Psychological Research (2001) 65: 185–191

ORIGINAL ARTICLE

Jay Pratt · Jim McAuliffe

The effects of onsets and offsets on visual attention

Received: 26 May 2000 / Accepted: 31 January 2001

Abstract Two experiments are presented which examine the effect of onset and offset cues on early occurring attentional cueing effects and later occurring inhibition of return (IOR). The first experiment compared the effects of single onset cues, single offset cues, and simultaneous onset and offset cues (at opposite locations) at a 100-ms stimulus-onset-asynchrony (SOA) and IOR at a 900-ms SOA. Whereas the first experiment examined these conditions with choice localization keypress responses, the second experiment used simple detection keypress responses. Both experiments found that onset and offset cues presented in isolation produce early facilitation and late IOR. When onset and offset cues were simultaneously presented, facilitation but not IOR was found with localization responses, while neither facilitation or IOR was found with detection responses. Overall, these findings suggest that offset cues can be treated in the same manner as onset cues by the attentional system, although the onset cues may have priority in orienting attention when targets must be localized in space.

Introduction

In general, it would be useful if the sudden appearance of an object into our field of view caused a fast and reflexive orientation of attention toward that object. Such an allocation of attention allows us to gather important information about the object (size, speed, trajectory), which in turn allows us to respond in an appropriate and timely fashion. There is, in fact, considerable experimental evidence that the abrupt onset of an object does indeed capture attention (e.g., Posner, 1980; Posner & Cohen, 1984; Yantis & Jonides, 1984; Yantis & Hillstrom, 1994; see also Folk, Remington, & Johnston, 1992). The sudden disappearance of an object from our visual field may also signal an important change in our environment and might also cause an orientation of attention. Unlike abrupt onsets, however, there is relatively little experimental evidence regarding the effect of abrupt offsets on visual attention (Riggio, Bello, & Umiltà, 1998; and Samuel & Weiner, Attentional consequences of object appearance and disappearance; manuscript submitted[1]). Given this dearth of information, the present study is designed to gain further insight into how the sudden appearance and disappearance of objects affect the orientation of visual attention.

As noted earlier, there is extensive literature regarding the allocation of attention in response to the sudden appearance of an object (onset). A critical study in this literature was conducted by Posner and Cohen (1984). In this study, a cue (the brightening of one of the placeholder boxes) was presented at one of two peripheral locations for 150 ms and then removed. Following the onset of the cue, a simple detection target appeared randomly in one of the two locations after a delay of 0, 50, 100, 200, 300, or 500 ms. Posner and Cohen, replicating earlier work, found that targets were detected faster when they occurred at the same location as the prior cue and when the stimulus-onset-asynchrony

J. Pratt (✉)
Department of Psychology, 100 St. George Street,
University of Toronto, Toronto, Ontario, Canada M5S 3G3
Tel.: +1-416-9784216; Fax: +1-416-9784811
e-mail: pratt@psych.utoronto.ca

J. McAuliffe
Lakehead University, Thunder Bay, Ontario, Canada

[1]As noted by Samuel and Weiner (submitted), several studies have reportedly examined the effects of offsets, but most of these studies (e.g., Miller, 1989; Martin-Emerson & Kramer, 1997) have actually examined compound stimuli in which some components are offset to produce new stimuli. An example of such a stimuli, termed a 'morph' by Samuel and Weiner, is removing two components of a Figure-8 to make a 2. In a similar vein, Posner and Cohen (1984) used peripheral cues consisting of either light increments or decrements, but not true offsets. To the best of our knowledge, only Riggio et al., (1998) have examined true onset and offset cues in a typical attentional cueing paradigm.

(SOA) was less than 200 ms. They also found that detection responses were slower when the targets occurred at previously cued locations and the SOA was 300 ms or greater. The early facilitatory effect of the onset cue has become known as the attentional cueing effect, and is thought to occur because the onset cue automatically captures attention and, at short SOAs, the target location is being attended to. The later inhibitory effect has become known as inhibition of return (IOR), reflecting the notion that the return of attention to previously attended locations is inhibited. Together, the attentional cueing effect and IOR form a biphasic pattern of reaction times (RTs) that is commonly found for targets following the onset of a cue (e.g., Berger, Dori, & Henik, 1999; Maylor, 1985; Pratt & Abrams, 1999; Rafal, Calabresi, Brennan, & Sciolto, 1989).

