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Attentional capture by object appearance and disappearance

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In two experiments we examined whether the appearance of a new object has attentional priority over disappearance. Previous failures to show differences are possibly due to onsets and offsets always being presented as a sole visual transient. Rather than presenting each alone, we presented onset and offset singletons simultaneously with a display-wide luminance transient in order to force each to compete with other visual events. Results from Experiment 1 showed that targets associated with onsets accrued a reaction time benefit whilst targets associated with offsets did not. Experiment 2 showed that onsets attracted attention even when observers were attentionally set to look for offset. By contrast, offsets needed a relevant attentional set in order to attract attention. We argue that the appearance of an object has attentional priority over disappearance.

Keywords: Attention; Vision; Onset; Offset.

The perception and awareness of objects very much permeates our visual experience. One of the essential features of objects is that they can either appear in a scene (onset) or disappear (offset). Franconeri and Simons (2003) put forward the "behavioral urgency hypothesis" to account for the observation that certain dynamic events, such as onsetting stimuli, have a tendency to attract attention. The authors stated that a stimulus will only capture attention if it indicates an emerging threat that requires immediate action. "New objects, objects that move suddenly, and looming objects are all behaviorally important, and all strongly capture attention" (Franconeri & Simons, 2003, p. 1008; see also Abrams & Christ, 2005, and Franconeri & Simons, 2005, for debate). Clearly, an object that appears is of greater behavioural importance than one that disappears. One might therefore expect onsets to be processed, be identified, and initiate a response more rapidly than offsets.

The classic work of Yantis and Jonides (1984), in which a target item was associated with either an onset or an offset, is generally considered to be the first study to examine the relative efficacy with which appearance and disappearance attract attention. However, this work only allows an indirect comparison of each to be made. This is because the onsets and offsets in their experiments and follow-up work that this study initiated

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(e.g., Atchley, Kramer, & Hillstrom, 2000; Davoli, Suszko, & Abrams, 2007; Franconeri, Hollingworth, & Simons, 2005; Franconeri & Simons, 2003; Gibson, 1996; Humphreys, Olivers, & Noon, 2006; Jonides & Yantis, 1988; Yantis & Hillstrom, 1994; Yantis & Johnson, 1990; Yantis & Jonides, 1990) were not systematically equated with respect to the degree of perceptual change occurring at onset and offset locations (Martin-Emerson & Kramer, 1997; Miller, 1989).

An early study that does allow a direct comparison of onsets and offsets with respect to attentional capture was carried out by Theeuwes (1991). In a variant of a standard visual search task, observers were required to detect a target letter presented amongst three nontarget letters. Prior to the onset of the search display (e.g., 160 ms), a small black rectangle appeared either adjacent to the target or adjacent to one of the distractors. Results showed that reaction time (RT) was facilitated when the rectangle and the target spatially coincided relative to when they were displaced from each other, suggesting that the onset (i.e., rectangle) had captured spatial attention. However, in a second experiment Theeuwes found that an offsetting rectangle attracted attention to a comparable degree. Theeuwes concluded that "visual offsets are as effective as visual onsets in attracting attention to a location in space" (p. 89). Watson and Humphreys's study (1995) also allows a direct comparison of onsets and offsets. As with Theeuwes (1991), observers were required to detect a target letter presented amongst distractors. Critically, the letters were created either by the appearance or by the disappearance of short line segments. For instance, offsetting the upper and lower segments from a ⊟ symbol generated the letter "H", and, similarly, adding the same two segments to a ⊦ symbol generated the letter "E". In a series of five experiments, Watson and Humphreys found that targets generated by onsetting elements did not receive attentional priority compared with targets generated by offsetting elements. The authors thus concluded that onsets "neither guide nor gain automatic attention more efficiently than offsets" (p. 583). More recent work by Pratt and McAuliffe (2001) examined attentional capture by onsets and offsets within the precueing paradigm (e.g., Posner & Cohen, 1984). In the basic procedure, observers are usually required to identify or detect the presence of a target that occurs either on the left or on the right side of a centrally located fixation point. Prior to the presentation of the target (e.g., 100), an attention-capturing event (i.e., the "cue") occurs either on the same side as the subsequent target or on the other side. Pratt and McAuliffe's cues were small discs that could either appear or disappear. As with the findings of Theeuwes (1991) and Watson and Humphreys (1995), results showed no onset priority effect. That is, although both onsets and offsets attracted attention, RTs were no shorter for onset trials than for offset trials. The authors thus concluded that "both peripheral onset and offset cues produce covert shifts of attention, with no appreciable difference in their attention-capturing properties" (p. 189). Similar findings from studies that allow a direct comparison of onsets and offsets have also been reported by Chastain and Cheal (2001), and Riggio, Bello, and Umiltà (1998).

