Detectability of onsets versus offsets in the change detection paradigm

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The human visual system is particularly sensitive to abrupt onset of new objects that appear in the visual field. Onsets have been shown to capture attention even when other transients simultaneously occur. This has led some authors to argue for the special role that object onset plays in attentional capture. However, evidence from the change detection paradigm appears contradictory to such findings. Studies of change blindness demonstrate that the onset of new objects can often go unnoticed. Assessing the relative detectability of onsets compared with other visual transients in a change detection procedure may help resolve this contradiction. We report the results of four experiments investigating the efficacy with which onsets capture attention compared with offsets. In Experiment 1, we employed a standard flicker procedure and assessed whether participants were more likely to detect the change following a frame containing an onset or following a frame containing an offset. In Experiment 2, we employed the one-shot method and investigated whether participants detected more onsets or offsets. Experiment 3 used the same method but assessed whether onsets would be detected more rapidly than offsets. In Experiment 4, we investigated whether the effect obtained in Experiments 1-3 using simple shapes would replicate when images of real-world objects were used. Results showed that onsets were less susceptible to change blindness than were offsets. We argue that the preservation of information is greater in onsets than in offsets.

Keywords: change detection, attention, onsets, offsets, vision

Introduction

Introspection suggests that the human visual system is particularly sensitive to the detection of abrupt change that suddenly occurs in the visual field. For example, on the whole, a driver's attention is quickly captured by the sudden appearance of a child stepping out from behind a stationary vehicle. Indeed, there is an abundance of research suggesting that the abrupt onset of a new object elicits stimulus-driven capture of visual attention (e.g., Gellatly & Cole, 2000; Jonides, 1981; Jonides & Yantis, 1988). This makes functionally adaptive sense: organisms possessing the ability to rapidly detect and process an abrupt onset would have a greater chance of surviving and reproducing.

The primacy of onsets in capturing attention has been shown most conclusively in the *onset singleton task* (Jonides & Yantis, 1988; Yantis & Gibson, 1994; Yantis & Hillstrom, 1994; Yantis & Johnson, 1990; Yantis & Jonides, 1984). The basic paradigm involves the detection of a target letter among distractors in a standard visual search task. The crucial aspect of the procedure is the creation of one so-called onset item and several no-onset items. The search display is preceded by a placeholder display made up of block figure 8's positioned in a circular formation (see Figure 1a and 1b). After a short period (e.g., 500 ms), the figure 8's either disappear or shed a subset of their segments so that they are transformed into letters. Such items constitute no-onset stimuli because these have been created by virtue of segments offsetting rather than anything onsetting. At the same time as no-onset items are created, a further item (i.e., another letter) appears at a previously unoccupied location. This item constitutes an onset stimulus because it has been created by onsetting segments. Set size is manipulated whereby, for instance, 3 or 7 letters are created subsequent to the placeholder display.

The participants' task is to detect a target letter as quickly as possible. Importantly, the target is no more likely to be the onset item than it is any other (i.e., no-onset) item in the display. Hence, it does not benefit participants to direct attention to the abrupt onset letter first; how an item is created is task irrelevant.

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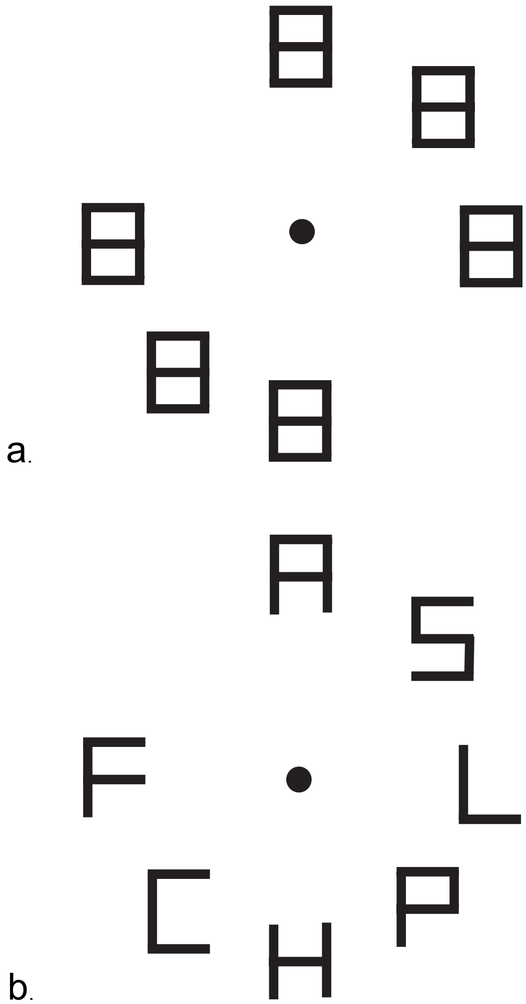

Figure 1. a. The placeholder display used in the onset singleton task. b. The placeholder display is replaced by the search display (shown here for set size 7). The offsetting of some of the figure 8 segments creates 6 no-onset items. Onsetting segments create a single onset item (letter P).

