Visual field asymmetry in attentional capture

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ABSTRACT

The present study examined the spatial distribution of involuntary attentional capture over the two visual hemi-fields. A new experiment, and an analysis of three previous experiments showed that distractors in the left visual field that matched a sought-for target in color produced a much larger capture effect than identical distractors in the right visual field, revealing a visual field asymmetry in color-based contingent capture. On the other hand, abrupt onsets in the two hemi-fields did not differ in the magnitude of their capture effect, indicating a symmetric distribution of onset capture. The different spatial patterns for contingent capture and onset capture reveal differences between the two types of attentional capture, possibly indicating differences in the underlying brain mechanisms.

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1. Introduction

Researchers have been interested in perceptual asymmetries because they are believed to reveal not only spatial characteristics of perception but also hemispheric lateralization of brain function. Perceptual asymmetries have been demonstrated in many behavioral tasks such as dichotic listening, visual word naming, line bisection and lightness comparison. For example, when two different auditory verbal stimuli are presented to the left and right ears simultaneously in dichotic listening tasks, normal individuals are better at reporting the items in the right ear compared to the left (Jerger & Martin, 2004; Kimura, 1961). Observers also name words in the right visual field more quickly than those in the left visual field (Scott & Hellige, 1998). Both the right ear advantage and the right visual field advantage for verbal stimuli are caused by left hemispheric dominance for verbal processing (Hellige, 1990; Kimura, 1961).

In contrast to the right hemi-field advantage for verbal stimuli, a leftward bias has been well established in non-verbal line bisection and lightness comparison tasks. In line bisection tasks, neurologically healthy adults tend to bisect lines slightly to the left of their physical center (McCourt & Garlinghouse, 2000; McCourt & Olafson, 1997). The systematic leftward line bisection error was first named by Bowers and Heilman (1980) as "pseudoneglect". Although the universality of the leftward bias has been challenged by some studies (Nielsen, Intriligator, & Barton, 1999), a review of 73 line bisection studies revealed a significant leftward bias in neurologically healthy participants (Jewell & McCourt, 2000).

In addition to line bisection tasks, chimeric tasks also reveal visual asymmetries. Chimeric tasks typically use pairs of mirror-reversed stimuli each of which contains a lateral gradient in some attribute (e.g., in lightness comparison tasks, the stimulus may get darker from left to right). Participants are required to pick the stimulus in which the particular attribute appears most strongly represented, and they tend to choose the stimulus with the key attribute on the left-hand side more than on the right-hand side (Luh, Redl, & Levy, 1994; Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994; Nicholls, Bradshaw, & Mattingley, 1999, 2001; Nicholls & Roberts, 2002). This leftward bias for features has been observed for facial stimuli (Luh et al., 1994), and also for many non-facial attributes such as brightness, numerosity and size (Nicholls et al., 1999, 2001).

Many of the visual asymmetries have been assumed to reflect asymmetries in visual attentional mechanisms (Holländer, Corballis, & Hamm, 2005; Kinsbourne, 1970; Palmer & Tzeng, 1990). For example, the leftward attentional bias is thought to be an outgrowth of right-hemisphere specialization for spatial attention (Corbetta & Shulman, 2002; Heilman & Van Den Abell, 1980; Kim et al., 1999; Nobre et al., 1997). One study has shown that the leftward bias in line bisection, chimeric face and chimeric dot enumeration tasks are not correlated, suggesting that there may be many lateralized spatial processes rather than one attentional bias in general (Boles, 2002).

Although numerous studies have revealed the lateralization of spatial attention in general, most have focused on attention under voluntary control. Surprisingly only a few studies have tested whether *involuntary capture of attention* is asymmetric. In one such experiment, Pollmann presented a high-salience distractor (a tilted letter T) while subjects searched for a low-salience target (an inverted letter T) that was in the contralateral visual field. He found that visual search was slowed more when the high-salience

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distractor appeared in the right visual field (Pollmann, 1996, 2000). Based on those findings, Pollman and colleagues proposed a model of asymmetric antagonistic hemispheric attentional gradients. According to the model, the left hemisphere orients only to the right visual field, while the right hemisphere has a more bilateral distribution of attention (Pollmann & Zaidel, 1998). Under this model, a rightward bias might be predicted for all kinds of involuntary attentional capture if all types of capture relied upon the same brain mechanisms. The goal of the present study was to examine the spatial distribution of two distinct types of attentional capture.