Vingilis-Jaremko, Ferber, and Pratt (2008) took a different approach to the issue by examining how onsets and offsets influence temporal order judgements (TOJs; Sternberg & Knoll, 1973). In TOJs, participants are presented with two temporally close or simultaneous signals and are asked to judge which of the two occurred first. Prior entry is the observation that given two simultaneous events, the event receiving an attentional bias will be reported as occurring first. Various models have been put forward to explain the mechanisms and processing involved in TOJs (e.g., Allan, 1975; Sternberg & Knoll, 1973; Ulrich, 1987), including accounts of which situations will give rise to prior-entry effects (Stelmach & Herdman, 1991). Vingilis-Jaremko et al. presented an onset or an offset transient to the left or right of a central fixation point. A line appeared 100 ms later either at the location of the transient or on the other side of fixation. After a brief delay of between 0 and 240 ms a second line appeared on the opposite side to the location of the first, and observers were required to indicate which of the two lines appeared first—that is, to make a TOJ. Results showed an equivalent prior entry effect, and hence equivalent capture, for the onset and offset transients. Vingilis-Jaremko et al. additionally examined what they called *prior exit* effects. That is, observers were also required to indicate which of two lines, present at the beginning of each trial, disappeared first. Results showed that when looking for offsets offset transients captured attention more effectively than onset transients. Indeed the prior exit effect was greater for offset transients than the *prior entry* effect was for onset transients. These results clearly reveal the influence of attentional control setting (Folk, Remington, & Johnston, 1992; see below) in capture by onsets and offsets.

One possible explanation for the general absence of an onset advantage in past studies is that the onset/offset cue was always a *sole visual transient*. That is, at the point in time at which the cue occurred no other visual event was presented. There is almost an inevitability of capture by a sole transient; a ceiling effect is likely to occur. This is analogous to a "one-shot" change blindness trial (e.g., Rensink, O'Regan, & Clark, 1997; Simons, 1996; Simons & Rensink, 2005) but one in which no "flicker" occurs; the change would effortlessly be detected regardless of whether the changing item was the appearance or disappearance of an object. In effect, the rapid attracting of attention by a sole onset or offset masks any subtle difference between the two in their relative ability to attract attention. This possibility is supported by work from Pratt and Hirshhorn (2003). Employing a variant of the precueing paradigm, observers were presented with onsetting and offsetting cues (i.e., discs) that occurred at the same time within the same trial. In other words, rather than comparing the effects of onsets and offsets between trials, the authors forced the onsets and offsets to compete with each other for attention simultaneously. Pratt and Hirshhorn found that targets presented adjacent to the onset disc accrued an RT advantage relative to targets presented adjacent to the offset disc. Pitting onsets against offsets in this manner, rather than presenting each as a sole visual transient, may have thus helped to reveal the difference in onset/offset capture. Indeed, Pratt and Trottier (2005) noted that onsets and offsets have similar attention capturing ability "save when the two cues are presented simultaneously at different locations (p. 773)". This is further supported by Pratt and Arnott (2008) who showed that the perceived spatial displacement of a visual probe induced by an adjacent transient (the "attentional repulsion effect"; Suzuki & Cavanagh, 1997) was greater when the transient was an onset than when it was an offset. Critically however, this only occurred when onsets and offsets occurred simultaneously. When each was presented alone between trials no larger repulsion effect for onsets occurred.

The problem of sole visual transients and ceiling effects can be circumvented by presenting a change in a display (e.g., an onset) simultaneous with a large task-irrelevant luminance transient. This is similar to a one-shot change blindness trial in which the visual display disappears momentarily before reappearing (e.g., Rensink et al., 1997; Simons, 1996; Simons & Rensink, 2005). Using this procedure, Cole and Liversedge (2006) assessed the degree to which an object that shifts its position towards an observer (i.e., looms) is subject to change blindness relative to object appearance. Results showed that object appearance attenuated change blindness relative to objects that loom. Cole and Liversedge argued that this showed attentional priority for new objects relative to looming objects (see also Cole, Kentridge, & Heywood, 2004; Cole, Kuhn, & Liversedge, 2007).