Although the biphasic pattern of RTs with onset cues is common, it is not a unanimous finding. Several studies have shown that onset cues consistently produce late occurring IOR, but not the early occurring attentional cueing effect. For example, Tassinari and colleagues (Tassinari, Agliotti, Chelazzi, Peru, & Berlucchi, 1994; Tassinari & Berlucchi, 1993) have found either no cueing effects or small inhibitory effects with SOAs less than 200 ms. Tassinari and Berlucchi have suggested that the early occurring inhibition is sensory in nature, while the later occurring inhibition (i.e., IOR) is attentional in nature. Recent work has suggested that the temporal (Maruff, Yucel, Dankert, Stuart, & Currie, 1999) and spatial (Pratt, Hillis, & Gold, in press) overlap between cues and targets may mediate both attentional cueing effects and IOR. More specifically, Maruff et al. suggest that facilitatory effects are typically found when onset cues overlap in time with the targets (i.e., cue remains present until target response) and inhibitory effects are typically found when the onset cues and targets do not temporally overlap (i.e., cue removed prior to target) (see also Tassinari et al., 1994). Maruff et al. further suggest that the early facilitation found at short SOAs with overlapping cues and targets may be due to sensory summation and not attention per se. At short SOAs, Pratt et al. suggest that onset cues and targets that do not overlap in space (i.e., are spatially distinct) are more likely to produce attentional cueing effects, while onset cues and targets that do spatially overlap are less likely to. The effect of spatial overlap does not appear to apply at long SOAs, as Pratt et al. found IOR for overlapping and non-overlapping cues and targets.

The effect of offset cues on attentional cueing effects and IOR is much less understood. In fact, only Riggio et al. (1998) have examined onset and offset cues with displays similar to that of the aforementioned studies [but see also Samuel & Weiner (submitted) for the role of onsets and offsets in complex displays]. Riggio et al. used a variation of the method introduced by Posner and Cohen (1984), which consisted of a central fixation point and two peripheral placeholder boxes (one on each side of fixation). The cue was an arrow that could either appear (onset) or disappear (offset) directly below one of the placeholders. Using this basic method, Riggio et al. compared 'on trials' (onset of arrow under one placeholder), 'off trials' (offset of arrow under one placeholder), 'on-off trials' (onset and then offset of arrow under one placeholder), and 'neutral trials' (arrows under both locations, no onsets or offsets) at short and long SOAs.

Over the course of three experiments, Riggio et al. (1998) consistently found IOR with on, off, and on-off trials at the long SOAs (500 ms, 1,000 ms), with the most IOR being produced by on-off cues. The attentional cueing effect was much more variable between experiments. In their first experiment, using an oscilloscope, they found attentional cueing effects for on, off, and on-off trials at a 50-ms SOA, with a trend for more facilitation with the on trials. Experiments 2 and 3, which used a computer monitor, failed to find either facilitatory or inhibitory effects for the three trial types with 50- and 150-ms SOAs. There did, however, appear to be a (non-significant) trend for a small facilitation effect with on trials. Riggio et al. concluded both onsets and offsets produce IOR, and that onsets and offsets may combine their activity in the superior colliculus (SC) to produce the larger IOR effects. They further noted that the inconsistent attentional cueing effects support a separation of facilitatory and inhibitory processes, rather than the notion that there is a single process (presumably attention) which has differential effects over time.

One aspect of onsets and offsets not examined by Riggio et al. (1998) (or Samuel and Weiner, submitted) is what happens to the allocation of attention when an onset and offset occur simultaneously in separate spatial locations. This combination of events may provide direct information about which type of event has priority in the attention system, and it is this question that is the major motivation for this study.