One of the two distinct types of attentional capture is the pure stimulus-driven capture that occurs when an irrelevant stimulus involuntarily captures attention by virtue of its own low-level salience. For example, onset capture, a prototypical example of stimulus-driven capture, occurs when an abrupt onset pulls a person's attention to a new object (or a location) in the absence of voluntary control (Christ & Abrams, 2006; Yantis & Jonides, 1984). The hallmark of onset capture is that it is both involuntary and occurs in the absence of any expectations, or top-down control (Jonides, 1981; Schreij, Owens, & Theeuwes, 2008; Yantis & Jonides, 1984, 1990).

The other type of capture is *contingent* capture, in which an irrelevant stimulus captures attention not because of its low-level salience but instead because it shares features with the sought-for target. For example, Folk, Leber, and Egeth (2002) required participants to identify a uniquely colored target letter in a rapid stream of letters presented at fixation. They found that participants often failed to correctly report the target at fixation if a distractor suddenly appeared in the periphery—but only if the distractor matched the target color. Because the effect of the distractor was contingent upon the color match between target and distractor (distractors with mismatching colors did not impair performance), they attributed the impairment to contingent attentional capture. A recent FMRI study of this "spatial blink" showed that spatial attention is drawn to the location of the target-colored distractor even though it was known to be irrelevant to the task (Serences et al., 2005). In sum, contingency upon top-down control makes contingent capture different from onset capture, although both are types of involuntary attentional capture.

Despite the apparent ability of onsets to capture attention in the absence of top-down control, some studies have shown that onset capture can be affected by an observer's attentional goals under some circumstances. Such observations have fueled a debate regarding the extent to which it is necessary to distinguish between onset capture and contingent capture—perhaps capture by onsets is a special case of contingent capture. For example, Folk and colleagues found that onsets of uninformative cues captured attention only if participants were required to detect an onset target, but not when participants were looking for a target in a designated color (Folk, Remington, & Johnston, 1992; also Gibson & Kelsey, 1998). Similarly, abrupt onsets of distractors fail to capture attention if the distractors do not share the sought-for target color (Du & Abrams, 2008; Folk et al., 2002). Finally, spatial information can also exert top-down control upon onset capture (Christ & Abrams, 2006). Each of the preceding results is consistent with the possibility that onset capture might be a special case of contingent capture because in each case the observer's expectations affected the influence of onsets. By comparing the spatial distribution of onset capture and contingent capture we might better clarify whether the two types of capture are both governed by the same underlying mechanism.

The present study was designed to determine the spatial distributions of both onset capture and contingent capture. The Pollmann (1996, 2000) work noted earlier might help to predict the outcome. However, there are some reason to question the extent to which those earlier findings can be generalized to new paradigms. In particular, the Pollmann experiments contained elements of both stimulus-driven capture and contingent capture. First, the distractor was highly salient due to the possession of a unique orientation, most likely evoking stimulus-driven attentional capture. At the same time, however, the distractor was characterized by a unique value on orientation—precisely the feature that subjects were searching for. Hence the distractor may also have triggered contingent attentional capture mechanisms. Thus, it is not know what the distribution of attentional capture would be in paradigms that are designed to examine pure onset capture, or pure contingent capture. In the current study, onset capture during visual search and contingent capture based on color were used to invoke the two types of attentional capture.

2. Experiment 1

In this experiment a spatial blink paradigm was used to study contingent attentional capture. The task is very similar to one that has been used recently by several groups of researchers (e.g., Du & Abrams, 2008; Folk et al., 2002; Serences et al., 2005) and hence makes a good paradigm for testing questions about the spatial distribution of the effect.

