations. That might lead to a different attentional effect than when only one location is cued by an abrupt onset. Furthermore, four gray boxes are less salient than a single white box because of their low luminance contrast, in addition to their difference in number. The more salient the stimulus, the more likely it captures attention (e.g., Theeuwes, 1992). Thus, we used a single white box (the most likely stimulus to capture attention) to examine whether stimulus-driven capture can occur outside focal attention in RSVP paradigm.

### *Method*

#### *Participants*

Fifteen undergraduates of the National Taiwan University participated in this experiment. All of them had self-reported normal or corrected-to-normal visual acuity and color vision.

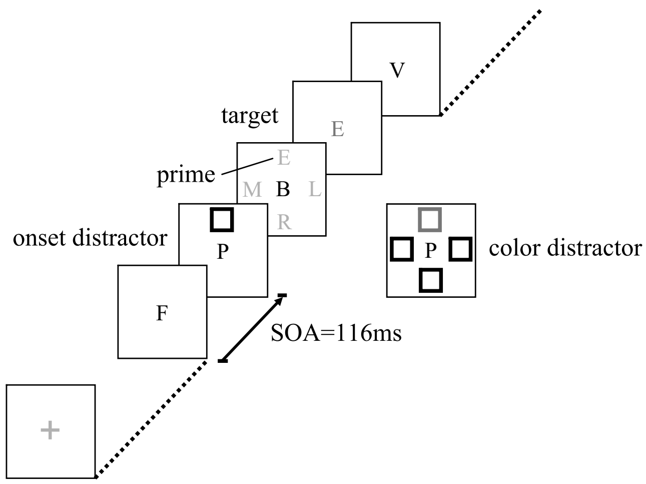


**Figure 1.** An example of the onset distractor in the congruent condition in Experiment 1 (not-to-scale). The color distractor is also illustrated on the right side. On the computer screen with a black background, black characters on the center stream shown here are green, gray, purple, or blue in the experiment, and the dark gray character stands for the red one. The fixation and the characters on the peripheral location are all gray (shown in light gray here).

*Apparatus, stimuli and design*

The stimuli were generated by an IBM compatible computer and shown on a View Sonic 14-inch color monitor. Each trial consisted of an RSVP sequence of 15 single letters presented on the center of the computer screen. Letters measured 1.3° in height and 1.2° in width. One letter in the sequence was red (RGB= (218, 37, 29)), and it was defined as the target letter. The remaining letters were non-target letters, and they were chosen randomly from a set of four possible colors, including green (RGB= (132, 195, 38)), gray (RGB= (170, 170, 170)), purple (RGB= (187, 144, 187)), and blue (RGB= (117, 197, 240)). These letters were presented on the screen against a dark background (RGB= (0, 0, 0)). Each trial began with a presentation of a gray fixation plus sign in the middle of the screen, measured 1.2° in height and 1.2° in width. The letters presented in each RSVP sequence were selected randomly without replacement from the English alphabet (I, O, W, & Z were excluded, following Folk et al., 2002). Across trials, the target appeared randomly at serial positions 8 through 12 of the letter sequence.

In the *no-distractor* condition, each of the 15 frames in a trial contained only the letters shown in the central stream. The remaining two conditions differed from the no-distractor condition in the way that two peripheral events occurred in each trial. In the *color-distractor* condition, the first event was appearance of four boxes (4.5° x 4.5°) at the four peripheral locations (5.2° above, below, on the right, and on the left of the central letter). One of the boxes was red and the remaining three were white. In the *onset-distractor* condition, there was only one white box appearing at one of the four possible peripheral locations. For both the *color-distractor* and *onset-distractor* condition, the singleton box appeared equally often across trials at each of the four locations. One intervening central letter was displayed between the distractor and the target, and hence the distractor-target lag was two.

The second peripheral event consisted of the appearance of four gray letters, one at each of the four peripheral locations. The letter at the location of the singleton box was *the prime*, and its identity might be *congruent* or *incongruent* with the target (with half trials each), and different from the other three letters, which were each chosen randomly without replacement from the remaining letters of the alphabet (excluding I, O, W, & Z). In the *congruent condition*, the identity of the prime was the same as the target. In the *incongruent condition*, the identity of the prime was different from the target, but the identity of one of the other three letters was the same as that of the target. Half trials in each congruency condition were used to counterbalance the interference from the identity of the prime, if existence.