Results consistently show that response time (RT) to detect a target letter is reduced when the letter happens to be an onset item compared to when a target happens to be one of the no-onset items. Furthermore, when the target is a no-onset item, RT increases dependent upon the number of distractor letters present, but stays virtually constant when the target is the onset item. In the parlance of visual search work, the onset item is said to be detected preattentively. In other words, the onset letter receives attentional priority before any of the no-onset letters. This effect demonstrates that the new object (i.e., onset letter) receives attentional priority regardless of how many other transients occur simultaneously.[1] This principle is apparent when one considers that for set size 7, transients occur at six other locations. Additionally, Gellatly, Cole, and Blurton (1999) demonstrated attentional capture by the onset singleton even when luminance transients occurred continuously and equally across the whole display. Indeed, Enns, Austen, Di Lollo, Rauschenberger, and Yantis (2001) have shown that luminance changes compete only weakly with the appearance of a new object.

However, the primacy of onsets has not gone unchallenged. For example, Yantis and Jonides (1990) subsequently showed that an onset will not necessarily capture attention if an observer has attention focused at another location. Thus, capture may not be absolute but modulated by what Folk, Remington, and Johnston (1992) call the "attentional control settings" employed by the observer. Folk et al. argued that the automatic capture of attention by a stimulus is contingent upon the stimulus sharing a feature property that is relevant in performing a target task. For example, luminance change may not capture attention if the target is defined by a property other than luminance change. Thus, Folk et al. (1992) propose that abrupt object onset has no special role with regard to attentional capture (see also Miller, 1989, and Watson & Humphreys, 1995).

Findings from the change detection paradigm also challenge the notion that the visual system is particularly sensitive to the appearance of new objects. Change blindness studies (e.g., O'Regan, Rensink, & Clark, 1999; Simons, 1996) have shown that observers typically miss "obvious" changes in the visual field if other transients occur simultaneously, even to the extent of failing to notice the onset of large objects. This anomaly could be explained by pointing to the fact that the visual transient, which normally alerts the system to the location of an abrupt onset, is eliminated in change detection studies. Indeed, detecting an onset in the absence of other simultaneous transients is trivially easy. In other words, one could argue that new objects do not capture attention in change detection tasks because they have lost the advantage of being the only transient to occur. However, results from the onset singleton task demonstrate that onsets can capture attention independently of their status as visual transients. That is, a new object being the only transient to occur is not a necessary condition of capture. Indeed, it is something of a paradox that new objects often go unnoticed in change detection tasks given that the onset singleton task demonstrates efficient capture by new objects independent of the number of simultaneous competing transients.

The principle aim of this research was to investigate the relative detectability of onsets compared with offsets in the change detection paradigm. If the visual system is particularly sensitive to the onset of a new object, then onsets should be better detected than offsets. If, however, object onset is no more special than any other change that can occur in the visual field, then onsets should not be more efficiently detected. Pitting one kind of change against other changes will also provide evidence of which stimulus attributes are likely to be retained and which are likely to be lost in the detection of change. Given that appearance and disappearance of stimuli are perhaps the most common forms of change in change detection experiments, surprisingly few studies have investigated the relative detectability of each. Indeed, to our knowledge, Mondy and Coltheart (2000) provide the only systematic investigation of onsets and offsets using the change detection paradigm. They found that detection of deletions was greater than the detection of addition to images of natural scenes. This lack of published research perhaps reflects the difficulty authors have had in reliably demonstrating any differences.