2.1. Method

2.1.1. Participants

Twenty-one undergraduate students from Washington University participated in a one-half hour long experiment for course credit. All reported normal or corrected-to-normal visual acuity and normal color vision. No participants had experience in similar experiments. Only one participant was left-handed based on their self-report.

2.1.2. Apparatus and procedure

All stimuli were presented on a 19-in. CRT with a 100 Hz refresh rate in a dimly lit room at a distance of 56 cm. The sequence of events on a trial is illustrated in Fig. 1. Each trial began with a 500-ms presentation of a white fixation cross in the center of the display, followed by the sequential presentation of 20 upper case letters at the center. The letters were selected randomly without replacement from the English alphabet, with the exception of "I". Letters were 1.5° in width and 1.8° in height. Each letter was presented for 40 ms, fol-
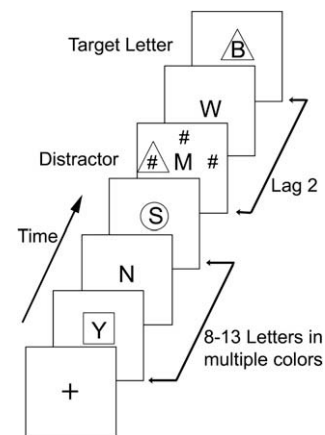

Fig. 1. A schematic representation of the procedure in Experiment 1. The shapes surrounding the symbols designate stimuli of different colors and did not appear in the actual experiment. The actual stimuli were in different colors and were presented on a black screen. Each frame was presented for 40 ms, and followed by a blank interval of 40 ms.
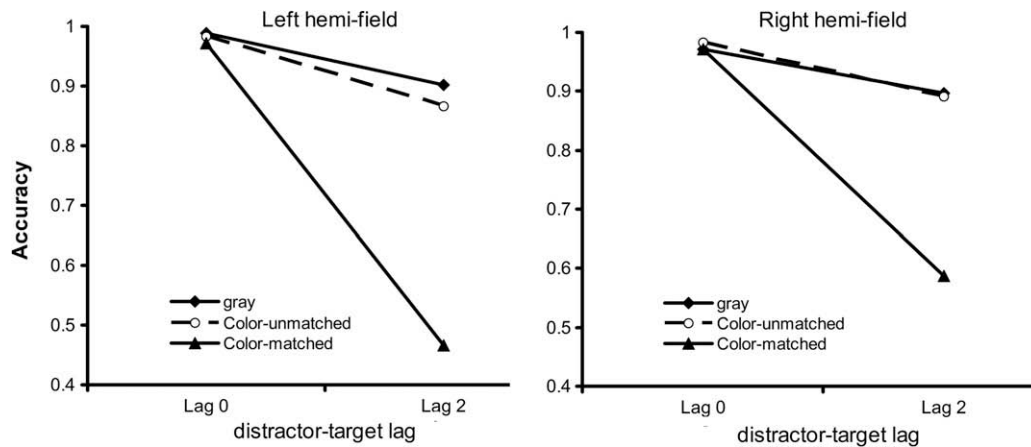
Fig. 2. Accuracy of target identification as a function of hemi-field, lag and distractor-condition in Experiment 1.

lowed by a 40-ms blank interval, yielding an SOA of 80 ms. Participants were required to report the sole red letter in the sequence (the target). Across trials, the target letter appeared in the 9th through 14th frame of the letter sequence. The colors of the remaining letters were randomly chosen from three colors (gray, blue or purple). Participants reported the target letter by pressing the corresponding key after each trial. The response was not a speeded response, as is common in tasks using rapid serial visual presentation (RSVP), so only accuracy was recorded as a dependent variable in the present experiment.

One of the letters in the 9th through 12th frames, randomly chosen with equal chance, was surrounded by four pound signs (#) whose inner edges appeared 4.5° above, below, right, and left of the center of the letter. On one-third of the trials all of the pound signs were gray; on the other trials one of the pound signs was either red or green (equally likely) and the other three were gray. Thus, two thirds of trials contained a distractor display that included a color-singleton distractor that either matched the target color or did not. For half of them, the color-singleton distractor appeared on the left (the distractor was on the right for the remaining trials). The frame containing the distractor could appear two frames before that containing the target (distractor–target lag of 2) or in the same frame as the target (lag of 0).

