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Attentional control settings prevent abrupt onsets from capturing visual spatial attention

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Rapid Communication

Attentional control settings prevent abrupt onsets from capturing visual spatial attention

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When a visual distractor appears earlier than a visual target in a target-detection task, response time is faster if the distractor appears at the same location as the target. When a visual distractor appears concurrently with a visual target in a target-detection task, response time is slowed relative to when no distractor is presented. Both effects have been taken as evidence of the capture of visual spatial attention, yet capture by early distractors is contingent on top-down attentional control settings (ACSs), and capture by concurrent distractors is not. The present study evaluated whether this incongruity is attributable to the timing of distractors (earlier than vs. concurrently with the target), or to the employed comparisons (same location/different location vs. distractor/no distractor). Using a task that presented both early and concurrent distractors, we observed that, regardless of timing, capture was contingent on ACSs when assessed by the same-location/different-location comparison. This result suggests that, although irrelevant stimuli cause nonspatial purely stimulus-driven effects, the capture of visual spatial attention is contingent on ACSs.

Keywords: Attentional control settings; Capture; Attention capture; Attention control; Distractor.

When searching a visual scene for a target of interest, the onset of an irrelevant new stimulus can capture visual spatial attention, causing an increase in the time required to find the target if attention is drawn away from the target's location (Davoli, Suszko, & Abrams, 2007; Jonides & Yantis, 1988; Theeuwes, 1990, 1991; Yantis & Jonides, 1984, 1990). While this disruption by abrupt onsets has been demonstrated repeatedly, considerable debate has emerged as to whether the capture of attention is automatic or whether it can be modulated through top-down attentional control settings (ACSs). On the one hand, evidence for automatic capture has come largely from distracted visual search tasks, where distractors are presented concurrently with the target to

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compete for visual spatial attention. In these visual searches, onset distractors slow response times (RTs) even when abrupt onsets are irrelevant to the task (e.g., Theeuwes, 1991). On the other hand, there is also considerable evidence for control through ACSs such that irrelevant onsets will only capture attention if attending to onsets facilitates finding the target item (e.g., Folk, Remington, & Johnston, 1992; Gibson & Kelsey, 1998). For example, if the target is itself an abrupt onset, then other irrelevant onsets will capture attention. If, however, the target is a colour singleton, irrelevant onsets will not capture attention because onsets are not task relevant. The evidence to support ACSs has come largely from early-distractor (i.e., cued) target-detection tasks where, prior to the appearance of the target, distractors are presented to test whether they will capture attention to different parts of the visual scene. In these tasks, only distractors that match a participant's ACS capture attention (for a recent review, see Burnham, 2007). The purpose of the present study is to address these discrepant findings by assessing the differences in concurrent-distractor and early-distractor tasks to determine whether the capture of visual spatial attention is purely stimulus driven, or whether it is contingent on ACSs.

There continue to be two predominant proposals that account for the different conclusions that have emerged from early- and concurrent-distractor tasks. One proposal surrounds the difference in the timing of the distractors. According to Theeuwes, Atchley, and Kramer (2000), ACSs do not prevent irrelevant stimuli from capturing attention, but rather allow attention to disengage from these stimuli more quickly. As such, in early-distractor tasks where irrelevant stimuli are presented in advance of the target, there is sufficient time to recover from attentional capture before the target appears. In contrast, because irrelevant stimuli are presented simultaneously with the target in concurrent-distractor tasks, there is no time to recover from capture. In support of this proposal, Theeuwes et al. observed that the effects of irrelevant stimuli in a concurrent-distractor task are eliminated if the distractors are presented between 150–300 ms in advance of the target. More recently, Schreij, Owens, and Theeuwes (2008) have demonstrated the converse; when the distractors from an early-distractor task are presented concurrently with the target, ACSs fail to eliminate RT costs by irrelevant onset distractors. According to this *timing* proposal, attentional capture by abrupt onsets is purely stimulus driven and cannot be prevented by ACSs.