Work from Brockmole and Henderson (2005) and Boot, Kramer, and Peterson (2005) does, however, suggest that the sole visual transient account cannot fully explain the general lack of an onset advantage. Brockmole and Henderson (2005) investigated the prioritization of appearing and disappearing objects in real-world scenes by measuring eye movements towards the region of a scene that involved a change. These changes were made either during fixation, which resulted in a visual transient, or during a saccade, which, due to saccadic suppression, abolished any visible transients. Overall, their results showed that both object appearance and disappearances were fixated more often than chance would allow, suggesting that both types of change capture attention. However, onsets were fixated significantly more often than offsets. Additionally, object appearances captured the eyes regardless of whether they occurred during a fixation or a saccade. By contrast, object offsets were only prioritized when they were accompanied by a transient signal and when the offset revealed an occluded object. Brockmole and Henderson (2005) posited a possible reason for the onset–offset asymmetry. Onsets necessarily provide a stimulus to fixate whereas offsets do not; they may only reveal background. This explanation was supported by additional analysis showing that locations where an offset had occurred were fixated more frequently when the offset revealed a previously occluded object than when the offset only revealed background. Boot et al. (2005) also examined oculomotor capture by onsets and offset transients by assessing the degree to which each disrupts search for a "colour singleton" (e.g., Cole, Kuhn, Heywood, & Kentridge, 2009; Jonides & Yantis, 1988). Results showed that whereas onsets captured the eyes on a large percentage of trials, offsets did not. The authors also systematically assessed whether the location of an offset is less likely to be fixated because such an event may only reveal background, rather than a visible object to guide fixation. Displays consisted of six squares, some of which included a circle inside. The transient event on each trial was either the onset of a circle, appearing in an unoccupied square, or the offset of an already-present circle. Importantly, therefore, an offset always left a square present to be fixated. Results again showed oculomotor capture by onsets but not offsets.

Attentional capture by onsets and offsets has also been examined in the context of inhibition of return (IOR; Posner & Cohen, 1984). Theeuwes and Godijn (2002) made the point that IOR can be used as a means of determining whether a stimulus has captured attention since IOR occurs as a consequence of initial capture. Thus, for instance, Samuel and Weiner (2001) examined the temporal pattern of IOR following onsets and offsets. They found that whereas onsets produced the distinctive pattern of IOR (i.e., initial facilitation followed by inhibition), offsets produced IOR at much earlier temporal intervals between transient and target. Indeed, IOR was apparent at the earliest (i.e., 80-ms) transient–target gap for offsets. These findings suggest that onsets attract attention and hold it for longer than do offsets. This makes functional sense given the greater potential importance of a new object than one that disappears. Additionally, the procedure employed by Pratt and Hirshhorn (2003; described above) also revealed differences in the propensity with which onsets and offsets induce IOR. Concurring with the findings of Samuel and Weiner, IOR was also observed earlier for offsets.

One of the most novel approaches to the issue of onset–offset capture was reported by Welsh and Pratt (2008). Their primary aim was to examine whether a to-be-performed action influences the type of stimulus events that can attract attention. In their experiment, half the participants were required to make a reaching response to a target (located on a display monitor) whilst the other participants were required to indicate its location by pressing a response key on a standard computer keyboard. In addition to the response mode, the other important manipulation was whether the target appeared together with an onset distractor or an offset distractor. For key-press responses, results showed that both onsets and offsets attracted attention and to an equal degree. However, when a reaching response was required, only onsets captured attention. Welsh and Pratt argued that when planning a reaching response, the attention system is particularly sensitive to the appearance of an object because such an object may need acting upon. By contrast, offsets that occur in the "action environment" will not, of course, need acting upon; thus the system will not be as sensitive to offsets.

In sum, the notion that the attention system should prioritize onsets over offsets, due to their potentially greater importance, has received mixed support. In the current experiments we further examine whether onsets have priority over offsets with respect to attentional capture. Rather than having each presented as a sole visual transient, an onset or an offset was presented at the same time as a display-wide luminance transient. Specifically, an array of objects occurred in a display and disappeared briefly (i.e., 250 ms). Upon reappearance, either an additional new object joined the display (i.e., an onset) or one of the "old" objects did not reappear (i.e., an offset). The target was then presented 250 ms after display reappearance and occurred either at the location of the change (i.e., "valid" trials) or elsewhere in the display (i.e., "invalid" trials). This is therefore based on a standard attentional capture paradigm in which the cue is presented at the same location as a target or at a different location (e.g., Folk et al., 1992). Because the onsets and offsets in our displays were masked by a flicker, they were not sole visual transients and hence did not pop out from the display. This therefore enabled a more sensitive measurement of any difference between appearance and disappearance with respect to attentional priority.