2.1.3. Design

Each trial was in one of three distractor-conditions: (1) the four pound signs could be all gray (gray); (2) one pound sign could match the target color of red (color-matched), or (3) one pound sign was a non-target color, green (color-unmatched).[1] In addition, the color-singleton distractor was equally likely to appear in either hemi-field (left or right). The experiment contained 20 replications of each combination of three distractor-conditions, two hemi-fields, and two distractor-target lags, for a total of 240 trials. Participants first served in one block of 12 trials for practice. They then completed the test trials, which were presented in a random order. After every 60 trials, they received a brief break.

2.2. Results and discussion

The accuracy of target identification is plotted in Fig. 2 as a function of distractor–target lag, and distractor-condition, shown separately for the two hemi-fields. Trials with gray distractors were randomly assigned to either the left or right hemi-fields in order to perform a distractor–target lag by distractor-condition by hemi-field, three-way ANOVA. First, we found a main effect of lag, with lower accuracy as lag increased, $[F(1, 20) = 89.14, p < .001, \eta_P^2 = 0.817]$. Next, there was a main effect of distractor-condition, with accuracy lowest in the color-matched condition, $[F(2, 40) = 35.003, p < .001, \eta_P^2 = 0.636]$. In addition, there was a main effect of hemi-field indicating lower overall accuracy when the color-singleton distractor appeared in the left hemi-field, $[F(1, 20) = 6.755, p < .05, \eta_P^2 = 0.252]$. The effects of lag and distractor-condition interacted $[F(2, 40) = 30.03, p < .001, \eta_P^2 = 0.6]$, reflecting the fact that the impairment caused by the color-matched distractors occurred mainly for lag 2. This is the pattern indicative of the spatial blink. Most importantly, the interaction between lag and distractor-condition depended on the hemi-field, yielding a three-way interaction between those factors $[F(2, 40) = 6.212, p < .005, \eta_P^2 = 0.237]$. This interaction reflected the finding that the impairment caused by the color-matched distractor at lag 2 (the contingent capture effect) was greater when the distractor appeared in the left hemi-field than when it was in the right hemi-field, as can be seen in Fig. 2.

The current experiment found that the spatial blink caused by color-matched distractors in the left hemi-field was much larger than that of color-matched distractors in the right hemi-field. The results clearly indicate that the color-based contingent capture effect is asymmetric over the two hemi-fields. Because every trial contained onset signals in both hemi-fields, the current experiment cannot address questions about lateralization of onset capture. That question is addressed in Experiment 2, after we describe the results of an analysis of three previous experiments that confirms and bolsters the findings of the present experiment.

3. Analysis of three previous experiments

In order to confirm the results of Experiment 1, we conducted an analysis of three similar experiments which were originally designed for other purposes (Du & Abrams, 2008). Du and Abrams (2008) examined the synergistic effects of top-down control and stimulus-driven saliency using a spatial blink paradigm very similar to that used in Experiment 1. The present Experiment 1 was similar to the *onset* condition of their Experiments 1A, 1B, and 2,

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[1] In Experiment 1, because the target color was always red, red distracters matched the target color and green distracters did not. Thus, color was confounded with distracter status. However, previous experiments that we have conducted with the same stimuli (Du & Abrams, 2008) have shown that the red and green colors used do not differ in their salience, and the present design was chosen because of its efficiency. Importantly, the analysis of three previous experiments reported in the present paper relies upon the data from three experiments in that earlier study in which the confound was not present, and the pattern of results is the same as that found in Experiment 1.

with only minor exceptions. First, color-singleton distractors appeared at one of four locations in the earlier study (4.2° above, below, left, or right to the center) rather than only two locations as in the current Experiment 1. Secondly, instead of reporting the sole red letter in the stream, for half of the participants in the earlier study the unique target color was green (and it was red for the other half). This guaranteed equivalent salience of color-matched and color-unmatched distracters across subjects. Finally, there were more than 2 lags in the experiments of the earlier study—but here we only analyzed lags 0 and 2 for comparison to the present Experiment 1. The three experiments included 52 participants altogether, providing a strong replication of Experiment 1 here.

