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Irrelevant singletons capture attention: Evidence from inhibition of return

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Previous research has shown that a salient feature singleton may capture attention in a stimulus-driven, bottom-up fashion (e.g., Theeuwes, 1992, 1994b). This conclusion has been challenged by others claiming that the observed attentional capture by irrelevant singletons may not be stimulus driven but due to top-down attentional control settings and/or nonspatial filtering costs. In the present study, we show that inhibition of return (IOR) occurs at the location of an irrelevant singleton. Participants were slower to detect a target presented at the location of the irrelevant singleton, relative to other locations. Since IOR can be observed only as a result of an *exogenous*, *stimulus-driven* shift of *spatial* attention, it is unlikely that top-down control settings and/or nonspatial filtering costs played a role. In line with earlier claims, the present findings provide strong evidence that salient singletons capture spatial attention in a purely bottom-up way.

Considerable debate has erupted over the extent to which top-down attentional control can prevent distraction from irrelevant stimuli. Attentional allocation is thought to be controlled by two distinct mechanisms. On the one hand, attentional control is thought to be *goal-directed* when attentional priority is given to only those objects and events that are in line with the current goals of the observer. On the other hand, attentional control is thought to occur in a *stimulus-driven* manner when, irrespective of the intentions or goals of the observer, objects and events involuntarily receive attentional priority, a phenomenon referred to as *attentional capture* (for reviews, see, e.g., Theeuwes, 1993, 1994a, and Yantis, 1996, 2000).

It is well known that a salient object can be detected in visual search without scrutiny. A stimulus that is locally unique in a basic visual dimension (such as color, orientation, or motion) will pop out from the search display. Time to find these types of elements—usually referred to as *feature singletons,* or simply *singletons*—is independent of the number of elements in the display.

When confronted with a display containing a feature singleton (such as a red element among gray elements), it may appear that the feature singleton captures attention in a purely stimulus-driven or bottom-up manner. It appears that attention is automatically, without any intention on the part of the observer, attracted to the location of the feature

singleton. Yet the conclusion that featural singletons capture attention in a purely stimulus-driven way is often incorrect, because in many experiments, the feature singleton is the search target (see, e.g., Yantis, 2000). Obviously, when participants are set to look for a particular feature singleton, it is difficult to argue that attentional allocation to the feature singleton target is stimulus driven. As was pointed out by Yantis and Egeth (1999), one can speak of attentional capture in a purely stimulus-driven fashion only when the stimulus feature in question is completely task irrelevant, so that there is no incentive for the observer to attend to it deliberately. As was expressed by Yantis and Egeth, "If an object with such an attribute captures attention under these conditions, then and only then can that attribute be said to capture attention in a purely stimulus-driven fashion " (p. 663).

Yantis and Jonides (1984; see also Jonides & Yantis, 1988; Theeuwes, 1990) used this notion to determine which singletons are able to capture attention in a purely stimulus-driven way. In these experiments, there was always one feature singleton present; yet the feature singleton was task irrelevant, because its location was uncorrelated with the position of the target. In other words, there was no incentive for participants to attend deliberately to the feature singleton. Using this paradigm, Jonides and Yantis concluded that only abrupt onsets capture attention exogenously; salient static singletons do not.

Theeuwes (1991, 1992, 1996; Theeuwes & Burger, 1998) also investigated whether feature singletons capture attention exogenously. He used a somewhat different paradigm, referred to as the *additional singleton* paradigm (e.g., Simons, 2000). In the additional singleton task, participants perform a visual search task, and one item in the search display is a unique salient feature singleton that is completely unrelated to the search task and is never the search item. These experiments typically show that search performance is slower when an additional salient singleton is present, relative to when no singleton is present. Unlike the paradigm employed by Yantis and colleagues (e.g.,

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Yantis & Egeth, 1999; Yantis & Jonides, 1984), in which the singleton is the target at chance level, in Theeuwes's additional singleton paradigm, observers have absolutely no strategic reason to search for the irrelevant singleton, because it is never the target. Attending to the irrelevant singleton would, therefore, consistently harm performance.