An additional aim was to examine any capture effects in the context of *contingent voluntary orienting* (Folk, et al., 1992). Folk et al. argued that the deployment of attention is largely dependent upon an observer's "attentional control settings"—that is, their goal-directed attentional set. Support for this notion came from their experiments showing that the propensity with which a visual stimulus attracts attention is contingent on the stimulus sharing some property that is relevant to an observer's task. For instance, a nominally "task irrelevant" colour cue is likely to capture attention when the target is defined by colour. Although one might assume the cue to be irrelevant, capture is occurring as a result of a subtle top-down attentional set. In the present study we examine attentional capture by onsets and offsets when attentional control is set to favour both onsets and offsets in Experiment 1 and only the offsets in Experiment 2.

EXPERIMENT 1

In Experiment 1 either a new object appeared or an old object disappeared amongst an array of seven old objects (see Figure 1). Participants were required to detect the presence of luminance change that occurred at one of eight small squares present in the display. This task would therefore have induced participants to adopt a specific form of attentional set referred to as *singleton detection mode*. Bacon and Egeth (1994) showed that a unique element (i.e., a "singleton") in a visual scene is likely to attract attention if observers are required to look for a target that is also a singleton. Thus, for instance, a circle presented amongst a number of squares will attract attention if the target is a vertical line amongst horizontal line distractors. Because the target line is itself a singleton capture will occur. By contrast, the same circle will no longer attract attention if the target is not a singleton. The present experiment was designed to examine whether onsets and offsets can each benefit from this particular type of attentional set to produce capture by both. The notion that control settings can reveal differences in salience of visual events is apparent in some of the work on attentional control settings. For instance, Folk, Remington, and Wright (1994; Experiment 4) found that onset cues captured attention to the same degree when participants were looking for both onset and motion targets. By contrast, although motion cues captured attention when participants were looking for motion targets, the capture effect was significantly reduced when participants were looking for onset targets. This shows that when compared with motion, the onset cue had a greater propensity towards attracting attention. On the basis of a follow-up experiment, Folk et al. suggested that this was a form of salience-based selection (based on top-down control). The important point in the context of the present experiment is that attentional control settings can reveal differences in the attention-capturing ability of different visual events.

Method

Participants

A total of 18 undergraduate psychology students took part in return for payment.

Stimuli and apparatus

The objects were contour drawings of varying shape, colour, and luminance and were presented inside a