3.1. Results and discussion

The average accuracies of target identification as a function of distractor–target lag, distractor-condition, and hemi-field for three experiments from Du and Abrams (2008) are shown in Fig. 3. All three experiments showed a pattern of results very similar to that from the present Experiment 1. First, only the color-matched distractors caused substantial impairment in target identification—the typical pattern associated with the spatial blink. More importantly, the spatial blink was larger when the color-matched distractor appeared in the left hemi-field compared to the right hemi-field.

An ANOVA revealed a main effect of distractor-condition, with accuracy lowest in the color-matched condition, [$F(2, 98) = 64.48$, $p < .001$, $\eta_P^2 = .568$], and a main effect of distractor–target lag, with lower accuracy at lag2, [$F(1, 49) = 57.17$, $p < .001$, $\eta_P^2 = .538$]. But there was no main effect of hemi-field, [$F(1, 49) = 2.35$, $p > .05$, $\eta_P^2 = 0.046$]. The effects of lag and distractor-condition interacted [$F(2, 98) = 52.82$, $p < .001$, $\eta_P^2 = .519$], indicating that the impairment caused by the color-matched distractors occurred mainly for lag 2 (an SOA of 160 ms). This indicates the presence of the spatial blink. Most importantly, the interaction between lag and distractor-condition depended on the hemi-field, yielding a three-way interaction between those factors [$F(2, 98) = 11.72$, $p < .001$, $\eta_P^2 = 0. 193$]. This interaction reflects the fact that the impairment caused by the color-matched distractors at lag 2 was greater when the color-matched distractors appeared in the left hemi-field compared to the right hemi-field.

The results of the combined analysis are consistent with those from Experiment 1. They confirm that the asymmetric distribution of the spatial blink is a very robust phenomenon, and show clearly that color-based contingent capture is asymmetric.

4. Experiment 2

Experiment 1 and the analysis of three previous experiments showed that color-matched distractors in the left hemi-field had a greater impact on target identification (a larger spatial blink) than their counterparts in the right hemi-field. Although these experiments are informative about contingent capture they are not at all informative regarding a possible asymmetric distribution of onset capture. This is because the onsets that occurred in Experiment 1 and the earlier experiments always appeared in both hemi-fields simultaneously. In the present experiment, we examined the spatial distribution of onset capture.

In order to study onset capture it was necessary to select a paradigm that differs from the spatial blink paradigm used in Experiment 1. This is because distractor onsets in the spatial blink paradigm have not been shown to induce any significant capture effect (Du & Abrams, 2008; Folk et al., 2002). Since visual search is one of the most widely used paradigms for the study of onset capture, we employed a variation of a classic visual search task in the current experiment.

4.1. Method

4.1.1. Participants

Thirty-six undergraduate students from Washington University participated in a half hour long experiment for course credit. All reported normal or corrected-to-normal visual acuity. All participants reported being right-handed.