The index of attentional capture by the peripheral distractor is the decrement in the accuracy of central target identification. If capture occurs, it indicates that attention shifts to the peripheral location and hampers target identification. Manipulation of the prime-target congruency is to examine whether such a capture effect is tied to location. If attention indeed shifts to the distractor location, the prime will be processed. Thus, the decrement in the accuracy of the central target identification will be worse when the prime is incongruent with the target than when it is congruent.

*Procedure*

The procedures in this and the next two experiments were controlled by the DMDX program (Forster & Forster, 2003). The refresh rate was 19.27 msec per frame. The fixation display was presented for 964 msec and subsequently followed by a sequential presentation of 15 letters. Each letter in the sequence was presented for 58 msec, followed by a 58-msec blank interval, yielding an SOA of 116 msec. The three different distractor conditions were mixed within blocks.

The experiment consisted of 30 practice trials followed by a total of 240 experimental trials, with a short break after the first block of 120 trials. The participants received written and oral instructions regarding the nature of the stimuli and the task. They were fully informed about the various distractor conditions and were explicitly encouraged to ignore the distractor. Each trial was initiated by a space bar press. After the trial sequence, the participants were required to identify the target by typing in their response on the computer keyboard, and to guess if unsure.

### *Results*

Results are shown in Figure 2. Data in the no-distractor condition were dummy coded into the two congruency conditions randomly. All accuracy data were subjected to an analysis of variance (ANOVA) with distractor type and prime-target congruency as within-subjects variables. The main effects of distractor type and the interaction between distractor type and prime-target congruency were significant [$F(2,28) = 4.34$, $MSE = 0.02$, $p < .03$, and $F(2,28) = 6.11$, $MSE = 0.01$, $p < .01$, respectively]. Accuracy was lower in the *incongruent* condition than in the *congruent* condition for the color distractor [$F(1,42) = 16.29$, $MSE = 0.04$, $p < .001$], but not for the onset distractor [$F(1,42) = 0.19$, $MSE = 0.00$, $p > .1$]. Difference in accuracy was found only in the *incongruent* condition [$F(2,56) = 9.46$, $MSE = 0.03$, $p < .001$], but not in the *congruent* condition [$F(2,56) = 0.33$, $MSE = 0.00$, $p > .1$]. A Tukey test ($\alpha = .05$) in the *incongruent* condition revealed that only the mean accuracy in the *color-distractor* condition differed significantly from that in the other two distractor conditions.

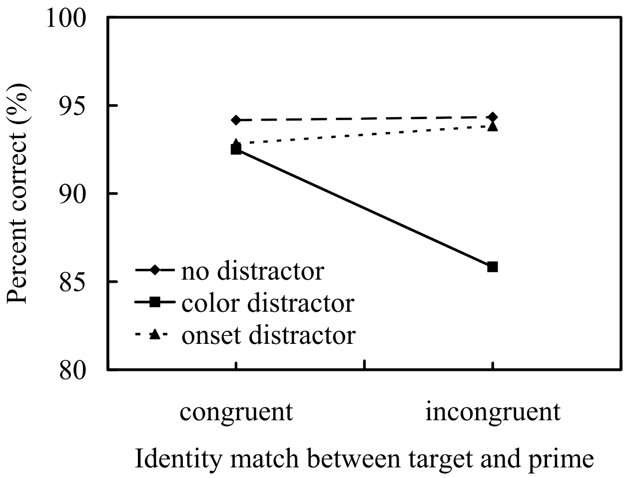


**Figure 2.** Mean percentage of correct target identification in Experiment 1.

### *Discussion*

The results of this experiment are consistent with those of Folk et al. (2002). When attention is set for the color red, an irrelevant peripheral red distractor captures attention to its position and the identity of the letter in that position is processed. This is revealed by the lower identification accuracy when the identity of the prime and the target are incongruent. However, this is not the case for an onset distractor; no difference in the identification accuracy is found regardless of whether the prime and target are congruent or not. These results suggest that under the condition we used in this study, an onset distractor, unlike a color one, cannot capture attention outside the RSVP stream.