Experiment 1

The purpose of Experiment 1 is twofold. The first purpose is to determine if onset cues and offset cues produce equivalent effects at both short and long SOAs. Thus, this experiment conceptually replicates the on trial and off trial conditions of Riggio et al. (1998), but with choice keypresses based on the location of the target (left hand for left target, right hand for right target) rather than simple keypresses based on target detection. The second purpose was to determine where attention is oriented when simultaneous onset and offset cues occur in separate visual hemifields. To examine this issue, a condition was included in which an offset occurs in one placeholder at the same time an onset occurs in the other placeholder. It is possible that simultaneous onsets and offsets equally capture attention, which would result in equivalent RTs at the two locations. It is also possible, however, that the attentional system is more sensitive to one event than the other. In this case, one might expect

onset cues to drive the orientation of attention, as the abrupt appearance of a new object in the visual field is likely to have greater attentional priority than the disappearance of an old object.

Method

Participants

Ten undergraduate students from the University of Toronto participated in the experiment in return for course credit.

Apparatus and procedure

The experiment took place in a dimly lit sound attenuated room. Participants were seated 44 cm in front of a computer monitor. The viewing distance was held constant with the use of an adjustable head/chin rest. The computer keyboard was within easy reach of the participant and was used as the response device.

The sequence of events in Experiment 1 are shown in Fig. 1. The trial sequence began with a blank screen for 500 ms. Following that, the initial display was presented for 1,500 ms. In all conditions the initial display consisted of two placeholder boxes located on the horizontal meridian to the left and right of a fixation dot. The boxes were centered 4.5° from the fixation dot and were 1° square, presented in white (31.5 cd/m^2), on a black background (0.5 cd/m^2). Following the initial display, three different cue events could occur. In the 'onset' condition, the initial display included a white dot in one of the boxes and the cue was the appearance of another white dot in the opposite box. In the 'offset' condition, the initial display consisted of a dot in one of the boxes and the cue was the disappearance of that dot. The 'onset-offset' condition began exactly the same as the other two conditions (i.e., a dot in one of the placeholders) but the offset of the dot coincided with the onset of a new dot in the opposite placeholder. Thus, this condition consisted of an offset cue at one location and a simultaneous onset cue at the other location. The target was the enlargement of one of the placeholder boxes (from 1.0° to 1.2°) and occurred either 100 or 900 ms after the onset of the cue (SOA = 100 ms or 900 ms). In all cases, the cues and targets were presented in white (31.5 cd/m^2). Participants pressed the 'z' key on the computer keyboard with the index finger of their left hand if the target was at the left box and the '/' key with the index finger of their right hand if the target was at the right box. If the participants pressed the incorrect key or responded faster than 100 ms or slower than 1,500 ms, the response was considered an error and a short tone (200 Hz, 200 ms) was presented. Error trials were not repeated.

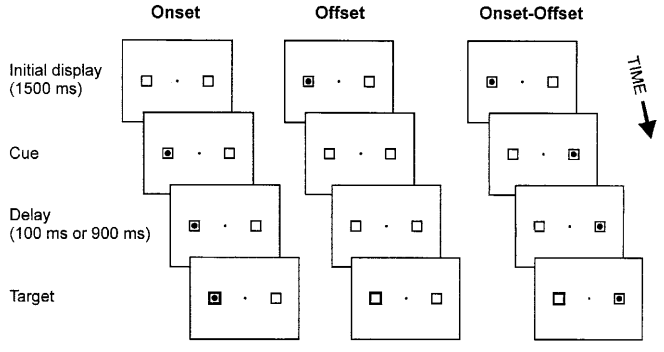

Fig. 1 Trial sequence used in Experiment 1. Onset and offset cues, and targets, were equally likely to occur in either the left or right placeholder

Design

Participants completed 432 trials (four blocks of 108 trials) in a single session. There were 36 valid and 36 invalid trials for each of the three conditions (onset, offset, onset-offset) at each SOA (100 and 900 ms). The conditions and SOA were randomized across the experiment. In addition, the location of the cues and targets were randomly determined for each trial. Participants were provided with a short break after each block of trials.