4.1.2. Apparatus and procedure

All stimuli were presented on a 19-in. CRT with a 100 Hz refresh rate in a dimly lit room at a distance of 56 cm. The sequence of events on a typical trial is illustrated in Fig. 4. Each trial began with an 800-ms presentation of a black fixation cross in the center of the screen, followed by a preview display that consisted of a centrally-located fixation cross and three figure-eight placeholders. Each placeholder was 1.5° high and 0.5° wide. The placeholders were arranged at the corners of an imaginary isosceles triangle at a distance of 4.5° from the center of the display. One placeholder was on the midline, directly above the fixation cross, the others were to the left and right of fixation. After an 800 ms delay, two line segments were removed from each placeholder to reveal the search display. At the same time, a new letter also appeared either 4.5° to the left or 4.5° to the right of the central cross. Thus, the search display contained four letters, one of which was a new object. The search display always contained one target letter (either an S or an
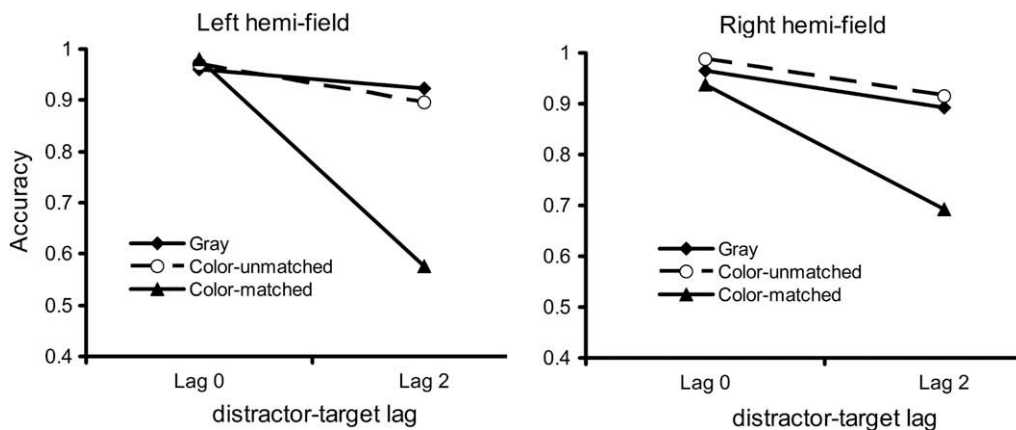

Fig. 3. Accuracy of target identification as a function of hemi-field, lag and distractor-condition from the meta-analysis of three previous experiments.
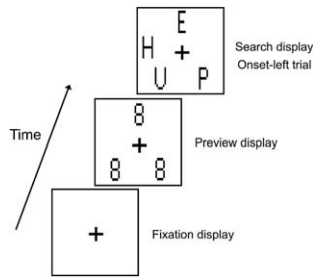
Fig. 4. Sequence of events on a typical trial of Experiment 2. In this example, the target letter H appeared in an onset element in the left hemi-field. On other trials, the onset was on the right. The target could appear in either an onset or an old location. See the text for further details.

H), and participants pressed one of two keys as quickly as possible to indicate the target letter that was present. The non-target locations contained either a U, E, or P, each equally likely. The target letter was equally likely to appear in any of the four locations. Thus, on one-quarter of the trials, it was the abruptly onset new object (the *onset* condition), whereas on the other three-quarters of the trials, the target letter appeared at one of the locations that had been occupied by a placeholder (the *old* condition). In the old condition, the new letter that abruptly onset was a distractor – equally likely to be to the left or right of fixation. The search display remained visible until the participant responded or 1600 ms had elapsed. As in Experiment 1, feedback was given if the participant responded too quickly, too slowly, or incorrectly.

4.1.3. Design

Following 16 practice trials, participants served in 320 experimental trials. This included 80 trials in the onset condition (40 with the target on the left and 40 on the right), and 80 trials with the target appearing at each of the three locations in the old condition (left, middle, and right). Trial types were randomly mixed. At intervals of 80 trials, participants were given the opportunity to take a break.

4.2. Results and discussion

First consider the error rates, which are shown in Fig. 5. We computed an ANOVA comparing accuracy as a function of the onset condition (onset vs. old) and target location (hemi-field: left vs. right), excluding the targets presented in the middle condition from analysis. There was a main effect of onset condition, with more accurate responses for onset targets, [$F(1, 35) = 10.79$, $p < .005$, $\eta_P^2 = 0.236$]. But we found no main effect of hemi-field,
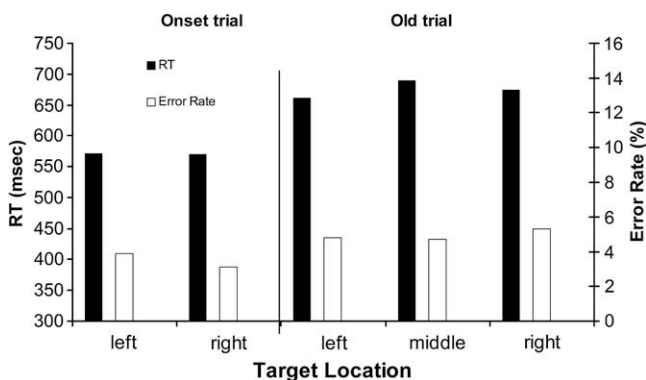
[$F < 1$]. The interaction between onset condition and hemi-field approached significance, with target onsets on the right resulting in slightly fewer errors than those on the left [$F(1, 35) = 3.30$, $p = .078$, $\eta_P^2 = 0.086$]. Nevertheless, simple effects tests revealed no reliable visual field asymmetry in error rates for onset targets [$t(35) = 1.41$, $p > .05$]. And error rates of old targets did not differ across the two hemi-fields either, [$t(35) = 0.84$, $p > .05$].