Thus, an onset distractor which does not share the same defining feature as the target still fails to capture attention when the RSVP paradigm is used, just like it does when a spatial cueing paradigm is used (Theeuwes, 1991; Yantis & Jonides, 1990). To sum up, it seems clear that it is difficult for stimulus-driven capture to occur outside focal attention, regardless of whether an RSVP (as in this experiment) or a spatial cueing paradigm (as in previous studies) is used. However, before concluding that contingent capture can occur outside focal attention and stimulus-driven capture probably cannot, we need to test whether contingent capture can also occur when a spatial cuing paradigm is used, in which a shift of attention is required.

## Experiment 2

In this experiment, a modified spatial cueing paradigm was used to test whether a contingent color distractor can capture attention in this paradigm as well. Participants were required to identify a red letter. Before the target, a central arrow cue pointing to the target location was presented, and participants were informed to focus attention at the cued location. A red distractor appearing simultaneously with the target outside the cued location was used to test whether it captured attention or not.

## *Method*

### *Participants*

Another group of fifteen undergraduates of the National Taiwan University similar to the one in the previous experiment participated in this experiment.

### *Apparatus, stimuli, and design*

The stimuli were presented on an Eizo 16-inch color monitor, controlled by a Genuine Intel processor. The refresh rate was 11.71 msec per frame. The sequence of events during a trial is shown in Figure 3. In the beginning, a fixation display was shown, which consisted of a central fixation dot, 0.8° in diameter, and four outline boxes, which extended 4.8° x 4.8° each. The four boxes appeared 4.5° above, below, on the right, and left of the central fixation dot. Next, in the cue display, the central fixation dot changed to an arrow, which extended 1.0° in length and 0.8° in width. It pointed to one of the four peripheral locations to inform the target position. The target display contained four letters, each extended 1.6° x 1.6°. The target letter was always a U or an H. The letters on the other locations were selected from a set consisting of E, L, U, or H, depending on the condition.

The presence of a color distractor (yes, no) and the match of the identity between the distractor and the target (congruent, incongruent) were designed as two orthogonal factors. The target letter was always red (RGB= (218, 37, 29)). In the *with-distractor* condition, one of the non-target letters was also red, rendering the contingent distractor. The colors of the other two letters were randomly chosen without replacement from four different colors that included green (RGB= (0, 146, 64)), yellow (RGB= (248, 196, 0)), blue (RGB= (0, 124, 195)), and indigo (RGB= (41, 22, 111)). In the *without-distractor* condition, the three non-target letters were all randomly chosen without replacement from these four different colors. In the *congruent* condition, one of the non-target letters was identical to the target letter. In the with-distractor condition, this letter was always red. In the without-distractor condition, this letter was chosen randomly from the three non-target letters. In the *incongruent* condition, the response to this distracting letter was incompatible with the response to the target letter. For example, when the target was an H, the distracting letter was a U.

### *Procedure*

At the beginning of each trial, the fixation display was shown for 995 msec. Then the cue dis-

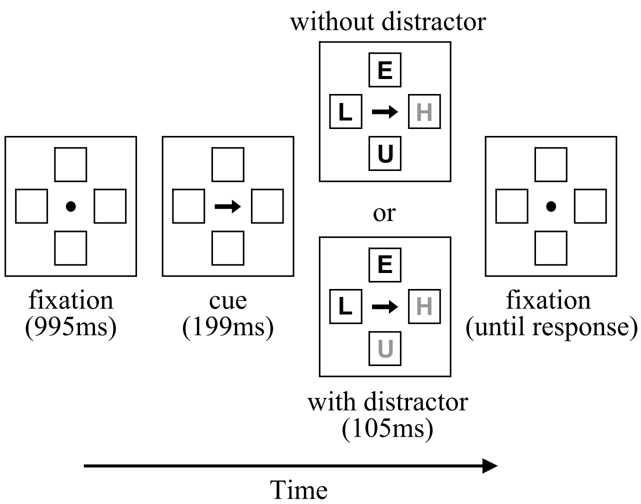


**Figure 3.** The displays and procedure used in Experiment 2 (not-to-scale). On the computer screen with a black background, the outlines of the box, the fixation dot, and the central arrow cue are all in dark gray. Gray characters shown here are red in the experiment, and black characters shown here are green, yellow, blue, or indigo in the experiment.

play was shown and remained visible for 199 msec, followed by the target display. The target display was presented for 105 msec, and was subsequently replaced by the fixation display, which remained on the screen until response. Presentation of target for only 105 msec prevented eye movement and encouraged participants to focus their attention on the cued location as soon as possible.