Theeuwes (1991, 1992, 1994b, 1996) explained the increase in search time for conditions in which an irrelevant singleton was present in terms of attentional capture. Because attention was exogenously captured by the irrelevant singleton, attention needed to be deallocated from that location before it could be directed to the location of the target singleton. Note that, in line with the definition of attentional capture (see Yantis & Egeth, 1999), any spatial attention directed to the location of the irrelevant singleton would, indeed, suggest attentional capture. The requirement that "one can only speak of attentional capture in a purely stimulus-driven fashion when the stimulus feature in question is completely task-irrelevant" (Yantis & Egeth, 1999, p. 663) was clearly fulfilled. Other researchers using Theeuwes's paradigm (or variations of the paradigm) also have shown that the presence of a salient singleton interfered with search for a target (Bacon & Egeth, 1994, Experiment 1; Caputo & Guerra, 1998; Joseph & Optican, 1996; Kawahara & Toshima, 1996; Kim & Cave, 1999; Kumada, 1999; Turatto & Galfano, 2001).

Recently, however, Folk and Remington (1998) offered an alternative explanation for the interference observed by Theeuwes. They suggested that the increase in search time caused by the irrelevant singleton is due to what they call *filtering costs*, in line with the notion suggested by Kahneman, Treisman, and Burkell (1983). The idea of filtering costs is that the presence of an irrelevant singleton may slow the deployment of attention to the target singleton by requiring an effortful and time-consuming filtering operation. According to this line of reasoning, attention is employed in a top-down way and goes directly to the target singleton; simply because, in addition to the target singleton, another irrelevant singleton is present, directing attention to the target singleton may require more time than it does when no irrelevant singleton is present. Note that this view does not entail an exogenous shift of spatial attention to the location of the irrelevant singleton. The filtering cost explanation is compatible with the notion that top-down control selectively guides spatial attention to the target singleton.

A study conducted by Theeuwes (1996) appears to be inconsistent with the filtering hypothesis of Folk and Remington (1998). Participants performed a typical additional singleton search (e.g., Theeuwes, 1992). The response congruency of the character at the location of the irrelevant distractor was manipulated. On half of the trials, the character at the distractor location was associated with the same response as that required by the target, whereas on the other half, it was opposite to that required by the target. Theeuwes (1996) argued that the identity of the character at the location of the irrelevant singleton could have an effect on responding only if, at some point, spatial attention was deployed to the location of the distractor. If, in line with Folk and Remington's filtering notion, attention goes directly and exclusively to the target location, there should not be a congruency effect of a character presented at the irrelevant singleton location. In other words, if attention never goes to the location of the irrelevant singleton, it is impossible that the identity of a character can have any effect on responding. It should be noted that the task was designed in such a way that the identity of the character could become available only after focal spatial attention was directed to that location. In addition to the typical interference effect caused by the irrelevant singleton, Theeuwes (1996) showed a congruency effect, providing strong evidence that before a response was made, spatial attention was at the location of the irrelevant singleton. This finding was completely in line with the notion that spatial attention was captured by the irrelevant singleton.

Folk and Remington (1998) came up with an alternative explanation for the congruency effect reported by Theeuwes (1996). In line with the notion of perceptual load (Lavie, 1995), they suggested that when the number of objects is small, identity information can influence response mechanisms in parallel. In other words, they claimed that attention went in parallel to both the target and the irrelevant distractor, causing a congruency effect on responding. Even though it is not clear whether such parallel processing reflects the same processing mechanisms as filtering costs, it is clear that this explanation is not in line with the notion that the irrelevant singleton captures spatial attention.

In addition to the notion of filtering costs, yet another explanation for Theeuwes's (1992) findings was offered by Bacon and Egeth (1994). They argued that in Theeuwes's experiments, the irrelevant singleton did not capture attention *exogenously* but because, against the instructions of the experimenter, participants chose to search for singletons instead of searching for a particular feature (such as the feature red). Because participants chose the *singleton detection mode* over the instructed *feature search mode*, any singleton could capture attention. In this way, it is argued, attention went to the irrelevant singleton as a result of a top-down control setting, rather than as a result of bottom-up attentional capture. This notion is consistent with the *contingent capture* model suggested by Folk, Remington, and Johnston (1992), which suggests that only stimuli that match the top-down control settings will capture attention; stimuli that do not match the top-down settings will be ignored.