The second proposal involves the different measures of attentional capture used in early- and concurrent-distractor tasks. In early-distractor tasks, attentional capture is assessed by comparing RTs when distractors are presented at the eventual target location to those when they are presented at another location (henceforth referred to as valid and invalid distractors). If a distractor captures attention, then RTs should be faster following valid than following invalid distractors as attention will have been drawn to the target location. In contrast, in concurrent-distractor tasks, all distractors are invalid, and capture is instead inferred by comparing trials with distractors to trials without distractors. If an irrelevant distractor captures attention, then it should cause slowed RTs relative to when no distractor is present. According to Folk and Remington (1998), however, the comparisons employed in concurrent-distractor tasks may also measure distractor costs that are unrelated to the capture of visual spatial attention. In particular, the presence of a distractor causes a nonspatial filtering cost in RT (Treisman, Kahneman, & Burkell, 1983), and Folk and Remington have argued that although ACSs can eliminate the capture of visual spatial attention, they cannot prevent filtering costs. To support this proposal, Folk and Remington tested an early-distractor task with a no-distractor condition. In this task, although there was no difference in RT between trials with valid and invalid distractors, these early distractors did result in slower RTs than on no-distractor trials. According to this *filtering-cost* proposal, attentional capture by abrupt onsets is not purely stimulus driven, but rather is contingent on top-down ACSs.

In the present study we compare the timing and filtering-cost proposals using a combined early-and concurrent-distractor task (Experiment 1) and a concurrent-distractor-only task (Experiment 2).

EXPERIMENT 1

Participants in Experiment 1 looked for a specifically coloured target, establishing an ACS for that colour, and every trial could contain both an early and a concurrent distractor presented in colours that matched, or did not match, the target colour. Of note, while the appearance of these distractors produced colour discontinuities that could have captured attention, they were also added to displays as abrupt onsets, allowing us to test whether ACSs can control attentional capture by onsets. Importantly, early and concurrent distractors were visually identical to each other and differed only in the timing of their presentation. Further, both types of distractors could be presented at the target location or a nontarget location. Thus, this task will allow us to compare the *timing* proposal against the *filtering-cost* proposal. The critical comparison will be to assess whether the effect of nonmatching concurrent distractors on RT is spatially specific. According to the *timing* proposal, RTs should be faster for valid than invalid nonmatching concurrent distractors, because there is insufficient time to recover from attentional capture. If this result is observed, an important control will be to verify that this spatial effect is eliminated for nonmatching early distractors, for which there should be sufficient time to overcome capture. In contrast to the timing proposal, the filtering-cost proposal predicts that there should be no difference in RT for valid and invalid nonmatching concurrent distractors, because the distractor effect is due to a nonspatial filtering cost. If this result is observed, an important control will be to verify that these nonmatching concurrent distractors do slow RT relative to trials without distractors, as these distractors should cause a filtering cost despite the ACS manipulation. Thus, we can compare the timing and filtering-cost proposals through these two control conditions and the critical comparison of whether or not the effect of nonmatching concurrent distractors is spatially specific.

Method

Participants

Participants were 19 University of Toronto undergraduate students enrolled in an introductory psychology course. All participants gave informed consent, were naive to the purpose of the experiment, and received partial course credit as compensation.

Apparatus and procedure

Participants completed the experiment in a dimly lit room using a personal computer with a VGA monitor. Viewing distance was fixed through a head-and-chin rest. Each participant was assigned green or red as the target colour (counterbalanced across subjects).

Each of the 576 trials began with the presentation of placeholders situated at the three possible target locations, which were 3.75° of visual angle above, to the left of, or to the right of the centre of the display (see Figure 1). Each placeholder was a diagonal cross that subtended 0.5° of visual angle, centred within a square box 1.5° in height.