The target was always presented at the cued location. To ensure that participants responded to the red letter, and not just to the cued location, we included catch trials. At the location to which the arrow cue pointed, there was a probability of 80% that a red letter would be shown (i.e., the target). In the remaining 20% of the trials (i.e., the catch trials), however, this location would show a letter that was not red, and the participants had to withhold their response. In half of the catch trials, one of the three non-target letters was still red. It would prevent participants from just responding to the red letter and not focusing to the cued location.

The experiment consisted of 20 practice trials followed by a total of 360 formal trials, including 72 catch trials. Each block consisted of 120 trials, with short breaks in between. Participants were requested to identify the red target letter as quickly and accurately as possible. If the red letter was a U, they ought to press "U" on the keyboard; if it was an H, then "H" was to be pressed. If no red letter was shown at the cued location, they were not to press any key until the next trial began. Both reaction time and error rate were recorded.

### *Results*

Outliers defined as reaction times that exceeded 3 standard deviations above or below the mean of each participant were discarded (approximately 2% of all observations).

Mean reaction times for correct target identifications in each of the two distractor conditions are shown in Figure 4. These data were subjected to an ANOVA with distractor presence (yes, no) and target-distractor congruency as the within-subjects variables. The main effect of distractor presence and the interaction of distractor presence and target-distractor congruency were significant [$F(1,14) = 14.61$, $MSE = 2414.53$, $p < .01$, and $F(1,14) = 8.77$, $MSE = 1226.19$, $p < .02$, respectively], but no main effect of target-distractor congruency was found [$F(1,14) = 4.16$, $MSE = 562.80$, $p > .06$]. In the *with-distractor* condition, reaction times were slower when the red distractor was incongruent with the target than when it was congruent [$F(1,28) = 12.55$, $MSE = 1725.21$, $p < .01$], but no such effect was found in the *without-distractor* condition [$F(1,28) = 0.46$, $MSE = 63.77$, $p > .1$]. In the *incongruent* condition, reaction times were slower when the red distractor was presented than when no red distractor was presented [$F(1,28) = 23.22$, $MSE = 3541.01$, $p < .0001$], but no such effect was found in the *congruent* condition [$F(1,28) = 0.65$, $MSE = 99.70$, $p > .1$]. The overall error rate was 4.2%, and there were no significant effects in these error rate data. No speed and accuracy trade-off was observed.

### *Discussion*

Results of this experiment show that even when attention shifts to a certain location indicated by a spatial cue in advance, a color distractor

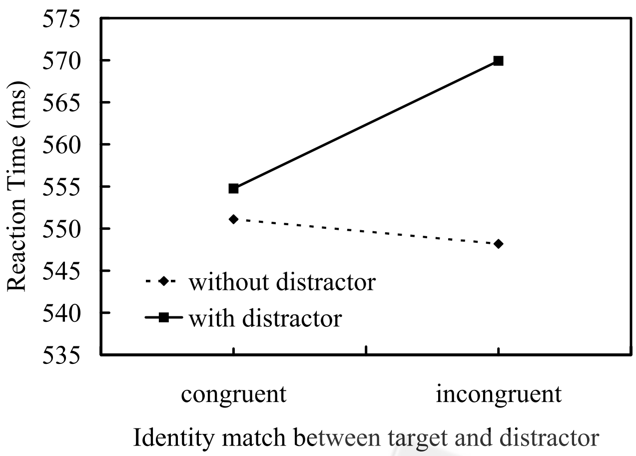


**Figure 4.** Mean reaction time for correct target identification in Experiment 2.

which shares the same defining feature as the target can still capture attention. While previous studies showed that by using a spatial cueing paradigm, stimulus-driven capture cannot occur outside focal attention (Theeuwes, 1991; Yantis and Jonides, 1990), results in this experiment demonstrate that contingent capture can. Summarizing Experiment 1 and 2, the results remain the same that contingent capture can occur outside focal attention whereas stimulus-driven capture cannot, regardless of whether an RSVP or a spatial cueing paradigm is used.