Even though it is possible that attentional capture by irrelevant singletons in Theeuwes's experiments was the result of top-down control settings, it should be noted that, according to the definition provided by Yantis and Egeth (1999), the observation that attention first goes to the irrelevant singleton would present a strong case of purely stimulus-driven capture (see also Theeuwes & Godijn, 2001). In line with the definition used by Yantis and Egeth, there was no incentive to attend to the irrelevant feature singleton, because it was never task relevant and attending to the singleton consistently harmed performance. If observers attended to the irrelevant singleton regardless of these performance costs, this would (according to Yantis & Egeth, 1999) present a strong case of stimulus-driven attentional capture.

The present study was designed to determine whether salient singletons capture attention in a purely stimulus-driven fashion. We designed an experiment that rules out the two above-mentioned alternative explanations. First, it rules out the notion that interference of irrelevant singletons is due to filtering costs, as was advocated by Folk and Remington (1998). Second, it rules out the notion that attentional capture by irrelevant singletons is the result of top-down control settings, such as the singleton detection mode, as was suggested by Bacon and Egeth (1994). In the present study, participants had to detect the offset of a gray dot. The participants viewed displays consisting of eight outline circles equally spaced around a fixation point on an imaginary circle. In the center of each of the eight outline circles was a small gray dot. All the outline circles were gray except for one, which was red. The red circle constituted the uniquely colored irrelevant singleton. The participants viewed the display for 1,300 msec and then had to detect whether or not one of the small dots was turned off. The target dot that was extinguished was presented at chance levels in the red circle. In other words, the location of the target (i.e., the location at which the small gray dot would be extinguished) was uncorrelated with the location of the uniquely colored red singleton. We measured detection times and separated trials in which the target dot was extinguished in the uniquely colored red circle from those in which it was extinguished in any of three nonsingleton circles.

In the present study, we used the phenomenon of *inhibition of return* (IOR; Posner & Cohen, 1984) to determine whether spatial attention went to the location of the irrelevant singleton. The basic claim underlying IOR is that after attention is reflexively shifted to a location in space, there is delayed responding to stimuli subsequently displayed at that location (see Klein, 2000, for a review). If the red circle captured attention exogenously and 1,300 msec later the dot happened to be extinguished in the red circle (i.e., the irrelevant singleton), then because of IOR, we would expect detection times to be slower than when the dot was extinguished in any of the gray circles (the nonsingleton). If the red circle did not capture attention, there is no reason to expect any differences in detection times between a dot extinguished in a gray circle (a nonsingleton) versus a dot extinguished in a red circle (a singleton).

Two aspects of IOR are particularly important for the present study: First, if responding to the offset of the dot at the location of the singleton is slowed, one has to assume that such slowing is due to the occurrence of IOR. IOR is typically associated with attentional *spatial* processing. Since only one singleton was present, it is impossible to attribute such IOR slowing to such notions as filtering costs or parallel processing of information at different locations.

Second, IOR at a particular location in space follows only after attention has shifted *reflexively* to that location. Typically, IOR does not follow a shift of attention that is directed endogenously (voluntarily; Posner & Cohen, 1984; Pratt, Kingstone, & Khoe, 1997). In other words, if IOR occurs, it can only be the result of a shift of exogenous attention or, in the terminology used in the visual search literature, the result of *purely stimulus-driven attentional capture.* As was recently shown by Pratt, Sekuler, and McAuliffe (2001), if participants use a top-down attentional control setting, such as a singleton detection mode, one will not find IOR effects (but see Gibson & Amelio, 2000). Finding IOR rules out the possibility that attentional capture is due to some top-down strategy used by the participant.