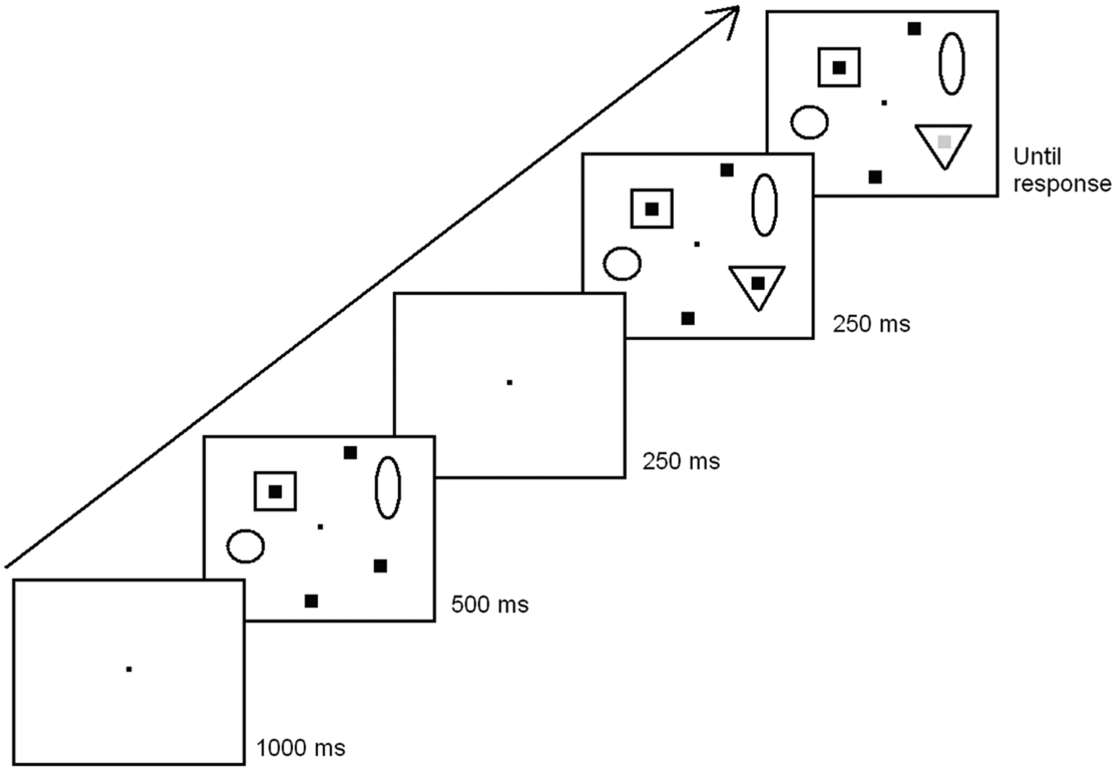

Figure 1. *The trial sequence in Experiment 1. The figure shows an onset trial in which an additional object joins the display when all the items reappear. In this example, the target, a change in luminance at one of the small squares, occurs at the same location as the onset. Offset trials were identical with the exception that one of the old objects does not reappear (as well as no new object appearing). Experiment 2 was identical to this procedure with the exception that one of the small squares offsets in the final frame rather than changing luminance. For clarity of image, the figure shows 3 (then 4) objects and 4 potential target locations; there were actually 7 or 8 objects and 8 possible target locations. Also note that the stimuli shown here are not to scale.*

virtual rectangle measuring 8.5° in height and 10.6° in width. Because of the large global luminance transient that occurs as a result of the flicker, it is not necessary to match all objects with respect to luminance and colour to equate for salience. Indeed, we generated objects in this way in order to create a display of random nonhomogeneous items. Furthermore, as Figure 1 shows, the objects in our displays occurred in pseudorandom locations. Although it is more usual to present objects at nonrandom locations (i.e., evenly spaced out on the edge of an imaginary circle), a nonrandom arrangement of objects would have meant the presence of a salient gap at the beginning of onset trials at the location where the onset would appear. This would not only signal to the observer the location of the onset but the gap itself may serve as an attention-capturing stimulus. Each shape measured between 2.8° and 0.9° in both height and width and was presented against a light-purple background measuring 46.3 cd/m^2 in luminance. The colour coordinates of the background, measured in Lu′v′ colour space (using a Cambridge Research Systems ColorCal chromameter), were 0.208 (u′) and 0.469 (v′). Presenting contour objects ensured that targets in all trials were presented on the same coloured background. Thus, all targets were of the same contrast and hence equally perceptible. No object occluded any other object. The lines comprising the objects were either 0.034° or 0.069° thick. The target was a small square measuring 0.069° along each side and was grey measuring 56 cd/m^2 in luminance. Distractor squares (i.e., nontargets) were identical to the target with the exception that they measured 27 cd/m^2 in luminance. The experiment was carried out in a dimly lit room and was driven by a Pentium PC running at 60 Hz linked to a standard CRT monitor.

Design and procedure

A 2×2 fully repeated measures design was employed. The first factor was the singleton type (onset or offset) that occurred within a trial. The second factor was target location; targets appeared either at the singleton location or elsewhere. The trial sequence is shown in Figure 1. Each trial began with the presentation of a fixation point for 1,000 ms before the appearance of the first image, containing either seven (onset trials) or eight (offset trials) objects, for 500 ms. A blank frame then followed for 250 ms before the display reappeared. The target then occurred 250 ms later. The eight distractor squares were present in each trial and appeared, disappeared, and reappeared together with all display objects. When the seven objects initially appeared in the onset condition, five of the distractor squares were located outside objects and three inside. When the new object occurred four of these squares were now located outside objects and four inside. For offset trials four squares were located inside four objects and four outside of objects. When the offset occurred five squares subsequently lay outside of the objects. The target frame remained until the participant responded. The beginning of a trial was initiated by the participant's response on the previous trial. Participants were explicitly told to ignore the figures and events occurring in the "background", just to simply respond as soon as they detected the change in brightness at one of the small squares. They were also instructed to maintain fixation for the entire duration of each trial and that although speed was paramount they should refrain from responding on "catch" trials. Observers were seated approximately 80 cm from the display. A total of 24 trials were presented where a target appeared at an onset location and 24 where a target appeared at an offset location. A total of 336 trials were presented where a target appeared at a nonsingleton location, equally divided between onset and offset trials. Thus there was a one in eight chance of the target appearing at the onset/offset object location. A further 96 (20%) trials were presented where no target appeared. Catch trials occurred equally between onset trials and offset trials. Hence, a total of 480 trials were presented in the experiment.