One of the more novel aspects of change blindness research is the number of experiments that have been conducted using real-world scenes. Although this results in greater ecological validity, it may also lead to effects being contaminated by confounds. For example, Mondy and Coltheart's (2000) work involved changes occurring to objects of differential interest. Because changes to objects of central interest are more readily detected than changes occurring for objects of marginal interest (Rensink, O'Regan, & Clark, 1997; Simons, 2000), it is unclear how this might interact with the detection of onsets/offsets. Furthermore, detection tasks involving real-world scenes are further contaminated by higher-order schematic knowledge of such stimuli, as well as being mediated by semantic informativeness (Hollingworth & Henderson, 2000). Again, it is unclear how this knowledge might interact with onset/offset effects. Simons (1996) has also found that participants are able to use the strategy of naming items in a change detection display to assist detection. Therefore, we felt that in order to understand general principles of change detection, more conventional stimulus displays would be more appropriate. Thus, in Experiments 1-3, we used simple shapes in order to minimize these potential confounds (Figure 2). We then assessed (in Experiment 4) whether the effects observed in these three experiments would translate to displays using real world objects.

In Experiment 1, we employed the *continual alternation flicker* paradigm to investigate whether observers are more likely to detect a change to a display following the onset of an object or following its offset. In other words, is it appearance or disappearance that finally alerts an observer to change? In Experiment 2, we addressed the onset/offset issue by using the *one-shot* paradigm and assessing whether change detection accuracy is greater when an object appears or disappears. In Experiment 3, we again used the one-shot method and asked whether any differences in detection accuracy between onsets and offsets observed in Experiment 2 would be reflected in differences in RT. We also used Experiment 3 to examine levels of confidence in detecting onsets and offsets. Finally, Experiment 4 replicated the procedure employed in Experiment 2 with the exception that images of real household objects were used.

Experiment 1

In our first experiment, we employed a standard flicker procedure and assessed whether observers are more likely to detect the change following the onset of an object or an offset. Given the arguments stated above concerning the selection priority of object onset, one might expect the detection of change to occur with greater frequency following the onset of an object rather than an offset. Participants viewed the type of stimuli shown in Figure 2 and were asked to indicate as quickly as possible when they detected the change.

Method

Participants

Nine undergraduate psychology students from the University of Keele took part in the experiment and reported normal or corrected-to-normal visual acuity. Each took part as partial fulfillment of a course requirement.

Stimuli and apparatus

Between 18 and 24 objects were presented inside an imaginary rectangle centered at fixation (see Figure 2). The rectangle measured 8.5° of visual angle in height and 10.6° in width. Objects could be squares, rectangles, circles, diamonds, triangles, and ellipses of varying color and luminance. Each was sized between 2.8° and 0.9° in height and width and was presented against a uniform light purple background.

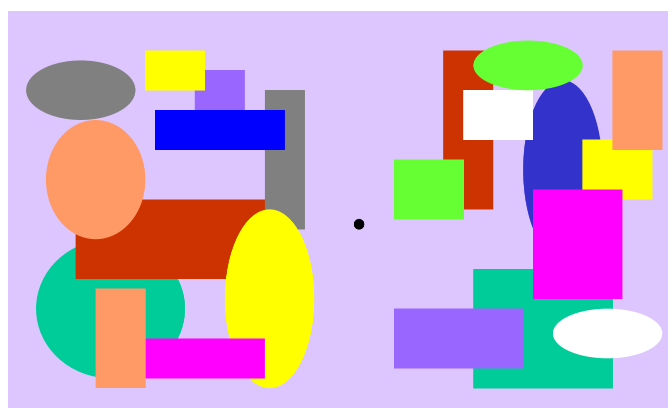

Figure 2. An example of the stimulus display used in Experiments 1-3.

The objects presented in each trial were chosen pseudo-randomly with the restriction that each was arranged so that they formed two groups either side of fixation. An approximately equal number of objects appeared on either side and each object could either occlude other objects or be occluded itself. Finally, no one object possessed a unique color. As Mondy and Coltheart (2000) have pointed out, such an object would constitute a color singleton and may pop out. The experiment was driven by one of two pentium PCs running at 60 Hz linked to a standard color monitor. The experiment was carried out in one of two dimly lit rooms and formed part of a set of vision experiments lasting no longer than 2 hr.

Design and procedure

A single-variable, two-alternative forced-choice procedure was used. Participants viewed continual alternation of displays and were informed that a single change occurs on every trial either to the left or to the right of the central fixation point. They were not informed of the nature of the change, only that "something changes across frames." Participants were asked to fixate the central point at the beginning of each trial but were then free to scan the image for the change. They were asked to respond as quickly as possible when they had detected the change but were told that accuracy of their left/right decisions was important. Participants responded by pressing either the back-slash or forward-slash buttons on a standard U.K. keyboard. Each stimulus frame was displayed for 1200 ms with intervening 600 ms blank frames. The beginning of a trial was initiated by the participants' responses on the previous trial. The frame pairs within each trial were identical with the sole exception that one had an object missing. There were 128 trials presented. The change occurred on the left in 64 trials and on the right in the remaining 64. Demonstration trials were shown, followed by 16 practice trials. Participants were positioned with their head located approximately 80 cm from the monitor and asked to minimize head and body movement. The program driving the experiment offered participants a break after 64 trials.