EXPERIMENT 1

Since we wanted to use the occurrence of IOR as a means to determine exogenous attentional capture at the location of the singleton, we chose a detection task, rather than a discrimination task, because there is evidence showing that IOR is more robust in detection tasks than in discrimination tasks (see, e.g., Klein & Taylor, 1994; Terry, Valdes, & Neill, 1994; but see, e.g., Fuentes, Vivas, & Humphreys, 1999; Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997).

Method

Participants. Ten participants, ranging in age between 18 and 30 years, participated as paid volunteers. All had self-reported normal or corrected-to-normal vision and reported having no color vision defects.

Apparatus. A Dell Pentium Optiplex GX-1 with a Dell SVGA color monitor controlled the timing of the events, generated stimuli and recorded reaction times (RTs). The space bar of the computer keyboard was used as a response button. Each participant was tested in a sound-attenuated, dimly lit room, his or her head resting on a chinrest. The monitor was located at eye level, 93 cm from the chinrest.

Stimuli. The visual field consisted of eight circles (1.2º) equally spaced around the fixation point on an imaginary circle (5.2º). In the center of each of the outline circles was a small gray target dot (0.3º; 16.5 cd/m^2). All the circles were gray (CIE chromaticity coordinates .285, .315; 13.5 cd/m^2) except one, which was red (CIE chromaticity coordinates .592, .361; 13.5 cd/m^2). Red and gray were matched for luminance.

Initially, a center fixation cross, along with eight gray circles each having a small dot in the middle, was presented. After 500 msec, the center fixation point was extinguished. One of the gray circles changed to an equiluminant red 980 msec later. In order to attract attention back to the central fixation cross (see, e.g., Posner & Cohen, 1984, who used a similar procedure), the center fixation cross reappeared after 350 msec. On 80% of the trials, one of the small dots inside one of the circles was extinguished 950 msec later, constituting the target event. If the small target dot was to be extinguished, it was extinguished within a circle presented at one of four possible locations (+45, 135, 225, or 315 deg of arc). After 183 msec, the display was extinguished. The total time between the presentation of the red circle and the disappearance of the target was 1,300 msec, a time interval that is known to be large enough to generate IOR (see, e.g., Klein, 2000).

Design and Procedure. Each participant performed 120 trials. Twenty percent of the trials (24 trials) were catch trials in which none of the small target dots was extinguished and participants were required to refrain from responding. Of the four possible target loca-

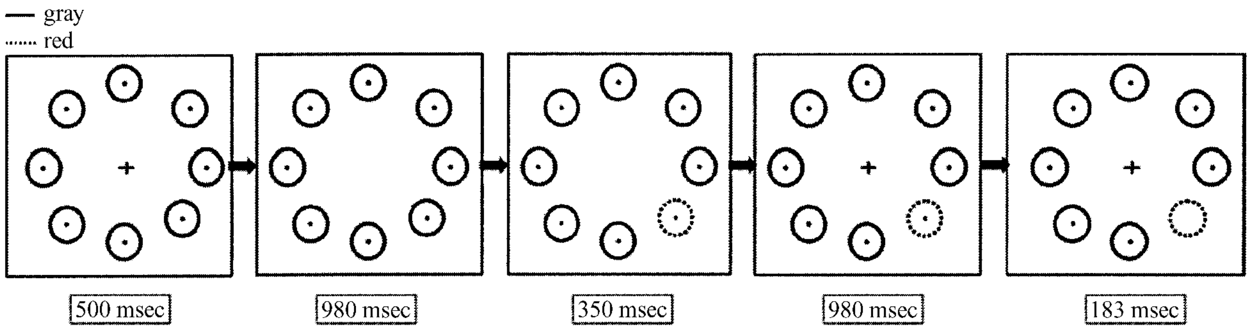

Figure 1. Sequence of frames on a given trial. After 500 msec, the fixation cross was switched off. After 980 msec, the color of one of the gray circles changed from gray to equiluminant red, revealing a color singleton. After 350 msec, the fixation cross was switched back on. After another delay of 950 msec, a small gray dot in one of the circles was switched off. The target dot was switched off in 80% of the trials, either within the color singleton circle or in one of the nonsingleton circles. The participants detected the offset of the small gray dot.

tions, the small dot disappeared at chance in the red circle. When the participants detected the offset of one of the small dots, they were required to press the space bar as quickly as possible. The participants were instructed not to respond when no dot disappeared.