Results and discussion

All RTs lying outside 2 standard deviations for each participant's condition mean were omitted from analysis. This accounted for 5.5% of the data. Mean response for catch trials was 6.2%. Figure 2 shows mean RTs for each of the four conditions. An analysis of variance (ANOVA), with singleton type (onset or offset) and target location (valid or invalid) as within-participants factors, revealed that although participants' RTs on onset trials were somewhat faster than those on offset trials, this difference did not reach statistical significance, $F(1,\ 17) = 3.7$, $p < .08$. The main effect of validity was, however, significant, $F(1,\ 17) = 5.9$, $p < .05$, as was the interaction, $F(1,\ 17) = 10.4$, $p < .01$. Figure 2 suggests that the significant main effect of validity is due to facilitation for targets at valid locations in the onset condition. Analysis of the simple effect for both singleton conditions (i.e., onsets and

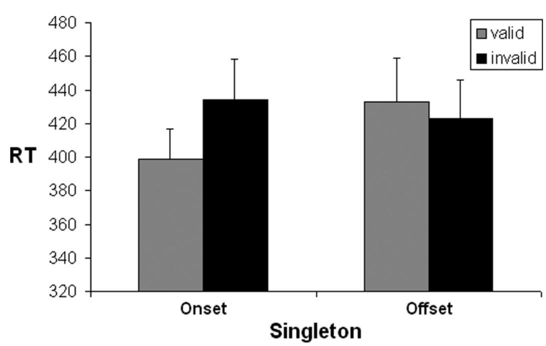

Figure 2. *Results from Experiment 1. Mean reaction time (RT, in ms) for each singleton type (onset or offset) and target location (valid or invalid).*

offsets), revealed that whilst new onsets captured attention, $t(17) = 3.6$, $p < .01$, offsets failed to do so, $t(17) = 1.3$, $p < .2$. Indeed, although nonsignificant, RTs were longer for trials in which the target appeared at the offsetting object.

One could argue that the onset advantage is due to an artefact caused by having targets occurring both inside and outside the contour boundaries of objects. Targets may have been, for instance, more easily localized and hence responded to more rapidly when positioned inside an object than when outside. Since targets for onset valid trials were always located inside an object whereas offset valid trials were always located outside an object the difference between valid and invalid for the offset condition could have been less pronounced than in the onset condition. We therefore performed an additional analysis in which we only used RTs for trials in which the target appeared inside an object for the onset condition and trials in which the target only appeared outside an object for the offset condition. Results again showed an onset singleton advantage where onset valid trials RTs were shorter than onset invalid trials (399 ms, $SD = 75$, and 427 ms, $SD = 105$, respectively), $t(17) = 3.1$, $p < .01$. By contrast, RTs for offset valid trials were slightly longer than those for offset invalid trials (433 ms, $SD = 110$, and 425 ms, $SD = 96$, respectively), $t(17) = 1.1$, $p < .35$.

The results from Experiment 1 unambiguously show that targets occurring at the location of an onset were subject to facilitated RT. By contrast, targets associated with offset did not accrue any benefit. This suggests that object appearance had priority over object disappearance. Importantly, onset priority has occurred when participants were in singleton detection mode, an attentional setting that should have aided capture by both onsets and offsets. However, only onsets were able to take advantage of this attentional set.

EXPERIMENT 2

Experiment 1 showed that whilst an onsetting object was able to attract attention an offsetting object failed to do so. In Experiment 2 we examined whether object appearance would capture attention when observers had an attentional set in favour of offsets. This was achieved by replicating the design employed in Experiment 1 with the sole exception that participants were required to detect the offset of a small square. Hence, rather than observers' singleton detection mode being set for a neutral singleton (i.e., luminance change), as in Experiment 1, they had an attentional set biased against onsets and in favour of offsets. This is therefore a stringent test of the onset priority effect. If onsets still attract attention under these conditions, one can have greater confidence in the onset advantage.