Results and discussion

The mean RTs from the correct trials are presented in Fig. 2. The mean RTs were analyzed with a 3 (condition: onset, offset, or onset-offset) × 2 (SOA: 100 or 900) × 2 (trial type: valid or invalid) repeated measures ANOVA. Note that for purposes of the analysis, and consistent with one of the predictions, the location of onset in the onset-offset condition was considered the valid location. There was a main effect for condition, $F(2, 18) = 5.6$, MSE = 236, $P < 0.02$. Planned comparisons indicated that mean RT in the onset condition (353 ms) was faster than mean RT in the offset condition (363 ms) and the onset-offset condition (364 ms). The main effect for SOA, $F(1, 9) = 69.7$, MSE = 1015, $P < 0.001$, indicated that participants responded faster when the SOA was 900 ms (336 ms) than when it was 100 ms (384 ms). There was also a trend for a main effect for trial type, $F(1, 9) = 4.2$, MSE = 404, $P < 0.06$, with valid trials (356 ms) faster than invalid trials (364 ms).

Two of the interactions were significant. One was the two-way interaction between SOA and trial type, $F(1, 9) = 27.3$, MSE = 580, $P < 0.001$. The other two-way interactions involving condition failed to reach significance, Fs(1, 18) < 2.2, Ps > 0.15. The other significant interaction was the three-way interaction between condition, SOA and trial type, $F(1, 18) = 7.5$, MSE = 242, $P < 0.005$.

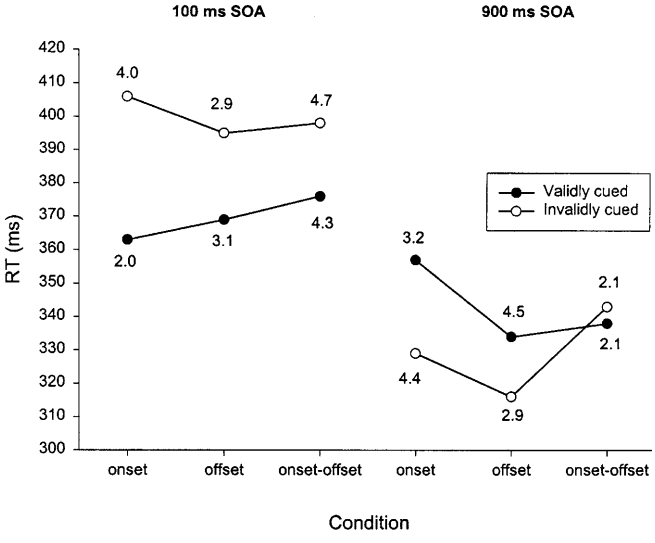

Fig. 2 Mean RTs and percent errors from Experiment 1

To understand the interactions, separate 3 (condition) × 2 (trial type) repeated measures ANOVAs were conducted for each SOA. The 100-ms SOA analysis found only a main effect for trial type, $F(1, 9) = 16.5$, $P < 0.005$. The other main effect and the interaction failed to reach significant, Fs(2, 18) < 1.8, Ps > 0.19. The 900-ms SOA analysis found main effects for condition, $F(2, 18) = 5.0$, $P < 0.02$, and trial type, $F(1, 9) = 8.5$, $P < 0.02$, as well as an interaction, $F(2, 18)$, 5.9, $P < 0.02$. Planned comparisons indicated that invalid trials were significantly faster than the valid trials for the offset condition and the onset condition (Ps < 0.05), but did not differ from each other in the onset-offset condition ($P > 0.47$).

The error rates are shown in Fig. 2 and were analyzed with a 3 (condition) by 2 (SOA) by 2 (trial type) ANOVA. No main effects or interaction effects were found (Ps > 0.11).

As mentioned earlier, the onset and offset conditions were conceptual replications of Riggio et al. (1998), with choice localization responses rather than simple detection responses. Like Riggio et al., the present results indicate that onset and offset cues produce IOR at a long SOA. Unlike Riggio et al., the present results also indicate the presence of facilitation at the short SOA for both types of cues, whereas Riggio et al. found null effects.