The participants were told to keep their eyes fixated at the fixation cross. The participants received 120 practice trials prior to the experimental trials. The participants received feedback about their performance (in terms of RTs and missed and false alarm error rates) after each block of 30 trials.

Results and Discussion

When the offset occurred in the color singleton (the uniquely colored red circle), RT to detect the offset was longer (mean RT of 350 msec) than when the offset appeared in a nonsingleton circle [mean RT of 322 msec; $F(1,9) = 11.06, p < .01$]. This finding indicates that IOR occurred at the location of the uniquely colored red singleton. Error rates were low (missed targets, 1.8%) and were not systematically related to whether the offset appeared in the singleton or not. False alarm error rates were also low (5.8%).

EXPERIMENT 2

Even though it has recently been argued that finding a biphasic pattern of early facilitation and late inhibition should not be considered as the definitive signature of IOR (Pratt, Hillis, & Gold, 2001), finding such an early facilitation component would provide additional evidence that we are dealing with shifts of spatial attention. In Experiment 2, we used a short stimulus onset asynchrony (SOA) to determine whether such an early facilitation component occurred.

Method

Participants. Twelve naive participants, ranging in age between 18 and 30 years, participated as paid volunteers.

Apparatus, Stimuli, and Design. The experiment was identical to Experiment 1, except that in 80% of the trials, one of the small dots was extinguished 133 msec after the presentation of the uniquely colored singleton. The complete display was switched off 183 msec after the offset of the target dot. In the present experiment, the center fixation dot remained on throughout a trial.

Results and Discussion

When the offset occurred in the color singleton, RTs to detect the offset were shorter (mean RT of 328 msec) than when the offset appeared in one of the nonunique gray circles [mean RT of 347 msec; $F(1,11) = 7.06, p < .05$]. This finding indicates that early in time (within 133 msec), attention was drawn to the location of the colored singleton. Error rates were low (missed targets, 2.3%) and were not systematically related to the conditions manipulated. False alarm rates were 9.0%

EXPERIMENT 3

Even though Experiment 1 showed a clear IOR effect, there are several concerns regarding the method. First, one may argue that the equiluminant color change that we used in Experiment 1 to reveal the color singleton represented a change not only in luminance, as would be the case with abrupt onsets, but also in color. Even though it is known that an equiluminant color *change* cannot capture attention even when observers are set to look for such a change (Theeuwes, 1995), it is still possible that small luminance changes occurred when the singleton was revealed. To rule out the possibility that either color or luminance changes caused IOR, the colors of all the elements but one were changed, leaving a singleton as the only unchanged element in the display. Second, in Experiment 1, the singleton was presented at one of the four quadrants of the visual field, and the target dot, if it was extinguished, was extinguished within a circle presented at one of these four possible target locations. Within these constraints of these four possible target locations, the target dot disappeared at chance level in the singleton. However, the whole visual field consisted of circles, suggesting that the singleton predicted the target with a 25% probability, which is considerably higher than if the target were equally likely at any one of the eight possible locations. Thus, in Experiment 1, the singleton location was unpredictive relative to any of the other possible target locations; however, it was not unpredictive relative to the whole stimulus display consisting of eight circles. In the present experiment, the singleton and the target dot were equally likely at any of the eight possible locations. In other words, there was a 12.5% chance that the singleton and the target dot location would coincide. Third, it may be argued that it was specifically the color red among gray that caused the attentional capture and the subsequent IOR. To ensure that it was not the color red that mattered, in the present experiment, the singleton was the only gray element among red elements.

Method

Participants. Ten naive participants, ranging in age between 18 and 25 years, participated as paid volunteers.