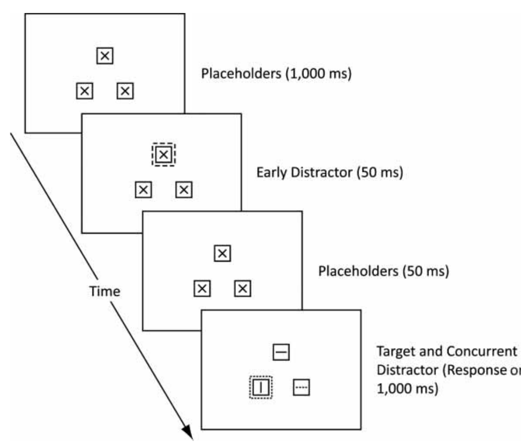

Figure 1. *An example of the sequence of events on one trial. The early distractor is presented in green (shown here as dashed lines), and the target and concurrent distractor in red (shown here as dotted lines). Black and white are reversed.*

The placeholders were drawn in white on a black background. After 1,000 ms an early distractor was added to the placeholder display. The distractor was a red or green square box 1.75° in height and was centred on one of the placeholders. The distractor was visible for 50 ms and was then extinguished for a further 50 ms, after which the target display was presented. For the target display, the placeholder crosses were replaced with line segments (0.5° in length) that were randomly oriented horizontally or vertically. Two lines were presented in white, and the third in the target colour. Participants had to report the orientation of the target-coloured line by pressing an assigned key on a standard keyboard. On three-quarters of the trials, a concurrent distractor was presented simultaneously with the target at one of the possible target locations. On the remaining trials, no concurrent distractor was presented. The concurrent distractor was drawn in red or green and had the same size, shape, and position as the early distractor. Thus, both distractor types were indistinguishable from each other, other than through the temporal position of their presentation (earlier than, or concurrently with, the target). The trial terminated when the participant made a response, in which case RT was recorded, or 1,000 ms had elapsed. All stimuli were then extinguished, and the next trial began after a 1,000-ms intertrial interval.

The colour of the early distractors was randomly determined on each trial with an equal likelihood of being red or green, as was the colour of the concurrent distractor. The position of the early distractor was randomly determined on each trial with an equal likelihood of being in any of the three target positions, as was the position of the target. The position of the concurrent distractor was similarly determined with the exception of a fourth possible position—namely, not present. The colour and positions of the distractors and targets were not predictive of each other. By coding colours according to whether they matched, or did not match, the target colour, and positions according to validity, this produced the trial types that are depicted in the top portion of Figure 2. Of note, trials with no concurrent distractor are an exception to this naming convention, as the absence of a distractor has neither a colour nor a position. Due to this exception, we analysed this data set using two separate designs, which are described below.

			Concurrent Distractor				
			Matching		Non-matching		
			Valid	Invalid	Valid	Invalid	None
Early Distractor	Matching	Valid	569	619	589	585	567
		Invalid	590	620	599	594	588
	Non-matching	Valid	571	628	587	580	582
		Invalid	583	625	594	586	585
	Exp 2	None	544	576	540	536	525

Figure 2. *A visual depiction of the performed analyses. The shaded cells were compared in Analysis 1 of Experiment 1. Analysis 2 in Experiment 1 compared rounded rectangles and rectangles to circles. The results of Experiment 2 are presented at the bottom of the table. Also included are the mean reaction times (in ms) for each trial type.*

Results and discussion

Error trials (7.78%) and trials for which RT did not fall within 2.5 standard deviations of a participant's mean (1.45%) were not included in the RT analyses that follow.