Method

Participants

A total of 20 undergraduate psychology students took part in return for payment. None of the participants took part in Experiment 1.

Stimuli and apparatus

All aspects of the stimuli and apparatus were as described previously.

Design and procedure

All aspects of these were also as described for Experiment 1. Thus, a 2×2 fully repeated measures design was employed with singleton type (onset or offset) and target location (at the singleton location or elsewhere) as factors. The only difference between Experiments 1 and 2 was that one of the eight probe squares disappeared instead of changing luminance, and observers were instructed to respond as soon as they detected one of the squares disappearing.

Results and discussion

We omitted RTs lying outside 2 standard deviations for each participant's condition mean, which accounted for 5.8% of responses. Mean response for catch trials was 5.9%. Figure 3 shows mean RTs for each of the four conditions. An ANOVA with singleton type (onset or

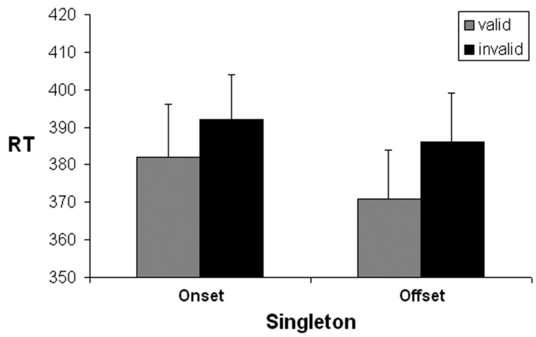

Figure 3. *Results from Experiment 2. Mean reaction time (RT, in ms) for each singleton type (onset or offset) and target location (valid or invalid).*

offset) and target location (at the singleton location or elsewhere) as within-participants factors found a significant main effect of singleton type, $F(1, 19) = 7.5, p < .05$. This shows that RTs were shorter for offset trials than for onset trials. This is probably due to observers adopting an attentional set for offset. A significant main effect of target location also occurred, $F(1, 19) = 15.8$, $p < .001$. However, unlike in Experiment 1, the interaction was not significant, $F(1, 19) < 1$. Analysis of the target location effect for the onset and offset singleton conditions revealed that both onsets and offsets captured attention, $t(19) = 2.2$, $p < .05$, and $t(19) = 2.6$, $p < .05$, respectively. As with Experiment 1, we carried out the same additional analysis to examine a potential artefact caused by targets occurring inside and outside objects. Again we only analysed trials in which the target appeared inside an object for the onset condition and outside an object for the offset condition. Results showed that RTs for onset valid trials were shorter than those for onset invalid trials (382 ms, $SD = 62$, and 401 ms, $SD = 61$, respectively), $t(19) = 3.1$, $p < .01$. RTs for offset valid trials were also shorter than those for offset invalid trials (371 ms, $SD = 57$, and 379 ms, $SD = 54$, respectively), $t(17) = 1.7$, although this did not reach conventional statistical significance, $p < .1$.

The results from Experiment 2 clearly show that both onsets and offsets captured attention. This is perhaps not so surprising for offsets given that participants' attentional control was set to detect offset. However, the results are particularly intriguing for onsets. The appearance of a new object attracted attention despite the attentional set for offsets. This provides further evidence that object appearance has priority over object disappearance.

GENERAL DISCUSSION

In two experiments we have examined whether the appearance of an object has attentional priority over disappearance. Incorporating both the "flicker" paradigm (e.g., Simons & Rensink, 2005) and contingent attentional capture (Folk, et al., 1992), we presented onset and offset singletons amongst an array of old objects. Experiment 1 showed that targets associated with onsets were subject to shorter RTs than were targets presented elsewhere in the display. However, no such facilitation was observed for offsets. This occurred despite participants being in singleton detection mode (Bacon & Egeth, 1994), which should have favoured both onsets and offsets. One can say that whereas onsets were able to benefit from this attentional set, offsets were not. Experiment 2 showed that onsets attracted attention even when observers were attentionally set to detect offset. By contrast, offsets needed the benefit of an attentional control setting for offset in order to attract attention.