Results

For technical reasons, only 7 of the 9 participants completed all 128 trials with the other 2 completing part of the experiment.[2] Only correct responses were analyzed; errors accounted for 3.3% of the data. Participants' correct responses were categorized according to whether they responded during the presentation of an onset frame or an offset frame. Overall mean RT for all correct responses was 7.7 seconds, with a range of 366 ms to 70.8 seconds. Figure 3 shows the distribution of responses for the duration of onset and offset frames. Both onset and offset RT within each frame duration show a positive skew reflecting the fact that most responses were made within 600 ms of a frame onset. This makes heuristic sense because one would expect a participant to wait as short a time as possible to respond after detecting an onset/offset. Furthermore, responses during blank frames were also infrequent making up 1.5% of correct RTs. Only 1.5% of responses occurred within the first 200 ms of frame onset. Again, one might expect this given that participants would be unlikely to respond within 200 ms of perceptually detecting a change.

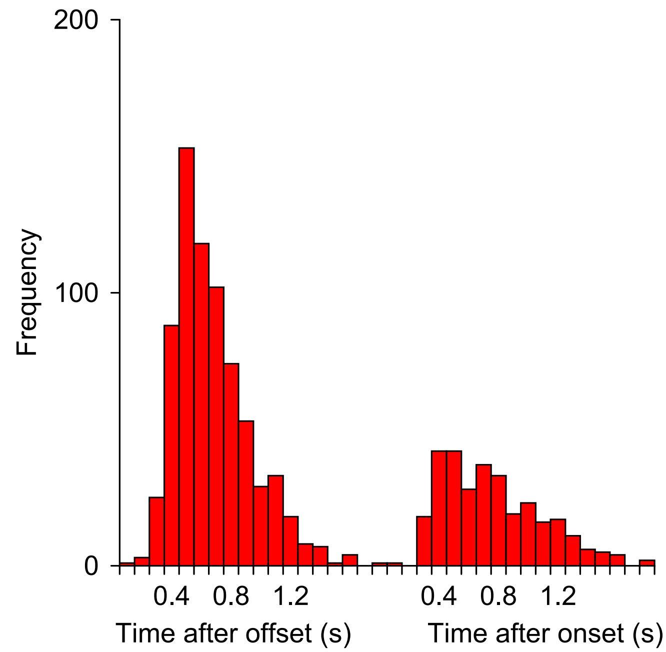

Figure 3. Frequency distribution of responses for the duration of onset and offset frames.

The crucial analysis, however, and most surprising, concerns the frequency of offset responses compared with onset responses: 70.2% of responses were made during an offset frame (i.e., after an object had offset) compared with 29.8% during an onset frame. Furthermore, all 9 participants responded more frequently following an offset. In order to test this for significance, each participant's percentage score for offset responses was entered into a one-sample *t* test comparing this percentage with the value that would be expected to occur if no effect of the onset/offset occurred (i.e., 50). This analysis revealed that participants were more likely to respond to an offset frame than chance would allow, $t(8) = 5.73$, $p < .0005$.

Given the argument that the visual system is particularly sensitive to object onsets (see "Introduction"), the finding that participants were more likely to respond during an offset frame was contrary to expectation. Indeed, this strongly suggests that it was the offsetting of an object that finally alerted participants to the change. Furthermore, the results support the findings of Mondy and Coltheart (2000) that deletions to a scene were more efficiently detected than additions. However, we will argue that it was the onset of an object that finally alerted observers to the change. This is motivated by the results of the following three experiments, as well as by pilot work, which has consistently shown that in change detection onsets are more efficiently detected than offsets. We posit an explanation in terms of participants waiting for the following frame to occur in order to verify a change they sense has happened on the previous frame.