Analysis 1: Critical comparison and timing-proposal control condition. The first analysis excluded no-concurrent-distractor trials and assessed the spatial effects of both distractor types using a 2 (early-distractor colour: matching vs. nonmatching) × 2 (early-distractor position: valid vs. invalid) × 2 (concurrent-distractor colour: matching vs. nonmatching) × 2 (concurrent-distractor position: valid vs. invalid) within-subjects design (the shaded cells of Figure 2). The corresponding analysis of variance (ANOVA) on mean RT produced a significant main effect of early-distractor position, $F(1, 18) = 7.39$, $MSE = 624.90$, $p = .014$, and significant main effects of concurrent-distractor position, $F(1, 18) = 39.81$, $MSE = 723.55$, $p < .001$, and concurrent-distractor colour, $F(1, 18) = 17.40$, $MSE = 553.45$, $p = .001$, which were qualified by a significant concurrent-distractor colour by concurrent-distractor position interaction, $F(1, 18) = 32.05$, $MSE = 1{,}507.93$, $p < .001$. All other main effects and interactions were not significant at the level of $p = .05$, although some approached significance as discussed below. As can be seen in the plot of the Concurrent-Distractor Colour × Concurrent-Distractor Position interaction (Figure 3), and as confirmed by two paired-samples t tests, RTs were significantly slower following invalid matching concurrent distractors than following valid matching concurrent distractors, $t(18) = 6.72$, $p < .001$, and there was no such difference in RT for nonmatching concurrent distractors, $t(18) = 1.54$, $p = .142$. Thus, in answer to our primary question of interest, concurrent distractors can affect RTs in a spatial manner, but this effect is eliminated when the concurrent distractors possess no task-relevant features.

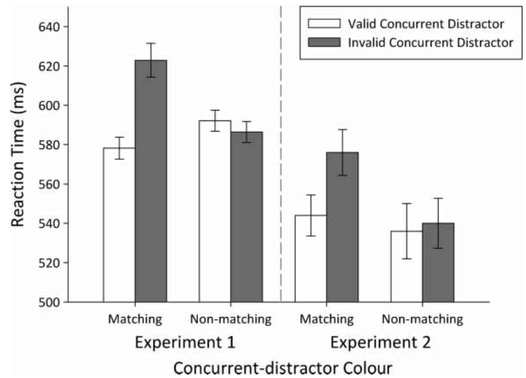

Figure 3. *Matching, but not nonmatching, concurrent distractors captured visual spatial attention in both Experiment 1 and Experiment 2. Error bars in all figures are 95% confidence intervals excluding between-subject variance (Cousineau, 2005).*

Interestingly, while there was a clear Colour × Position interaction for concurrent distractors, this interaction was not significant for early distractors ($F < 1$). Given the reliable main effect of early-distractor position, we can conclude that both matching and nonmatching early distractors generate spatial RT effects (of, respectively, $M = 9.96$ ms and $M = 5.63$ ms). The typical result in ACS early-distractor studies, however, is the elimination of spatial effects for nonmatching early distractors. One potential reason that we did not replicate this standard result is that, to some extent, the effects of early distractors may have been overridden by the concurrent distractors, which both appeared closer in time to the targets and remained visible for longer. In support of this possibility, the above ANOVA did produce a number of moderately nonsignificant interactions between early and concurrent distractors: Concurrent-Distractor Position × Concurrent-Distractor Colour × Early-Distractor Position, $F(1, 18) = 3.07$, $MSE = 426.64$, $p = .097$; Early-Distractor Position × Concurrent-Distractor Position, $F(1, 18) = 2.53$, $MSE = 616.93$, $p = .129$; Early-Distractor Colour × Concurrent-Distractor Position × Concurrent-Distractor Colour, $F(1, 18) = 1.99$, $MSE = 366.88$, $p = .175$; and Early-Distractor Colour × Concurrent-Distractor Colour, $F(1, 18) = 1.57$, $MSE = 594.52$, $p = .226$ (all other F-values < 1). More importantly, in this study we do have a no-concurrent-distractor condition where the effects of early distractors can be assessed independently of early/concurrent distractor interactions (the cells with circles in Figure 2). As predicted, a 2 (early-distractor colour) × 2 (early-distractor position) ANOVA on RTs in the no-concurrent-distractor trials produced the typical result observed in early-distractor ACS studies—namely, a significant main effect of early-distractor position, $F(1, 18) = 4.46$, $MSE = 614.03$, $p = .049$, and a significant Early-Distractor Position × Early-Distractor Colour interaction, $F(1, 18) = 6.62$, $MSE = 224.56$, $p = .019$. The main effect of early-distractor colour was not significant, $F(1, 18) = 1.65$, $MSE = 406.47$, $p = .215$. As can be seen in Figure 4, and as supported by two paired-samples t tests, RTs were significantly faster following valid matching early distractors than following invalid matching early distractors, $t(18) = 2.69$, $p = .015$, but there was no such effect for non-matching early distractors, $t(18) = 0.60$, $p = .559$. From these no-concurrent-distractor trials, we can conclude that early distractors behaved as would be predicted for a typical early-distractor ACS study.