The condition of most interest in the present experiment, the onset-offset condition showed a large facilitatory effect at the short SOA but no inhibitory effect at the long SOA. This suggests that there is an advantage for the appearance of new objects over the disappearance of old objects in initially capturing attention. However, this advantage appears to dissipate over time, such that there is no bias against attending to the location of a previous onset or offset cue when both cues occurred simultaneously.

Experiment 2

Although the onset and offset trials in the previous experiment partially replicated the earlier findings of Riggio et al. (1998) (IOR at a long SOA), these trials also partially failed to replicate Riggio et al. by yielding significant facilitation effects at a short SOA. It seems unlikely that the relatively minor differences in the displays and timing might have contributed to these differences between studies. However, one major difference between Experiment 1 and the Riggio et al. study is apparent – the type of response used. Whereas the previous experiment required participants to make a choice keypress based on the location of the target, Riggio et al. used a simple keypress response based on the detection of the target. To determine if the differences in the type of response (localization versus detection) contributed to the differences between the studies, the apparatus and methods used in Experiment 1 were used in Experiment 2 except the response was changed to a simple detection keypress.

Methods

Participants

Ten undergraduate students from the University of Toronto participated in the experiment in return for course credit. None of them had participated in the previous experiment.

Apparatus and procedure

This apparatus and trial sequence were the same as used in Experiment 1. There were, however, two changes in the procedure. First, participants were instructed to press the spacebar with their dominant hand as quickly as possible. Second, to avoid anticipatory responses, catch trials were added in which the cue occurred but not the target. Participants were instructed to withhold responding on such trials.

Design

Participants completed 600 trials (four blocks of 150 trials) in a single session. There were 40 valid, 40 invalid trials, and 20 catch trials for each of the three conditions (onset, offset, onset-offset) at each SOA (100 and 900 ms). The conditions and SOA were randomized across the experiment. In addition, the location of the cues and targets were randomly determined for each trial. Participants were provided with a short break after each block of trials.

Results and discussion

The mean RTs from the correct trials are presented in Fig. 3. The mean RTs were analyzed with a 3 (condition: onset, offset, or onset-offset) × 2 (SOA: 100 or 900) × 2 (trial type: valid or invalid) repeated measures ANOVA. As before, the location of onset in the onset-offset condition was considered the valid location. There was a main effect for condition, $F(2, 18) = 13.0$, MSE = 227, $P < 0.001$. Planned comparisons indicated that mean RT in the onset condition (313 ms) was faster than mean RT in the offset condition (329 ms) and the onset-offset

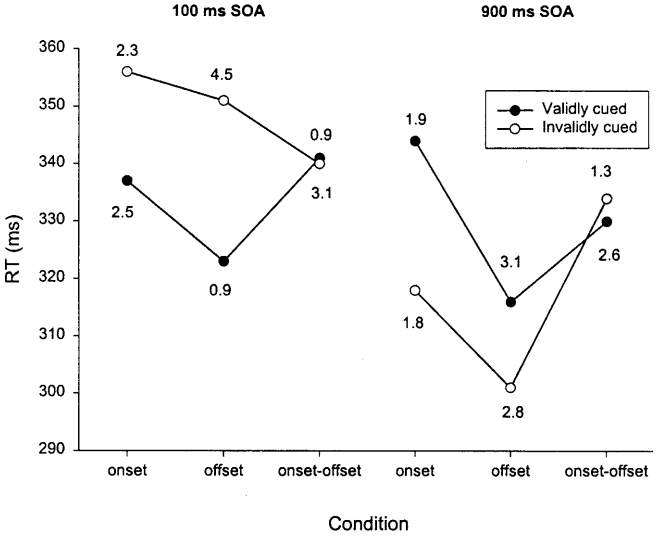

Fig. 3 Mean RTs and percent errors from Experiment 2

condition (325 ms). The main effect for SOA, $F(1, 9) = 11.2$, MSE = 915, $P < 0.01$, indicated that participants responded faster when the SOA was 900 ms (313 ms) than when it was 100 ms (331 ms). There was no main effect for trial type, $F(1, 9) < 1$.