These data thus demonstrate that object appearance has priority over disappearance. This in turn provides support for Franconeri and Simons's (2003) behavioural urgency hypothesis. A visual event is likely to capture attention if it indicates a potential need for immediate action. As we set out in the introduction, object appearance might therefore be expected to be processed, be identified, and initiate action more rapidly than offsets. This type of notion has long been appreciated within vision research. For instance, Titchener (1901) wrote that, "The moving, the new and the sudden are all possible—even probable—sources of danger" (p.209). Additionally, the present findings provide support for the similar notion that object onset has a special status within visual attention (e.g., Cole et al., 2004; Cole, Heywood, & Kentridge, 2005; Yantis, 1993).

We posited that previous failures to show an onset advantage (e.g., Chastain & Cheal, 2001; Pratt & McAuliffe, 2001; Theeuwes, 1991; Watson & Humphreys, 1995) are partly due to onsets and offsets being presented as sole visual transients. Such transients are likely to induce a rapid shift in attention irrespective of whether they are onsets or offsets, thus leaving no room to tease apart any capture differences of each. By contrast, we forced onsets and offsets to simultaneously compete with other visual transients during a "flicker" in an attempt to reduce what might be viewed as an attentional capture ceiling effect in past studies. Employing a flicker type display also circumvents the problem of equating sensory change at the onsets and offsets. In order to effectively examine the relative efficacy of onset and offsets in terms of attentional capture, the onsetting stimulus needs to, at the very least, be the same stimulus that offsets and vice versa. This ensures that, pixel for pixel, the same degree of change occurs in both conditions (Boot et al., 2005). However, this alone will not guarantee parity of low-level sensory change. For instance, forward luminance masking can occur at the location of an offset such that it will be perceived to exist after its physical disappearance (Gellatly & Cole, 2000; Gellatly, Cole, & Blurton, 1999; and Gibson, 1996; see also Di Lollo, Enns, Yantis, & Dechief, 2000). Employing a flicker method controls for sensory factors; because of the large display-wide luminance change brought about by the flickering scene, the relatively small transient change that occurs at the location of the onset/offset location is masked. Furthermore, since the target does not occur until 500 ms after display offset local masking/persistence is unlikely to be occurring.

Controlling for luminance change by briefly offsetting old objects has been employed by a number of authors (e.g., Brockmole & Henderson, 2005; Cole, Kentridge, Gellatly, & Heywood, 2003; Cole & Liversedge, 2006; Davoli et al., 2007). Because all new object appearance and old object reappearance occurs in the same manner the sensory transients that accompany new and old objects are identical. A related procedure was employed by Franconeri et al. (2005) who also investigated whether new objects can capture attention in the absence of a unique sensory transient. In their experiment the transient usually associated with object appearance was hidden by a large "annulus" that passed over a display of objects, briefly occluding each. A new object was then revealed simultaneous with the reappearance of the original objects. Unlike the present experiments, Franconeri et al. found that under these conditions new objects did not attract attention. However, using the annulus method, Cole and Kuhn (in press) showed that an onset cue presented in a precueing-type display (e.g., Posner & Cohen, 1984) did capture attention (see also Davoli et al., 2007).

Because the new objects in the present experiments attracted attention in the absence of a unique sensory transient, these findings suggest that attentional capture occurred at the relatively high level at which objects are represented. In other words, capture may have occurred via representations of *object-files* (Kahneman, Treisman, & Gibbs, 1992). According to Kahneman et al., representations of a subset of all visible objects are continuously updated via cognitive mechanisms that enable each to retain coherence over space and time. Indeed, our new objects were new in the sense of their past history within the display (rather than any unique luminance transient).

Although our primary aim was to examine the issue of onsets and offsets in attentional capture, the present results also reveal an interesting finding regarding contingent attentional capture (Folk et al., 1992). Specifically, Experiment 2 showed that an onset can attract attention even when observers are set to detect offset. This is contrary to the basic assumption of attentional control settings and some of the work in this field. For instance, Atchley et al. (2000) found that when looking for offsets, offset transients attracted attention but onsets did not. It is not immediately evident why this difference between Atchley et al.'s and the present study occurred.

It may simply be that in the present Experiment 2 (and indeed Experiment 1) singleton detection mode would have been adopted, and the onset item was itself a singleton. The combination of onset priority and an appropriate top-down set may have been enough to allow onset capture.

In conclusion, the central finding from the present work is that object appearance has attentional priority over disappearance. Onsets were able to benefit from participants being in singleton detection mode whereas offsets were not. Furthermore, onsets attracted attention even when participants were set to detect offset.

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