Analysis 2: Filtering-cost proposal control condition. The second analysis included all trials, but data were collapsed across the concurrent-distractor position condition in order to assess whether matching and nonmatching concurrent distractors produce the RT costs normally reported in concurrent-distractor ACS studies (see Figure 2; round rectangles and square rectangles were compared against circles). The resulting 2 (early-distractor colour) × 2 (early-distractor position) × 3 (concurrent-distractor type: matching vs. nonmatching vs. none) design was analysed using a within-subjects ANOVA on RT, producing significant main effects of concurrent-distractor type, $F(2, 36) = 29.84$, $MSE = 479.26$, $p < .001$, and early-distractor position, $F(1, 18) = 5.28$, $MSE = 691.49$, $p = .034$. The remaining main effect and interactions were not significant: Concurrent-Distractor Type × Early-Distractor Colour, $F(2, 36) = 2.71$, $MSE = 245.73$, $p = .08$; Early-Distractor Colour × Early-Distractor Position, $F(1, 18) = 2.60$, $MSE = 405.47$, $p = .124$; Concurrent-Distractor Type × Early-Distractor Colour × Early-Distractor Position, $F(2, 36) = 1.76$, $MSE = 172.63$, $p = .187$; Concurrent-Distractor Type × Early-Distractor Position, $F(2, 36) = 1.52$, $MSE = 206.50$, $p = .232$; all other F-values < 1. As can be seen in Figure 5, and as confirmed by two paired-samples t tests, concurrent distractors caused significant increases in RT relative to no-concurrent-distractor trials, regardless of whether they matched the target colour,

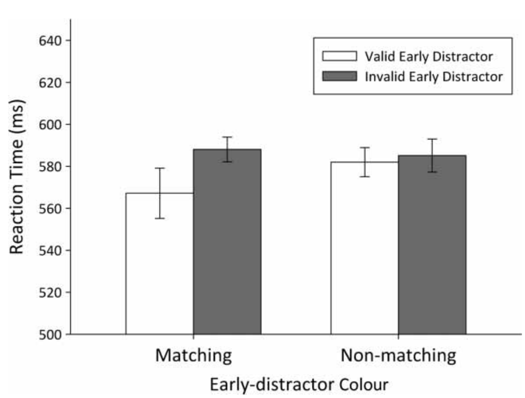

Figure 4. *On trials when no concurrent distractors were presented, early distractors produced the Early-Distractor Position × Early-Distractor Colour interaction observed in typical early-distractor attentional control setting studies; matching, but not nonmatching, early distractors have a spatial effect on reaction time.*

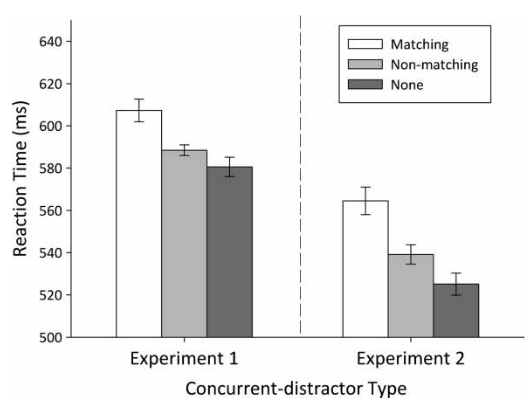

Figure 5. *Concurrent distractors in Experiments 1 and 2 produced the effect that is typically observed in concurrent-distractor attentional control setting studies; both matching and nonmatching concurrent distractors slowed reaction times relative to trials with no concurrent distractor.*

$t(18) = 6.20$, $p < .001$, or not, $t(18) = 3.67$, $p = .002$. Therefore, nonmatching concurrent distractors produce a reliable slowing of RT that, as was demonstrated in Analysis 1, is not spatially specific.