Apparatus, Stimuli, and Design. The experiment was similar to Experiment 1. But unlike Experiment 1, in which only one circle changed color, all the circles but one changed from gray (CIE chromaticity coordinates .271, .319; 8.4 cd/m^2) to red (CIE chromaticity coordinates .613, .343; 8.4 cd/m^2). In other words, the singleton was the only element in the display that did not change.

Each participant performed 240 trials. Twenty percent of the trials (48 trials) were catch trials. Of the remaining 192 trials, the target dot was extinguished at chance level at any of the eight possible locations. Each participant received 120 practice trials.

Results and Discussion

When the offset occurred in the color singleton (in this case, a uniquely colored gray circle), RTs to detect the offset were longer (mean RT of 316 msec) than when the offset appeared in a nonsingleton circle [mean RT of 304 msec; $F(1,9) = 13.30$, $p < .01$]. The results basically replicate those of Experiment 1 and indicate that IOR occurred at the location of the uniquely colored gray circle. Note that an across-experiments analysis showed that there were no reliable differences in the degree of IOR between Experiments 1 and 3. It appears that none of the methodological concerns outlined above held up. Error rates were low (2.2%) and were not related to the conditions manipulated. False alarm rates were low (3.5%).

GENERAL DISCUSSION

The present results show that a static irrelevant, uniquely colored singleton can cause an IOR to the location of the singleton. These results can only be interpreted as evidence of *purely stimulus-driven* attentional capture: early in time, attention was reflexively shifted to the location of the uniquely colored singleton. The reappearance of the fixation cross 350 msec after the presentation of the uniquely colored singleton allowed attention to move back to the center fixation location. The subsequent movement of attention back to the previously attended location of the uniquely colored singleton was inhibited, resulting in longer RTs when a target was presented at that location than when it was presented at any other location in the visual field.

It is generally agreed that IOR is the product of the reflexive, involuntary orienting systems and cannot be modulated by any top-down control settings (e.g., Posner & Cohen, 1984; Pratt et al., 1997; Pratt, Sekuler, & McAuliffe, 2001). Recently, however, there has been some debate as to whether the occurrence of IOR depends on attentional control setting. Gibson and Amelio (2000) used Folk et al.'s (1992) spatial-cuing task and showed that IOR was observed when onset cues preceded onset targets, but not when they preceded color targets. This led Gibson and Amelio to conclude that attentional control settings do play a role in the generation of IOR. However, Gibson and Amelio's conclusion may be flawed, because they used an explicit attentional set (e.g., an attentional set for onset or an attentional set for color). The attentional set may have caused this unusual pattern of results. Indeed, Pratt, Sekuler, and McAuliffe included a random condition in which there was no explicit attentional set (any cue–target combination was equally likely) and showed that attentional control settings had no effect whatsoever on the magnitude and the occurrence of IOR.

The evidence that attentional control settings do not have any consequences for IOR is important because it suggests that the present findings can only be interpreted as evidence for exogenous, purely stimulus-driven attentional capture (e.g., Posner & Cohen, 1984; Pratt et al., 1997; Pratt, Sekuler, & McAuliffe, 2001). Others (e.g., Bacon & Egeth, 1994; Folk & Remington, 1998) have argued that Theeuwes's (1991, 1992, 1996) earlier findings showing exogenous attentional capture by feature singletons could be interpreted as the result of attentional control settings. Even though participants were required to search for a particular feature in Theeuwes's earlier experiments, it was argued by Bacon and Egeth (1994) that the participants in Theeuwes's experiments may have adopted a *singleton detection mode* in which they searched for the odd one out. Because the participants adopted such a singleton detection control setting, irrelevant singletons may have captured attention. In this view, attentional capture is not due to automatic involuntary capture but, rather, is the result of top-down attentional control settings.

In line with this notion, one may claim that the detection of the offset (i.e., the target event) may have induced a singleton detection control setting, which then may have resulted in top-down modulated attentional capture. Even though such an interpretation may explain the facilitation at the early SOAs in Experiment 2, it cannot explain the occurrence of IOR at the longer time intervals in Experiments 1 and 3, because there is evidence that a top-down attentional control setting to look for a singleton *cannot* result in IOR (Pratt et al., 2001). As was noted, Pratt, Sekuler, and McAuliffe (2001) provided evidence that IOR is associated with involuntary, bottom-up, stimulus-driven attentional processes.