Mean reaction times are shown in Fig. 5. We conducted an ANOVA in which trials in which the target appeared in the middle location were excluded from analysis. There was a main effect of the onset condition, with faster RTs when targets appeared in new objects (onset condition) compared to old, [$F(1, 35) = 138.156$, $p < .001$, $\eta_P^2 = 0.798$]. But we found no main effect of hemi-field, [$F(1, 35) = 1.17$, $p > .05$, $\eta_P^2 = 0.032$]. The interaction between onset condition and hemi-field approached significance, [$F(1, 35) = 3.12$, $p = .086$, $\eta_P^2 = 0.082$]. As seen in the figure, this stems from a slight (but not significant) advantage for old targets on the left compared to on the right. This was confirmed by a simple effects test [$t(35) = 1.744$, $p = .09$], while onset targets yielded essentially the same RT regardless of the hemi-field, [$t(35) = 0.10$, $p > .05$].

We also analyzed the error rates of old trials as a function of the target location (middle, left and right) and the location of the distractor onset (left vs. right), shown in Fig. 6. A 2 by 3 ANOVA found neither a significant main effect of onset location, [$F(1, 35) = 1.639$, $p > .05$]; nor a main effect for the location of the target, [$F(2, 70) < 1$]; the interaction between the two was also not significant, [$F(2, 70) = 2.337$, $p > .05$].

The RT of old trials as a function of the target location (middle, left and right) and the location of the distractor onset (left vs. right) is shown in Fig. 6. A similar ANOVA on the RTs revealed a significant main effect for the location of the target, [$F(2, 70) = 4.446$, $p < .05$]; indicating that old-left trials had the fastest responses (as noted earlier). The main effect for onset location and the interaction were not significant, both [$Fs < 1$]. This pattern of results indicates that the onset of a distractor in either hemi-field had an equivalent impact on ongoing visual search.

In the present experiment, onset targets produced reliable benefits in both speed and accuracy, but their benefits were symmetric across the two hemi-fields. Participants did not reveal any hemi-field biases toward the onset signals.

5. General discussion

The present experiments focused on spatial characteristics of two distinct types of involuntary attentional capture. We found a visual field asymmetry for contingent attentional capture (contingent upon the color of the target), but no such asymmetry for abrupt onset capture. In particular, Experiment 1 showed that col-
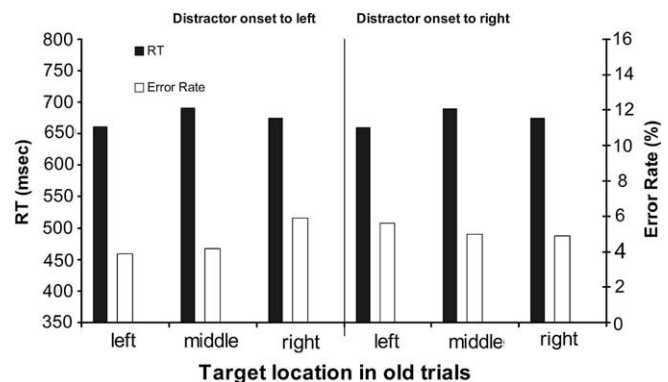

Fig. 5. Error rates and RT as a function of target location and onset condition in Experiment 2.