As found in Experiment 1, two of the interactions were significant. One was the two-way interaction between SOA and trial type, $F(1, 9) = 16.9$, MSE = 310, $P < 0.003$. The other two-way interactions involving condition failed to reach significance, Fs(1, 18) < 3.0, Ps > 0.08. The other significant interaction was the three way interaction between condition, SOA and trial type was significant, $F(1, 18) = 3.6$, MSE = 442, $P < 0.05$.

Once again, separate 3 (condition) × 2 (trial type) repeated measures ANOVAs were conducted for each SOA. The 100-ms SOA analysis found a main effect for trial type, $F(1, 9) = 5.6$, MSE = 544, $P < 0.04$, and a trend for condition, $F(2, 18) = 3.4$, MSE = 143, $P < 0.06$. The interaction of condition and trial type was also significant, $F(2, 18) = 3.9$, MSE = 289, $P < 0.05$. Planned comparisons revealed faster responses to valid trials in the onset and offset conditions (Ps < 0.04), but not in the on-off condition ($P > 0.9$). The 900-ms SOA analysis found main effects for condition, $F(2, 18) = 9.3$, MSE = 311, $P < 0.005$, and trial type, $F(1, 9) = 14.7$, MSE = 258, $P < 0.005$, and for the interaction, $F(2, 18) = 3.9$, MSE = 295, $P < 0.04$. Planned comparisons indicated that invalid trials were significantly faster than the valid trials for the offset condition and the onset condition (Ps < 0.03), but did not differ from each other in the onset-offset condition ($P > 0.65$).

The error rates are shown in Fig. 3 and were analyzed with a 3 (condition) × 2 (SOA) × 2 (trial type) ANOVA. No main effects were found (Ps > 0.3), and only the interaction of SOA by trial type, $F(1, 9) = 5.1$, $P < 0.05$, was significant (all other interactions Ps > 0.10). The interaction occurred as there were more errors with uncued trials at the short SOA, while at the long SOA more errors occurred with cued trials. These results indicate that there was no speed-accuracy tradeoff in effect as more errors were found in the slower conditions at both SOAs.

For the most part, the results from the present experiment replicate the findings from the first experiment. Both onset cues and offset cues produced facilitatory effects at the short SOA and inhibitory effects at the long SOA. As before, the finding of early facilitation is consistent with Experiment 1 of Riggio et al. (1998) (oscilloscope display) but not their Experiments 2 and 3 (CRT display). Also replicating the results from the preceding experiment was the lack of IOR found in the on-off condition at the long SOA. However, unlike the first experiment, the on-off condition did not produce facilitation at the short SOA. Thus, while the effect of the single onset or offset cues did not differ between the types of keypress responses (simple detection or target localization), the onset-offset cues were affected.

General discussion

The present study was designed to further examine the effect of onset and offset cues on visual attention, with particular consideration to a situation in which onset and offset cues occur simultaneously. In Experiment 1, when onset and offset cues appeared in isolation, both types of cues produced attentional cueing effects at the short SOA and IOR at the long SOA with location-based choice keypress responses. However, when the two cues occurred at the same time in opposite locations faster responses were found for targets at the onset cue location at the short SOA and no advantage for either cued location at the long SOA. Experiment 2, using simple detection keypress responses, found the same biphasic pattern of early facilitation and late IOR for both types of cues when presented in isolation. Unlike the first experiment, no advantage for either type of cue was found at either the short or long SOAs when the two cues were presented simultaneously.

Facilitation

Although peripheral cues have traditionally been thought to produce facilitation at short SOAs (e.g., Posner, 1980; Posner & Cohen, 1984), there are several reports of such cues producing either no facilitation or small inhibitory effects (e.g., Berlucchi et al., 1989; Tassinari et al., 1994; but see Berger et al., 1999). In their study of onset and offset cues, Riggio et al. (1998) found early facilitatory effect with oscilloscope displays but not with CRT displays when either type of cue was presented in isolation. The results of the present study are consistent with the traditional attention-capturing notion of a peripheral cue (and the results of the oscilloscopic display experiment of Riggio et al.), as both onset and offset cues produced robust facilitation when presented in isolation. Moreover, there was no clear advantage for either type of cue producing more facilitation, as there was slightly more facilitation with onset cues in Experiment 1 and with offset cues in Experiment 2 (although neither of these differences between cues were statistically significant). Overall, the results from the present study indicate that both peripheral onset and offset cues produce covert shifts of attention, with no appreciable difference in their attention-capturing properties.