Speed–accuracy trade-offs

To assess whether speed–accuracy trade-offs could account for the observed effects of distractors on RT, the error rates from the conditions within Analyses 1 and 2 were also analysed. The 2 (early-distractor colour) × 2 (early-distractor position) × 2 (concurrent-distractor colour) × 2 (concurrent-distractor position) ANOVA from Analysis 1 was applied to the recorded error rates, revealing a significant interaction between only concurrent-distractor colour and concurrent-distractor position, $F(1, 18) = 7.32$, $MSE = 5.55$, $p = .014$. The main effect of concurrent-distractor position, $F(1, 18) = 3.14$, $MSE = 2.18$, $p = .093$, and all other main effects and interactions were not significant (all ps > .1). The significant interaction between concurrent-distractor colour and position probably resulted from participants having made fewer errors following valid matching concurrent distractors ($M = 5.9\%$) than following invalid matching concurrent distractors ($M = 10.3\%$), and comparable numbers of errors for valid and invalid nonmatching distractors ($M = 7.9\%$ and $M = 6.9\%$, respectively). Importantly, this interaction parallels the effect of concurrent distractors on RT. That is, in the conditions where distractors improved RT, distractors also improved accuracy, and, therefore, the effect of distractors on RT cannot be attributed to speed–accuracy trade-offs.

The 3 (concurrent-distractor type) × 2 (early-distractor colour) × 2 (early-distractor position) ANOVA from Analysis 2 was also applied to the recorded error rates. This analysis revealed a significant interaction between only concurrent-distractor type and early-distractor position, $F(2, 36) = 6.67$, $MSE = 0.59$, $p = .003$; all other main effects and interactions were not significant (ps > .1). Importantly, across the three concurrent-distractor types, if anything, accuracy improved from the matching-concurrent-distractor trials (8.8%) to the nonmatching-concurrent-distractor trials (7.3%) and to the no-concurrent-distractor trials (7.2%). Thus, as with Analysis 1, for those conditions where significant improvements in RT were observed, accuracy also improved (although not significantly), precluding any speed–accuracy trade-offs.

EXPERIMENT 2

The critical result from Experiment 1 was the demonstration that the effect of nonmatching concurrent distractors on RT was not spatially specific. Because this concurrent-distractor effect may have been biased by the early distractors that were also presented on every trial, much as the early-distractor effects were biased by the concurrent distractors, Experiment 2 was designed to assess the concurrent-distractor effects from Experiment 1 when no early distractors were present.

Method

Participants

Participants were 8 undergraduate students enrolled at the University of Toronto. A total of 2 participants received partial credit towards an introductory psychology course as compensation; the remaining 6 were not compensated. All participants were naive to purpose of the experiment.

Apparatus and procedure

Experiment 2 was the same as Experiment 1 except that (a) no early distractors were presented, and (b) 384 trials were completed by each participant.

Results and discussion

Error trials (8.14%) and trials for which RT did not fall within 2.5 standard deviations of a participant's mean (2.15%) were not included in the RT analyses that follow.