Fig. 6. Error rates and RT of old trials as a function of target location and onset location of distractor in Experiment 2.

or-matched distractors in the left hemi-field were more disruptive to identification of a central target than the same distractors in the right hemi-field. Color-unmatched distractors and gray distractors did not produce an asymmetric capture effect. This asymmetric spatial blink was corroborated by a reanalysis of three previous experiments. The result suggests that the neural network mediating contingent attentional capture may be more lateralized in the right hemisphere than in the left hemisphere. No such suggestion can be made regarding capture by abrupt onsets because no asymmetries were observed.

It is possible that the verbal stimuli used in Experiment 1 might have evoked mechanisms involved in reading, perhaps contributing to the spatial asymmetry that we observed. Nevertheless, the left hemisphere dominance of semantic processing might predict that such an occurrence would lead to a right visual field advantage – contrary to the results that we obtained. Future studies might consider whether non-verbal stimuli would lead to different conclusions about the spatial distribution of contingent capture.

The different spatial patterns observed for contingent capture compared to onset capture bear on suggestions that onset capture can be regarded as a special case of contingent capture. As noted earlier, several researchers have found that the extent to which onsets capture attention can be modulated by the observer's expectations. Thus, onset capture may be a special case of contingent attentional capture – with the effect of an onset depending not solely on its salient physical characteristics, but also to some extent on the observer's expectations or "attentional set". If onset capture was entirely a special case of contingent capture then we would expect onsets to reveal the same spatial asymmetries that we found for contingent capture based on color. However, the present findings of visual field asymmetries for contingent capture but not onset capture are more consistent with the existence of two separate mechanisms for the two types of attentional capture.

In the present study we did not make any direct observations of the underlying brain activity during performance of the experimental tasks. Nevertheless, our results may bear on recent work that has identified details of the brain mechanisms involved in the guidance of visual attention. In particular, several fMRI studies have identified candidate regions which might mediate contingent attentional capture (Serences & Yantis, 2007; Serences et al., 2005). Those candidate regions including the intraparietal sulcus (IPS), the frontal eye fields (FEF) and the temporo-parietal junction (TPJ) were sensitive to target-defining features and showed enhanced BOLD activity to color-matched distractors compared to color-unmatched distractors. Though these previous studies were not designed to examine lateralization of those regions, their data might shed light on the question regarding which region of the neural network for contingent attentional capture is more lateralized in the right hemisphere than the left hemisphere. For example, the right TPJ is specialized for detection of low-frequency targets and reorienting to spatially unexpected targets. Corbetta and Shulman (2002) proposed that the right TPJ works as a "circuit breaker" in attentional capture when detecting behavioral relevant stimuli. Indeed, in the Serences et al. (2005) study there was a numerically greater volume of activation in TPJ on the right than on the left side (although it is unclear whether the difference was statistically significant). Combined with the leftward bias found for color-matched distractors in the current study, we speculate that the right TPJ may play a role in determining the spatial deployment of contingent capture. But of course, this speculation should be confirmed by future studies.

The results from Experiment 2 showed that both reaction time and accuracy were symmetric across the two hemi-fields for onset targets and onset distractors. This pattern suggests that the neural mechanisms underlying stimulus-driven attentional capture by

abrupt onset, unlike contingent capture, may be symmetric across the two hemispheres.

The present findings also help to extend our knowledge of involuntary attentional capture beyond what would be possible on the basis of some of the earlier work on the topic. In particular, Pollmann (1996, 2000) reported a right visual field advantage for distractors during search. However, as noted earlier, those results were obtained under conditions in which both stimulus-driven and contingent factors might have been expected to play a role. In the present study, in contrast, we employed two different paradigms that each relied mainly on one or the other attentional mechanism. And we found that neither type of capture reflected a right visual field advantage. Further work will be needed to learn what other, if any, circumstances also produce a right visual field advantage.

It is worth noting one key difference between our contingent search task and the visual search task used by Pollmann: Our target was defined on the basis of color whereas Pollmann's was defined based on orientation (and the distracter was an element with a unique orientation). Thus, it remains possible that this difference accounts in part for the different patterns of results obtained. It remains an open question to determine the spatial distribution of contingent capture when features other than color serve as the basis for the search.

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