Evidence exists suggesting that observers can sense an event has occurred without having explicit conscious awareness of it. For example, Rensink (1998) asked observers to indicate when they were *aware* of change and when they *experienced* change in a standard flicker procedure. Rensink found that some observers could be aware of change before they could consciously identify the change. We argue that in Experiment 1 the onset of an object directed attention toward the approximate location of the appearance. This led to a feeling that a change had occurred at this position. Unsure of whether a change had actually occurred, participants then waited for the following frame to appear in order to confirm their sense of feeling. This would result in a greater frequency of responses during offset frames. Alternatively, detection may have been explicit, but given low certainty and the fact that participants were asked to respond only when they were certain, participants may have simply waited for the following frame.[3]

Additionally, if our confirmatory frame hypothesis is correct (whether due to implicit or explicit processes), then RT to detect offsets should also be shorter compared with onsets.[4] The rationale is that the participants' sense of change induced by onset would have directed their attention/gaze near to the change in readiness for the next (offset) frame. This should then result in quicker detection of the change following the offset of an item compared to that following an onset. It is, indeed, the case that the average interval between offsets and the responses that follow them (i.e., the trials in the population on the left of Figure 3) is shorter at 579 ms than the average interval between onsets and their following responses at 662 ms.

If participants did "sense" a change, the question remains as to what level of sensing did they experience before waiting for the following confirmatory frame. We do not suggest that participants experienced sensing in perhaps its true definition as given by Rensink (1998), i.e., the processing of stimuli without conscious experience. Our point is that participants were alerted to a "feeling" that a change had taken place in a location and needed another frame to confirm this.

The problem of associating object onset and offset with a particular RT in Experiment 1 is partly based on the fact that the stimulus sequence involved the constant alternation of appearance and disappearance. The aim of Experiment 2 was to eliminate this confound in order to address the role of onset and offset in change detection.

Experiment 2

In Experiment 2, we used a variation of the *one-shot* change detection procedure to more adequately control effects of onset and offset of an object. With the one-shot method, the observer is presented with a single pair of images only once and is asked to determine if a change occurred. This contrasts with the flicker method used in Experiment 1 where participants view continual pairs of displays until the observer responds. The advantage of the one-shot method with particular respect to assessing onsets and offsets is that appearance and disappearance can be isolated within a single trial. That is, a single trial involves either an object appearing or disappearing. Hence, participants were presented with a pair of images and were required to indicate whether they thought a change had occurred on the left half of the display or on the right half.

Method

Participants

Ten participants took part in the experiment. Eight were members of the Durham psychology department and two were undergraduates from the University of Keele. All were naive to the aims of the experiment, and none had taken part in Experiment 1.

Stimuli

All stimulus attributes were identical to those of Experiment 1 with the exception that each stimulus frame was intervened by a 100-ms blank frame. Furthermore, given the increased difficulty of detection in the one-shot procedure, an attempt was made to make the change easier to detect. This was achieved by making the target objects approximately 20% larger than they had been in Experiment 1.

Design and procedure

These were identical to Experiment 1 with the following exceptions. Participants viewed single pairs of displays and were asked to fixate the point positioned at the center of the display for the entire duration of each trial. They were told that accuracy rather than speed was important and that they were to guess if they were unsure of the answer. As with Experiment 1, object attributes (e.g., color and location) for each trial were distributed pseudo-randomly with the exception that for every trial where an onset occurred (i.e., a display pair where an object was added to the second display), the same pair would be repeated on another trial with the presentation order of the two frames being reversed.[5] This crucial control ensured that any difference in the detection rates of each pair could only be due to the onset or offset of an object. All other factors that could potentially influence detection were identical for onsets and offsets. Thus, for example, eccentricity, color, luminance, and contrast, with respect to the background and the surrounding objects, were all controlled. The experiment was run in a single session that lasted for approximately 20 min. Twenty-four practice trials were given.

Results

From the 64 onset and 64 offset trials, participants responded with a mean correct response rate (i.e., correct detection of change to the left or right) of 51.1 (80%) for onsets and 41.8 (65%) for offsets. Each participant's score for onsets and offsets was entered into a within-subject *t* test. The mean detection difference of 9.3 proved to be significant, $t(9) = 5.1$, $p < .001$. The results clearly suggest that an onset was better detected than an offset. Given that Experiment 1 contained potential confounds resulting from the constant alternation of onset and offset in each trial, we believe that Experiment 2 provides stronger evidence that appearances of objects in the change detection paradigm are less susceptible to change blindness than disappearances. The aim of Experiment 3 was to provide further support for the hypothesis that onset of an object captures more attention more effectively than offset in the change detection paradigm. In Experiment 3, we assessed onset priority with the use of a second dependent measure.