As with Experiment 1, two separate analyses were performed on RT. First, no-concurrent-distractor trials were removed from the data set, and the spatial effects of matching and nonmatching concurrent distractors were assessed using a 2 (concurrent-distractor colour) × 2 (concurrent-distractor position) within-subjects ANOVA on RT. This analysis revealed significant main effects of concurrent-distractor colour, $F(1, 7) = 28.38$, $MSE = 131.38$, $p = .001$, and concurrent-distractor position, $F(1, 7) = 5.74$, $MSE = 496.06$, $p = .048$, which were qualified by a significant two-way interaction, $F(1, 7) = 6.42$, $MSE = 235.95$, $p = .039$. As confirmed by two paired-samples *t* tests, matching concurrent distractors caused a significant spatial effect, $t(7) = 3.08$, $p = .018$, but nonmatching concurrent distractors did not, $t(7) = 0.61$, $p = .563$. The second analysis included all trials, but data were collapsed across the concurrent-distractor-position condition in order to assess whether matching and nonmatching concurrent distractors produce RT costs relative to no-concurrent-distractor trials. The 3 (concurrent-distractor type: matching vs. nonmatching vs. none) within-subjects ANOVA on RT revealed a significant main effect of concurrent-distractor type, $F(2, 14) = 49.37$, $MSE = 64.65$, $p < .001$. As confirmed by two paired-samples *t* tests, relative to no-concurrent-distractor trials, both matching, $t(7) = 8.57, p < .001$, and nonmatching concurrent distractors, $t(7) = 4.52$, $p = .003$, slowed RT. These results replicate the key findings from Experiment 1 that, although nonmatching concurrent distractors slow RT relative to no-concurrent-distractor trials, the effect is not specific to the location of the distractor.

A secondary analysis on error rates was also performed using the same two ANOVAs from the RT analyses, in order to assess whether the observed RT effects could be attributed to speed–accuracy trade-offs. The 2 (concurrent-distractor position) × 2 (concurrent-distractor type) ANOVA on error rates revealed no significant main effects (both ps > .1) and a nonsignificant two-way interaction, $F(1, 7) = 3.75$, $MSE = 0.43$, $p = .094$. This nonsignificant interaction paralleled the RT results with responses being more accurate following valid (7.6%) than following invalid (11.0%) matching concurrent distractors, thus precluding any speed–accuracy trade-offs. The 3 (concurrent-distractor type) ANOVA on error rate revealed a significant main effect, $F(2, 14) = 4.74$, $MSE = 0.22$, $p = .027$. Again, however, the effect of distractors on error rate paralleled the effect on RT: Response accuracy and speed both increased from matching-concurrent-distractor trials (9.9%) to nonmatching-concurrent-distractor trials (7.8%) and to no-concurrent-distractor trials (6.6%). Therefore, the observed effects of concurrent distractors on RT cannot be attributed to speed–accuracy trade-offs, as improvements in RT also resulted in improvements in response accuracy.

GENERAL DISCUSSION

The present study asked whether concurrent-distractor effects that persist despite ACSs result from a spatially specific cause, or whether the disruptions occur for targets appearing throughout the visual field. The purpose of this question was to resolve the seemingly discrepant conclusions that have emerged from early- and concurrent-distractor studies regarding the effect of ACSs on attentional capture by abrupt onsets. We first demonstrated that these discordant conclusions do not result from the types of stimuli used in each paradigm, as we observed both the typical ACS early-distractor effect and the typical concurrent-distractor effect using identical stimuli. We further demonstrated that although onset concurrent distractors cause a slowing of RT even when they do not match the attentional set, this slowing is not spatially specific. That is, even when the concurrent distractor appears at the same location as the target, RTs are slowed relative to trials with no concurrent distractor. Therefore, the cognitive disruption caused by a completely task-irrelevant onset distractor cannot be attributed to the capture of visual spatial attention, because the effect is not related to the spatial location of the distractor.