Given the many similarities between the present experiments and the last two experiments of Riggio et al. (1998), it is not clear why the former found robust facilitation effects and the latter did not. To summarize, Riggio et al. used short SOAs of 50 ms (Experiment 3) and 150 ms (Experiment 2) with CRT displays and simple detection responses. The present study used a short SOA of 100 ms with CRT displays, and either choice localization responses (Experiment 1) and simple detection responses (Experiment 2).

Although there are some minor differences in the displays and apparatus used, there is no obvious culprit as to the contradictory findings between the two studies. Indeed, the same confusion applies to why other studies, using relatively basic and similar cueing paradigms, have sometimes produced early facilitation effects and sometimes not (and, sometimes, even early inhibition). Despite some recent attempts to determine the exact conditions under which early facilitation might, or might not, occur (e.g., Berger et al., 1999; Maruff et al., 1999; Pratt et al., in press), considerably more research will be required before unequivocal conclusions can be reached.

While the effects of onset and offset cues in isolation were the same between the two experiments in the present study, the same was not true when the two types of cues were presented simultaneously. Specifically, choice localization keypress responses were faster for targets at onset-cued locations than offset-cued locations (Experiment 1), but no differences between simultaneously cued locations were found with simple detection keypress responses (Experiment 2). These results may be due to the different attentional demands for each type of response. Our speculation is that simultaneous onset and offset cues both capture attention, but because the appearance of new visual information is typically more important than the disappearance of old information, the attentional system assigns priority to the onset cue. Because target detection presumably requires few attentional resources, there is sufficient attention at both the onset and offset cue locations to quickly detect the target. Thus, there would be no differences in RTs between simultaneous onset and offset cues with simple detection responses. Target localization responses, however, presumably require more attentional resources and, in this situation, the priority given to the onset cue location yields faster RTs than does the offset cue location. Thus, it is possible that when onset and offset cues are simultaneously presented, and localization responses are required, the onset cue has priority at short SOAs.

Inhibition of return

Consistent with the notion that peripheral cues produce biphasic patterns of RTs, the onset and offset cues in isolation produced facilitation at the short SOA and IOR at the long SOA with both types of responses. Once again, there were no differences between the magnitudes of the IOR with the two cues, although there was a slight trend for more IOR with the onset cues (mostly seen with the localization responses in Experiment 1). The finding of IOR with either type of cue is consistent with the results from all three of the experiments from Riggio et al. (1998). The present results therefore provide converging evidence that both the appearance of a new object and the disappearance of an old object are capable of producing IOR at peripheral locations. The fact that IOR appears to be much more stable than early facilitation effects (i.e., IOR found for both onset and offset cues for all experiments in the present study and Riggio et al.) does suggest that IOR may be a more reliable indicator of where attention is allocated in the visual field than facilitation.

Unlike the findings at the short SOA, no difference in RTs was found between simultaneous onset and offset cues at the long SOA for either of the present experiments. This was somewhat unexpected, given that both types of cues produced robust IOR effects in isolation, and presumably the simultaneous cues each captured some amount of attention. Indeed, there is evidence that both onset and offset locations were inhibited, as RTs at both of the simultaneously cued locations are more similar to the RTs from isolated validly cued locations than the isolated invalidly cued locations. Averaging RT across the two types of cues reveals that the mean RTs for isolated validly cued trials (345 ms in Experiment 1, 330 ms in Experiment 2) were very similar to the mean RTs in the simultaneous cued trials (341 ms in Experiment 1, 332 in Experiment 2). On the one hand, this pattern of results is consistent with the findings of the double-onset-cue experiment by Posner and Cohen (1984). On the other hand, it is inconsistent with findings of Maylor's (1985) double-cue experiment, where she found double-cued RTs were faster than isolated cued trials but slower than isolated uncued trials.