Experiment 3

In studying the effects of object onset, Cole, Gellatly, and Blurton (2001) have recently emphasized the importance of demonstrating visual phenomenon with the use of different tasks. In particular, Cole et al. note that some effects reveal themselves only when tested with certain measures. For example, Rafal, Smith, Krantz, Cohen, and Brennan (1990) showed that the distracting effect an irrelevant stimulus had on the detection of a target revealed itself with eye movement RT but not with hand/finger RT. In Experiment 3, we used the one-shot procedure and assessed whether RT to detect the appearance of an object would be reduced compared with RT to detect a disappearance. If onsets are more efficiently detected, then the demonstration that onsets are subject to reduced RT compared with offsets would provide stronger evidence for a real advantage for object appearance.

In Experiment 2, responses would have been contaminated to an unknown degree by guesses. Therefore, Experiment 3 also intended to assess the level of confidence with which onsets and offsets are detected when contamination due to guessing was eliminated. This was achieved by simply instructing participants to respond only when they detected the change rather than guess when they were unsure. Thus, in addition to onsets being detected more rapidly than offsets, we expected participants to be more confident of detecting onsets. This would manifest itself in a greater frequency of onset RTs compared with offset RTs.

Method

Participants

There were 12 participants. All were University of Keele undergraduates who took part as partial fulfillment of a course requirement.

Stimuli, design, and procedure

All attributes of the experiment were identical to Experiment 2 with the following exceptions. Participants were informed that the experiment was a change detection reaction time task and that they were to respond as quickly as possible to the single change that occurs when the second image appears. They were told to respond only if they had detected a change and that an auditory beep would indicate the start of a trial. (Each trial in Experiments 1 and 2 was initiated by the participants' responses on the previous trial. Because observers were not required to respond on every trial, in this experiment, participants needed a warning of when the following trial began.)

Results

RT outliers were automatically excluded from condition means. The criterion for an outlier was a RT more than 2 SDs above or below a participant's mean. This resulted in the removal of approximately 5% of correct responses. Participants made errors on 10% of trials across all observers. Frequency of onset and offset responses was corrected by subtracting incorrect responses from correct responses for both onset and offset trials. This type of correction is unlikely to affect overall onset/offset effect given the robustness of the onset effect. Mean RT for the detection of onsets was 689 ms compared with 742 ms for offsets. Each participant's mean RT for onsets and offsets was entered into a within-subject *t* test. The difference of 53 ms proved to be significant, $t(11) = 2.55$, $p < .03$. Mean frequency of response to onset and offset was 28.1 and 17.7, respectively. This difference was also significant, $t(11) = 3.8$, $p < .003$.

Subsequent to the running of Experiment 3, we repeated the experiment on different participants in order to carry out an item analysis for each trial type.[6] As stated in the Method for Experiment 2 for every trial where an onset occurred, the same trial would be repeated in the experiment with the presentation order of the two frames being reversed. If onsets are indeed detected more efficiently than offsets, then this effect should not only manifest itself across the different participants but also across the different trial types. Thus, in addition to our original analysis comparing participants' mean onset RT with their mean offset RT (regardless of the different trial types), we now analyzed mean RT for each onset trial type with mean RT for each offset trial type (regardless of the different participants).

All aspects of the replication were identical with the sole exception that 10 participants were used as opposed to 12. Response outliers for the replication accounted for 6% of correct responses, and participants made errors on 7.4% of trials. Mean RT for the detection of onsets was 659 ms compared with 805 ms for offsets. The difference of 146 ms proved to be significant, $t(9) = 3.1$, $p < .01$. Mean frequency of response to onset and offset was 32.2 and 18.1, respectively. This difference was also significant, $t(9) = 4.7$, $p < .001$. These results demonstrate the replicability of the onset RT effect. The results of the item analysis showed that the onset primacy RT effect also occurred consistently across the different trial types, $t(31) = 6.7$, $p < .001$.

Experiment 3 has thus shown that participants detected change more rapidly when it was an onset than when the change was an offset. With respect to our contention that offsets are less efficiently processed than onsets in the change blindness paradigm, the data from Experiment 3 provide further support for this. Furthermore, the frequency of onset and offset response data shows that participants detected more onsets than offsets. This replicates the data from Experiment 2 and also concurs with our onset advantage hypothesis.

Experiment 4

Taken together, the results from Experiments 1-3 show that appearance of objects is more readily detected than disappearance. We argued in the "Introduction" that in order to discover general principles of change detection, more traditional abstract stimuli might be more appropriate than real-world settings. Clearly, these general principles should translate to more realistic scenes. The aim of Experiment 4, therefore, was to assess whether the basic finding demonstrated in Experiments 1-3 would replicate with pictures of an array of household objects placed on a table top (Figure 4).