The present findings are also inconsistent with the filtering hypothesis of Folk and Remington (1998). According to their view, the presence of an irrelevant singleton may slow responding; yet such slowing may not be accompanied by a shift of spatial attention to the location of the irrelevant singleton. If in the present experiments, the presence of the irrelevant singleton would not have resulted in a shift of attention to the location of the irrelevant singleton, there would have been no reason for IOR to occur at that location. It seems that filtering costs cannot explain the occurrence of IOR in the present experiment.

Even though there have been many studies showing IOR with abrupt onset cues, the present study shows that IOR can also occur with static singletons. Even though one may argue that the change of color at the singleton location in Experiment 1 could have produced IOR, this explanation does not hold for Experiment 3. In Experiment 3, the singleton was the only element that did not change. The finding that a static singleton can produce IOR is in line with the notion that IOR serves to discourage attention from reorienting to a location that was already attended (Klein, 2000; Posner & Cohen, 1984).

One may raise the question of why exogenous attentional capture has been reported in studies using Theeuwes's (1992) additional singleton search paradigm, and not in studies using Folk et al.'s (1992) spatial-cuing task. In a recent study by Theeuwes, Atchley, and Kramer (2000), it was shown that the attentional capture effect of an irrelevant singleton occurs within 100–150 msec of the presentation of the stimulus display (see also Kim & Cave, 1999, for a similar result). Around 150 msec after the presentation of the irrelevant singleton, top-down control allows the redirection of attention away from the irrelevant singleton, thereby reducing or eliminating the distracting effect of the irrelevant singleton. Since in the spatial-cuing paradigm of Folk et al. there was always a time lag between the presentation of the to-be-ignored cue and that of the target, it is possible that no interference occurred in these studies because there was enough time to redirect attention away from the to-be-ignored cue. The present study shows that this short-lived exogenous capture of attention that occurs within 100 to 150 msec after the presentation of the display is enough to generate IOR 1,300 msec later.

The notion that the occurrence of IOR is linked to stimulus-driven attentional capture is in line with evidence that points to an intrinsic link between oculomotor activity and IOR. According to Taylor and Klein (1998), any condition that activates an oculomotor program generates IOR (also see Rafal, Calabresi, Brennan, & Sciolto, 1989). Consistent with this notion is evidence that places the inhibition at the level of the superior colliculus (Posner, Rafal, Choate, & Vaughan, 1985), a structure known to be involved in producing reflexive saccades (e.g., Mohler & Wurtz, 1976). If one interprets the present findings along these lines, it would imply that the salient singleton generates an exogenous saccade, which becomes inhibited or suppressed. Even though it may appear that the oculomotor programming notion (e.g., Taylor & Klein, 1998) is quite different from the exogenous attentional capture account (e.g., Posner & Cohen, 1984), it should be noted that, theoretically, it may be impossible to distinguish between attentional and oculomotor effects. For example, according to the premotor theory, there is no distinction between attention and the oculomotor system: Attention is the result of programming an eye movement to a particular location (e.g., Rizzolatti, Riggio, Dascola, & Umiltà, 1987). If one assumes that IOR is generated by oculomotor programming and the allocation of attention to a location is necessary for oculomotor programming (for which there is strong evidence; see, e.g., Deubel & Schneider, 1996; Hoffman & Subramaniam, 1995; Kowler, Anderson, Dosher, & Blaser, 1995), one could maintain the viewpoint that it is the exogenous attentional capture to a location that produces IOR.

Overall, in line with earlier claims, the present findings provide strong evidence that salient singletons capture *spatial* attention in a purely bottom-up, exogenous way. Even though the employment of an attentional set or filtering costs may have played a role in explaining previous findings showing attentional capture of singletons, the occurrence of an IOR effect rules out the possibility that attentional capture is the result of top-down settings and/or nonspatial filtering costs.

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