Posner and Cohen (1984) interpreted their findings as evidence against an attentional explanation IOR because they considered visual attention to be an unitary beam of fixed size (similar to a spotlight) and, therefore, attention could not be allocated to both simultaneously cued locations. However, more recent evidence has shown that attention can be deployed with considerable flexibility in the visual field and that more than one location can be attended to at the same time (e.g., Driver & Baylis, 1989; Kramer & Hahn, 1995). Thus, there is good evidence to suggest that simultaneous onset and offset cues result in IOR at both locations. Moreover, following our earlier speculation that both simultaneous cues are attended to but the onset cue receives priority, it appears that both cues were sufficiently attended to in order to produce equivalent IOR at the long SOA.

In conclusion, the findings from the present two experiments suggest that uninformative peripheral onset and offset cues produce largely similar effects. Moreover, when the two types of cues occur simultaneously, there is an advantage to attending to the onset cues at short SOA when target location, not just detection, is required. This advantage, however, dissipates with time such that IOR is produced with both types of simultaneous cues.

Acknowledgements This research was supported by operating and equipment grants by the Natural Sciences and Engineering Council of Canada to Jay Pratt. We would like to thank Carlo Umiltá and two anonymous reviewers for their helpful comments.

References

Berger, A., Dori, H., & Henik, A. (1999). Peripheral non-informative cues do induce early facilitation of target detection. *European Journal of Cognitive Psychology, 11*, 119–137.

Driver, J., & Baylis, G. C. (1989). Movement and visual attention: the spotlight metaphor breaks down. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 448–456.

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent of attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance, 18*, 1030–1044.

Kramer, A. F., & Hahn, S. (1995). Splitting the beam: distribution of attention over noncontiguous regions of the visual field. *Psychological Science, 6*, 381–386.

Martin-Emerson, R., & Kramer, A. F. (1997). Offset transients modulate attentional capture by sudden onsets. *Perception & Psychophysics, 59*, 739–751.

Maruff, P., Yucel, M., Dankert, J., Stuart, G., & Currie, J. (1999). Facilitation and inhibition arising from the exogenous orienting of covert attention depends on the temporal properties of spatial cues and targets. *Neuropsychologia, 37*, 731–744.

Maylor, E. (1985). Facilitatory and inhibitory components of orienting in visual space. In M. I. Posner & B. B. Marin (Eds.), *Attention and performance XI* (pp. 189–304). Hillsdale, NJ: Erlbaum.

Miller, J. (1989). The control of attention by abrupt visual onsets and offsets. *Perception & Psychophysics, 45*, 567–571.

Posner, M. I. (1980). Orienting of attention., *Quarterly Journal of Experimental Psychology 32*, 3–25.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. G. Bouwhuis (Eds.), *Attention and performance X* (pp. 531–556). Hillsdale, NJ: LEA.

Pratt, J. & Abrams, R. A. (1999). Inhibition of return in discrimination tasks. *Journal of Experimental Psychology: Human Perception and Performance, 25*, 229–242.

Pratt, J., Hillis, J., & Gold, J. M. (in press). The effect of the physical characteristics of cues and targets on facilitation and inhibition. *Psychonomic Bulletin & Review*.

Rafal, R. D., Calabresi, P. A., Brennan, C. W., & Sciolto, T. K. (1989). Saccade preparation inhibits reorienting to recently attended locations. *Journal of Experimental Psychology: Human Perception and Performance*, *15*, 673–685.

Riggio, L., Bello, A., & Umiltà, C. (1998). Inhibitory and facilitatory effects of cue onset and offset. *Psychological Research, 61*, 104–118.

Tassinari, G., Agliotti, S., Chelazzi, L., Peru, A., & Berlucchi, G. (1994). Do peripheral non-informative cues induce early facilitation of target detection. *Vision Research, 34,* 179–189.

Tassinari, G., & Berlucchi, G. (1993). Sensory and attentional components of slowing of manual reaction time to non-fixated visual targets by ipsilateral primes. *Vision Research, 33,* 1525–1534.

Yantis, S., & Hillstrom, A. P. (1994). Stimulus-driven attentional capture: evidence from equiluminant visual objects. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 95–107.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance, 10*, 601–621.