Method

Participants

There were 10 participants. All were Keele University undergraduates who took part as partial fulfillment of a course requirement.

Stimuli

Objects were chosen from a selection of 26 household items. These were coffee jar, duster, 3 1/4-inch computer disk, video cassette, fitness shoes, scissors, calculator, milk carton, measuring ruler, clock, book, gloves, keys, cup, saucer, compact disc, tin opener, wallet, light bulb, washing up bottle, soft-drink can, bottle top, can opener, envelope, cheque book, and an instant mashed-potato sachet. Pairs of images were taken with a digital camera with one object being removed for one of the pairs. Each object could appear twice in the same display. This was to ensure that no one item was unique. Display attributes used in Experiments 1-3 were replicated as closely as possible (e.g., the same number of objects in each display, although some real-world objects were smaller). The display background was also different (white as opposed to light purple). As with Experiments 2 and 3, object attributes (e.g., color and location) for each trial were presented pseudo-randomly with the exception that for every onset trial the same pair of images would be repeated to create an offset trial by reversing the presentation order of the two frames. Again, this crucial control ensured that any difference in the detection rates of each pair could be due only to the onset or offset of an object with all other potentially confounding factors being controlled.

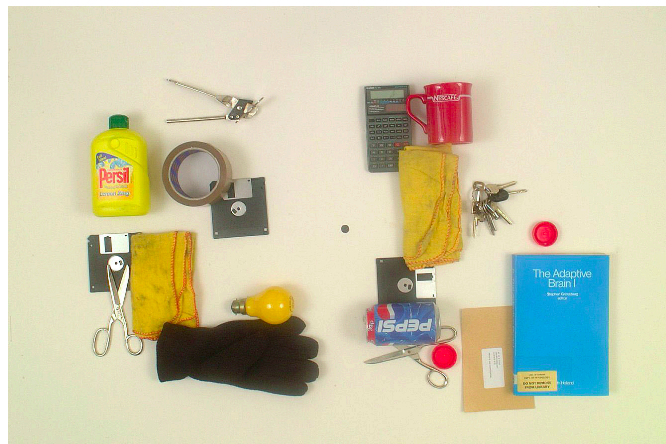

Figure 4. An example of an image used in Experiment 4.

Design and procedure

All aspects were identical to those of Experiment 2 with the exception that participants were informed that they would view pairs of pictures of household objects placed on a tabletop.

Results

Participants responded with a mean correct response rate (i.e., change to the left or right) of 49.9 (78%) for onsets and 45.9 (72%) for offsets. Each participant's score for onsets and offsets was entered into a within-subject t test. The mean detection difference of 4.0 proved to be significant, $t(9) = 2.5$, $p < .04$. These data demonstrate that the onset advantage observed with more traditional abstract stimuli (Experiments 2 and 3) translates to real-world stimuli. Again, this supports our contention that appearance of objects is less susceptible to change blindness than disappearance.

Discussion

The aim of this work was to assess how the detection of onsets compares with offsets in the change detection paradigm. This was in part motivated by the debate suggesting that the visual system may or may not be particularly sensitive to the onset of a new object (e.g., Yantis, 1993). In the "Introduction," we also reviewed evidence from the onset singleton paradigm demonstrating that RT to detect the presence of an onset target is independent of set size (e.g., Gellatly, et al., 1999). In other words, new object onsets receive attentional priority independent of the number of transients that simultaneously occur elsewhere in the visual field. We suggested that new objects failing to effectively capture attention in change detection tasks is somewhat paradoxical. In Experiment 1, we found that participants were more likely to detect the change during a frame that contained an offset than an onset. We argued that onsets induced a feeling that a change has occurred but participants waited for the following frame to confirm this. In Experiment 2, participants viewed single pairs of alternating frames and detected more changes when an object had onset compared to when an object had offset. Experiment 3 showed that participants also detected onsets more rapidly than offsets. Experiment 4 replicated the onset advantage when images of real-world objects were used. Although onsets do often go unnoticed, we believe these data show that onsets are better detected than offsets in change detection tasks.