## Experiment 3

This experiment is aimed to be a control for Experiment 2. In the previous experiment, we did not use an onset distractor for the reason that past studies using the spatial cueing paradigm have already shown the absence of attentional capture by an onset distractor (Yantis & Jonides, 1990; Theeuwes, 1991). However, one might argue that the modified spatial cueing paradigm in our Experiment 2 changes quite substantially from the previous studies and thus whether onset distractors indeed cannot capture attention is questionable. Therefore, for a fair comparison, an onset distractor that is not contingent on the target-defining feature (i.e., red) should be included to examine whether it may capture attention in such a modified spatial cueing paradigm.

In order to contrast with an onset distractor, a non-onset distractor is added as the baseline to evaluate the capture effect. To create the non-onset distractor, we used the non-onset technique in Todd and Van Gelder (1979) by adding two figure-eight placeholders at two of the four locations followed by the four letters. Thus, there were no grey boxes appearing peripherally as in Experiment 2. In the target display, four letters appeared, two from empty locations and two from the figure-eight placeholders by eliminating two segments of the placeholders. The distractor letter thus was either an onset letter or a non-onset one.

### *Method*

#### *Participants*

Sixteen undergraduates of the National Taiwan University participated in this experiment. All of them had self-reported normal or corrected-to-normal visual acuity and color vision.

#### *Apparatus, stimuli, design, and procedure*

The stimuli were generated by an ASUS compatible computer and shown on a ViewSonic 19-inch monitor. The sequence of events is illustrated in Figure 5. The stimuli and procedure were similar to that in Experiment 2 with the following exceptions. In the fixation display and the cue display, two figure-eight placeholders (1.6° x 1.6°, the same size as the letters in the target display) were added at two of the four locations, whereas there were no four grey boxes as in Experiment 2. There were a total of 720 formal trials in this experiment.

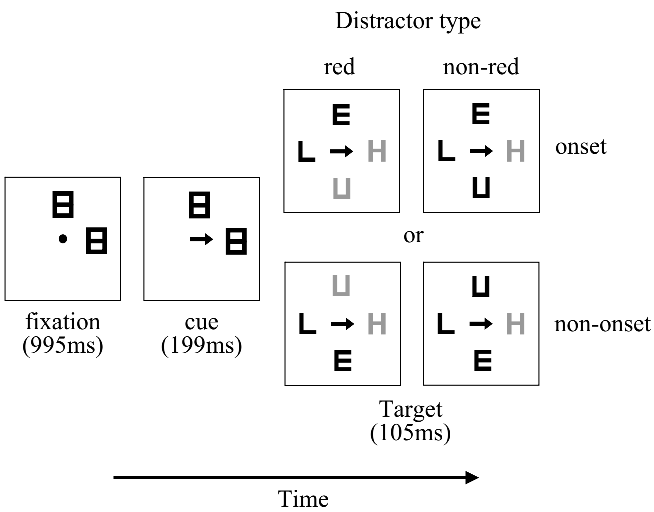


**Figure 5.** The displays and procedure used in Experiment 3 (not-to-scale). On the computer screen with a black background, the fixation dot, the figure-eight placeholders, and the central arrow cue are in dark gray. Gray characters are red in the experiment, and black characters are green, yellow, blue, or indigo in the experiment.

### *Results*

Results in catch trials indicated that among sixteen participants, the false alarm rate of one participant was 15%, and thus data from this participant was eliminated. For the remaining data, only 0.2% false alarm rate of the catch trials existed, indicating that participants indeed followed the instruction by responding to the red letter that appeared in the cued location.

Mean reaction times for correct target identifications are shown in Figure 6(A) and 6(B), separated by distractor type of color and onset respectively. These data were subjected to an ANOVA with onset distractor (onset, non-onset), color distractor (red, non-red), and target-distractor congruency as the within-subjects variables. Only the main effect of color distractor and target-distractor congruency were significant [Mean reaction time of red distractor was slower than that of non-red distractor, $F(1,14) = 10.66$, $MSE = 3626.59$, $p < .01$, and mean reaction time of incongruent distractor was slower than that of congruent distractor, $F(1,14) = 18.09$, $MSE = 2224.39$, $p < .001$]. There is no difference between mean reaction times of onset and non-onset distractor [$F(1,14) = 0.21$, $MSE = 28.06$, $p > .6$]. No interaction effects were significant, *ps* > .3. The overall error rate was 2.7%. Since no significant effects were observed in the error rate data, there was no speed and accuracy trade-off.