This result contradicts past studies that have concluded that spatial attentional capture is not contingent on top-down control (e.g., Kim & Cave, 1999), in particular those on which the timing proposal was based (Schreij et al., 2008; Theeuwes, 1994; Theeuwes et al., 2000). The present study, however, moves beyond this past work in two important ways. First, before comparing the timing proposal against the filtering-cost proposal, we were able to replicate the empirical results on which these two proposals were based (the noncontingent concurrent-distractor effect and the contingent early-distractor effect, respectively), making it unlikely that our new results can be attributed to differences between our paradigm and those of past studies. In addition, based on the contingent early-distractor effect (that nonmatching singleton early distractors did not capture attention), we know that our participants adopted a feature search mode specific to the target colour, rather than a singleton search mode for which any singleton would have captured attention (Bacon & Egeth, 1994). Past timing proposal studies, however, have not always replicated the typical contingent early-distractor effect. For example, Theeuwes et al. observed that irrelevant colour singletons captured attention when participants searched for a shape singleton if they were presented within the 100 ms preceding the target. It is possible, however, that colour singletons captured attention because their participants adopted a singleton search mode (see also Kim & Cave, 1999; Theeuwes, 1994). In the present study, we avoided the adoption of a singleton search mode by presenting both the target and distractors as colour singletons, forcing participants to search specifically for the target colour (see Bacon & Egeth, and Lamy & Egeth, 2003, for further elaboration of search mode). Using the paradigm of Theeuwes et al., Lamy and Egeth carefully controlled search mode and observed a similar result, but were unable to replicate the typical contingent spatial early-distractor effect (see their Experiment 4). When the typical contingent early-distractor effect has been replicated, irrelevant colour singletons and onsets do not capture attention, even when presented only 35 ms before the target (Chen & Mordkoff, 2007), or at the same time as the target, as in the present study.

Second, in the present study we differentiated spatial attentional capture from other forms of attentional capture. More specifically, one effect of a distractor on visual processing is to capture attention to the location of the distractor, speeding target detection when the target appears at that location. In addition to this capture of spatial attention, however, distractors also affect visual processing in other ways unrelated to spatial attention. For example, the identity of a distractor can interfere with the processing of the identity of the target, such as in flanker effects (Eriksen & Eriksen, 1974). As argued by Folk and Remington (1998), it is possible that such compatibility effects arise without the allocation of spatial attention, and, therefore, in the present study we differentiated between the capture of visual spatial attention and these other attentional effects. Thus, although the demonstration that the identity of irrelevant distractors can affect RT has previously been used to support the timing proposal (Theeuwes, 1994; Theeuwes et al., 2000), the effect of distractor identity on RT does not necessarily imply the capture of visual spatial attention. A similar argument applies to the findings by Schreij et al. (2008), who employed a task that was visually very similar to the typical early-distractor tasks with the important difference being that, on some trials, they also presented onset concurrent distractors at the same time as the target. These concurrent distractors slowed RT relative to trials without concurrent distractors, which the authors attributed to the capture of spatial attention. As we have shown in the present study, however (see also Folk & Remington; Lamy & Egeth, 2003), comparing concurrent-distractor to no-concurrent-distractor trials may reveal RT effects unrelated to the capture of visual spatial attention. While these studies demonstrate that ACSs do not allow people to completely ignore irrelevant distractors, they are compatible with the conclusion that ACSs completely prevent the capture of visual spatial attention.

Based on the results of the present study, therefore, we can reject the proposal that the discrepant findings between early- and concurrent-distractor tasks result from differences in the timing of irrelevant stimuli. Namely, in the present study, both matching early and matching concurrent onset distractors caused faster RTs when the target appeared at their locations. This spatial effect, however, was eliminated for both nonmatching early and nonmatching concurrent onset distractors. Thus, regardless of their timing, ACSs prevented all nonmatching onsets[1] from capturing visual spatial attention. Our results are compatible, however, with the filtering-cost proposal. Nonmatching distractors slow RT relative to when no distractor is present, and this effect may be due to the nonspatial filtering cost associated with the distractor item (Folk & Remington, 1998). Thus, while the capture of visual spatial attention by abrupt onsets is contingent on ACSs, irrelevant distractors can nevertheless compete for cognitive resources, causing slowed RTs.

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[1] Of note, the onset distractors used in the present study were also presented as colour singletons (relative to the other stimuli drawn in grey). It is possible that participants were able to ignore nonmatching onset distractors in the present study through the feature-based inhibition of the nonmatching colour (e.g., Lamy, Leber, & Egeth, 2004). Thus, it remains to be shown that noncolour-singleton (i.e., in this case grey) onsets can also be controlled through ACSs. Regardless, our conclusion that capture by onsets is contingent on top-down control settings is warranted—if capture by onsets was purely stimulus driven, stimuli that are onsets should always capture attention, regardless of their colour.

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