Our basic finding supports the notion that new objects have priority over existing (old) objects (e.g., Yantis, 1993). Participants were more likely to detect the onset of a new object compared to the offset of an old object. However, the findings have failed to support the only other published work on object onset/offset in change detection (Mondy & Coltheart, 2000). In their experiments, participants were required to detect and identify appearance and disappearance of objects, color changes to objects, and location changes. They found that of these four classes of change, object disappearance was most efficiently detected. However, there were major methodological differences between their experiments and ours. They were primarily interested in assessing a number of different changes in different situations, rather than investigating onset/offset per se. They also used images of naturalistic scenes rather than the abstract shapes used in Experiments 1-3 of this research. We have already remarked in the "Introduction" how this might introduce potential confounds associated with such stimuli. They also presented these images for a longer duration (5 s) than normally occurs in change detection studies. Because the main thrust of our research was to assess only onset/offset detectability, we believe our method successfully isolated differences between onsets and offsets while controlling for all other potential confounds.

We suggested that the failure of new objects to capture attention in change blindness studies is somewhat paradoxical given the findings from the onset singleton paradigm. This may be explained in terms of the degree of information contained in the onset compared with the amount of information contained in the competing transients. More information may be said to exist in an onset because the visual system has to construct a representation of the stimulus. For offsets, this representation has only to be deleted. However, although findings from the onset singleton task show that onsets capture attention regardless of the amount of competing transient, if the competition from these transients is large enough, then the onset is unlikely to be detected. In other words, there must be an upper limit to the effectiveness with which an onset can capture attention faced with competition from other transients. In principle, one could model this effect whereby, for example, the amount of information accrued by the onset is divided by the sum of information accrued by all other transients. If this ratio is relatively large, the onset will always be detected. However, as the ratio decreases, the onset has less chance of being detected because there is now greater competition from the other transients. The ratio would then reach a critical point whereby any other event is as likely to capture attention as the onset. Eventually, if enough competing transient occurs, the onset would no longer capture attention. Clearly, this point has been reached in a typical change detection task resulting in new objects failing to effectively capture attention. Conversely, this critical point is never reached in a standard onset singleton task leading to apparent effective capture by the onset, independent of set size (i.e., competing transient). Indeed, Martin-Emerson and Kramer (1997) showed that if the number of competing transients is large enough, onsets no longer captured attention. This is likely to be the reason why object onsets, although better detected than offsets, still do not capture attention in any strong sense as they do in the onset singleton task: the onset effect is relative rather than absolute. In some sense, onset singleton experiments are analogous to one-shot change blindness experiments with the exception that the former has less global transient.

The difference between findings from onset singleton and change blindness studies may also, in part, be due to the different displays used. Onset singleton displays usually have few well-organized items, whereas change blindness displays tend to be cluttered, disorganized, and are often naturalistic scenes. Hence, the noise from other transients is further reduced in onset singleton studies compared with change blindness.

Our basic findings also shed light on the issue of which aspects of stimulus information are likely to be retained and which are likely to be lost in the detection of change. Our data suggest that information concerning onset is more likely to be retained than information concerning offset. This does, however, pose other questions concerning the retention of onset information. For example, which specific attributes of objects are preserved when they onset but not when they offset? Is it the low-level detection of extra contour that leads to greater retention or the detection of additional luminance? Perhaps, it is the detection of a higher order object representation (i.e., what Kahneman, Treisman, and Gibbs [1992] call an object file). This question would be addressed by defining objects in change blindness studies in a number of different ways in order to tease out the specific information retained.

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Footnotes

1. One could argue that the onset item is selected first because of its status as a unique stimulus in the display. In other words, it is the only item doing something different (i.e., onsetting) from the other items. However, Jonides and Yantis (1988) showed this *feature singleton hypothesis* does not explain reduced RT to onset objects. A target that happens to also be a unique color or luminance does not capture attention. This has led to the suggestion that object onset may be the only stimulus property to capture attention in a purely stimulus driven manner (see Folk, Remington, & Johnston, 1992, 1993; Yantis, 1993).
2. The experiment proved more difficult, and hence longer, for some participants than the authors anticipated. As a result, one participant completed only 64 trials and a second participant completed 101 trials. However, this did not significantly affect the results. All 9 participants showed the same asymmetry of onset/offset response.
3. We thank an anonymous reviewer for pointing this out.
4. Again we thank an anonymous reviewer for this point.
5. Thirty-two onset trials and 32 offset trials were created in this way. These 64 trials would then occur twice in the experiment to make a total of 128 experiment trials.
6. The software running Experiment 3 did not allow us access to individual trial RTs. Thus we rewrote the software and repeated the experiment.

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