### *Discussion*

While comparing the capture effect of the color distractor and the onset distractor in the same spatial cueing paradigm, only the color distractor, but not the onset distractor, showed the capture effect. The results that the color distractor which shares the same defining feature as the target captures attention are consistent with the results in Experiment 2. However, the onset distractor which does not share the same defining feature as the target does not capture attention after all. These results confirmed, once again, those of the previous experiments that contingent capture occurs outside focal attention, whereas stimulus-driven capture does not.

Unlike the results in the previous experiment, there was no interaction effect between the color distractor and the target-distractor congruency in this experiment; the target-distractor congruency effect was not only observed with the red distractor, but also with the non-red distractor. The congruency effect observed in the non-red distractor condition might be due to parallel processing of all letters in the target display, and this may occur only when there are other onset letters and there is no distractor contingent with the target in the display. Since in this case the distractor was always either congruent or incongruent with the target in

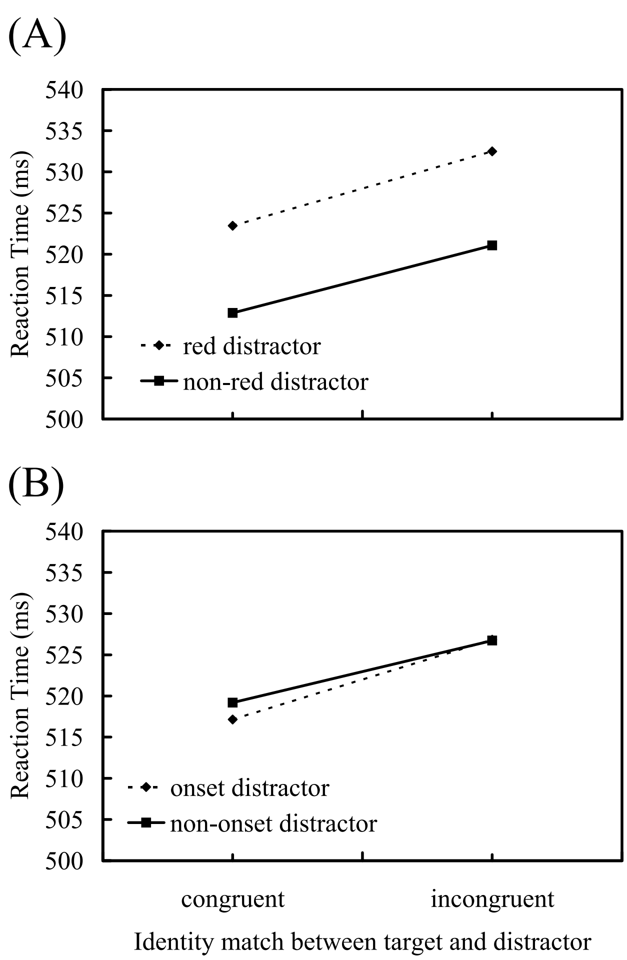


**Figure 6.** Mean reaction time for correct target identification in Experiment 3, separated by distractor type of color (A) and onset (B).

terms of the response type, and thus the distractor has become relevant to the task. However, observing only the congruency effect cannot be taken as sure evidence for attentional capture (e.g., Folk and Remington, 1998). When no competitive red distractor is presented in the display, priming from the same response type without shifting attention to the distractor location may have shortened the reaction time, compared to the condition when the response type is different.

## General Discussion

Two important conclusions can be drawn from this study. First, no stimulus-driven capture is found when focal attention is maintained at fixation in an RSVP paradigm (Experiment 1). This is consistent with the results obtained with a spatial cueing paradigm (Theeuwes, 1991; Yantis & Jonides, 1990; Experiment 3 in this study). It is therefore suggested that abrupt onsets, if not contingent on the target-defining feature, may not capture attention outside focal attention, regardless of whether an RSVP or a cueing paradigm is used. Second, contingent capture can still occur in a spatial cueing paradigm (Experiment 2 & 3), consistent with the results obtained in an RSVP paradigm (Folk et al., 2002). An irrelevant distractor that shares the same color with the target can indeed capture attention, and an act of shifting attention and focusing attention to the pre-cued location is not sufficient to eliminate such an effect of contingent capture. Altogether, it is thus evident that contingent capture, compared to stimulus-driven one, can be relatively more easily observed outside focal attention.

To answer the question raised in this study: Whether the result difference in past studies (Folk et al., 2002; Theeuwes, 1991; Yantis & Jonides, 1990) is caused by the difference between contingent capture and stimulus-driven capture, or by the different paradigms used, our answer is the former. What causes the difference between contingent capture and stimulus-driven capture outside focal attention? Under the condition that the target is defined by a specific color, the nature of attentional capture by the color distractor and an onset one seems to be different in the following way. Attentional capture by an onset may be induced by stimulus-driven orienting (i.e., it is task-irrelevant) *only*. However, contingent capture can be considered as induced by a hybrid attentional orienting, consisted of stimulus-driven (i.e., it is task-irrelevant) and goal-directed (i.e., it shares with the target its defining feature) orienting. The capture effect induced by this hybrid attentional orienting is naturally more effective than that induced by mere stimulus-driven orienting. Recent studies using functional magnetic resonance imaging (fMRI) have also found the activation brain areas that are consistent with this idea. For example, contingent capture evoked activation in the temporoparietal junction and ventral frontal cortex, in addition to the parietal brain areas activated by spatial attention shift that is usually driven by salient stimuli (Liu, Slotnick, Serences, & Yantis, 2003; Serences, Liu, & Yantis, 2005; Serences, Shomstein, Leber, Golay, Egeth, & Yantis, 2005; Serences & Yantis, 2007).

Contingent capture can be considered as attentional selection based on the target-defining feature. That contingent capture can occur outside focal attention implies that feature-based attention operates in a way of global modulation, independent of location. This is consistent with feature-based attention (Bichot, Cave, & Pashler, 1999; Cave, 1999; Hamker, 2004; Olds & Fockler, 2004; Saenz, Buracas, & Boynton, 2003; Sohn, Chong, Papathomas, & Vidnyanszky, 2005; Treue & Martinez Trujillo, 1999; van der Heijden, Kurvink, de Lange, de Leeuw, & van der Geest, 1996; Wolfe, Cave, & Franzel, 1989) and feature-integration theory (Treisman & Gelade, 1980).

For the two kinds of attentional orienting, voluntary and involuntary orienting (Jonides, 1981; Muller & Rabbitt, 1989), this study reveals the interaction between the two. Focal attention represents a top-down control of voluntary attentional orienting to a given location, and it can override the involuntary stimulus-driven capture. However, it does not eliminate contingent capture because contingent capture may involve a hybrid of the two kinds of attentional orienting as mentioned above, and thus may be more effective in capturing attention.

To sum up, we have ‘‘switched’’ the paradigms by using the RSVP paradigm to test the stimulus-driven capture and using the spatial cueing paradigm to test the contingent capture, and have led to the conclusion that it is the different types of attentional capture but not the different paradigms used that caused the different results in previous studies (Folk et al., 2002; Theeuwes, 1991; Yantis & Jonides, 1990). Contingent capture is more likely to occur outside focal attention, compared to stimulus-driven one, at least under the conditions we tested.

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# 注意力焦點外的顯著刺激能否攫取注意力：兩種實驗派典的比較

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過去研究顯示在快速序列視覺呈現（rapid serial visual presentation, RSVP）派典中，若令觀察者在視野中央尋找一個紅色目標物予以辨識，則出現在周邊的紅色干擾物仍能攫取注意力（Folk, Leber, & Egeth, 2002）。然而，另有研究採用線索提示（spatial cueing）派典，發現當注意力事先被中央線索指引至確定的周邊位置時，突現干擾物卻無法攫取注意力（Theeuwes, 1991；Yantis & Jonides, 1990）。上述兩群研究使用的實驗派典不同，可能因此影響注意力的分布，而造成不同的結果。本研究沿用前項派典的紅色目標物，比較兩種實驗派典下的紅色干擾物（與定義目標的特徵相關）或突現干擾物（與定義目標的特徵無關）能否攫取注意力。結果發現，在兩種不同的實驗派典下都是紅色干擾物可以攫取注意力，但突現干擾物不行，顯示先前研究結果的不同並非源自實驗派典的差異，而由綜合兩種實驗派典所得的結果可推論：在注意力焦點範圍之外，與目標定義特徵相符的顯著刺激有最大的可能性得以攫取注意力。

**關鍵詞：**快速序列視覺呈現、線索提示派典、顏色、突現刺激