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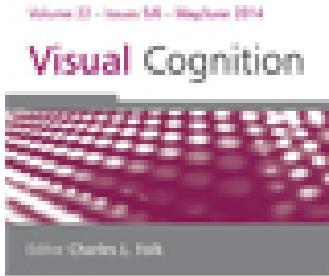
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The attentional window configures to object and surface boundaries

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The attentional window configures to object and surface boundaries

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Attention can select items based on location or features. Belopolsky and colleagues posited the *attentional window hypothesis*, which theorized that spatial and featural selection interact such that featural selection occurs within a “window” of spatial selection. Kerzel and colleagues recently found that the attentional window can take complex shapes, but cannot configure around non-contiguous locations. The current experiments investigated whether perceptual grouping cues, which produce perceptual objects or surfaces, enable the attentional window to configure around non-contiguous locations. Using the additional singleton paradigm, we reasoned that observers (1) would be slowed by a colour singleton distractor that appears within the observers’ attentional window and (2) would be unaffected by distractors that do not appear within the attentional window. In separate blocks of trials, a target appeared upon one of two objects. Observers were cued to the relevant surface, and we asked if responses were affected by distractors on the cued task-relevant surface, and on the uncued irrelevant surface. Colour singleton distractors slowed responses when they appeared on the cued surface, even when those locations were non-contiguous locations. Distractors on the irrelevant surface did not affect responses. The results support a highly adaptable attentional window that is configurable to the surfaces and boundaries established by intermediate-level vision.

Keywords: Visual attention; Attentional control; Object-based attention; Perceptual grouping; Attentional window.

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Attention restricts mental processing to important events in our environment. Over the last 20 years, researchers have debated how the visual system chooses what to select and what to ignore (i.e., attentional control) with two opposing theories summarizing the field. The first, bottom-up driven selection, proposes that the visual system selects the most salient item in our environment before selecting items fitting an observer's current goals (Theeuwes, 1992, 2010). The second theory of selection, goal-driven selection, posits that the visual system selects only items fitting an observer's current goals (e.g., Folk, Remington, & Johnston, 1992).

Attentional control can select items based on featural information (e.g., Saenz, Buracas, & Boynton, 2002; Zhang & Luck, 2008) or spatial location (Hillyard & Münte, 1984; Posner, Snyder, & Davidson, 1980), and these two mediums of selection interact in that the breadth of spatial selection determines whether an item's salience can attract attention (Belopolsky & Theeuwes, 2010; Belopolsky, Zwaan, Theeuwes, & Kramer, 2007). Specifically, Belopolsky and colleagues proposed that observers select items through an attentional window. Within this window, the most salient items are selected irrespective of their task relevance. Outside of this window, salient items will not be selected. Importantly, the size of this attentional window is set by task demands and the possible target locations. Demonstrating that task demands affect the size of observers' attentional window, Belopolsky and colleagues (2007) found that when observers focused attention on a small centrally located task (forcing observers to use a narrow attentional window), colour singleton distractors broadly surrounding the central task in a subsequent search task did not slow response times (RTs) to the target. In contrast, when observers attended to global aspects of the display (forcing observers to use a broad attentional window), colour singleton distractors in a subsequent search task slowed RTs. Thus, the size of observers' attentional window determined interference by colour singleton distractors.

Along with task demands, the breadth of possible target locations also adjusts the size of the attentional window. For instance, Theeuwes (1991) found that if observers were given 100% certainty about an upcoming target location, affording observers the ability to focus their attentional window at a single location, onset distractors at irrelevant locations did not affect RTs to the target (see Neo & Chua, 2006; Yantis & Johnston, 1990, for relevant results). When observers had less certainty about the target location, onset distractors did affect RTs.

Although the attentional window hypothesis offers an interesting contribution to the attentional control literature, it has not been fully described. Kerzel, Born, and Schönhammer (2012) provided a more detailed understanding of the attentional window when they demonstrated that the attentional window could configure itself around specific regions of space (an inner or outer ring of items). Interestingly, Kerzel and colleagues found that observers could only configure the attentional window around contiguous spatial regions. That is, when

observers had to select items based on a feature and the items were non-contiguous in space, observers were unable to restrict their attentional window to only relevant items (for non-contiguous locations see cued versus uncued locations in Figure 1a).

Although Kerzel and colleagues (2012) found that observers could not restrict the attentional window to non-contiguous locations, it is possible that observers can restrict their attentional window to relevant items if the non-contiguous locations are linked together by strong perceptual grouping cues. One possibility is to group locations through surface properties. In support of this possibility, the object-based attention literature indicates that when attention selects a perceptual object, surface, or perceptual group, it spreads through that object, surface, or group and selects its entirety (e.g., Cosman & Vecera, 2012; Hollingworth, Maxcey-Richard, & Vecera, 2012; Richard, Lee, & Vecera, 2008). It is possible that strong perceptual grouping cues can configure the attentional window. If this is true, then if observers know the relevant object in a search task they will select this object and attention will spread to locations within that object, while not

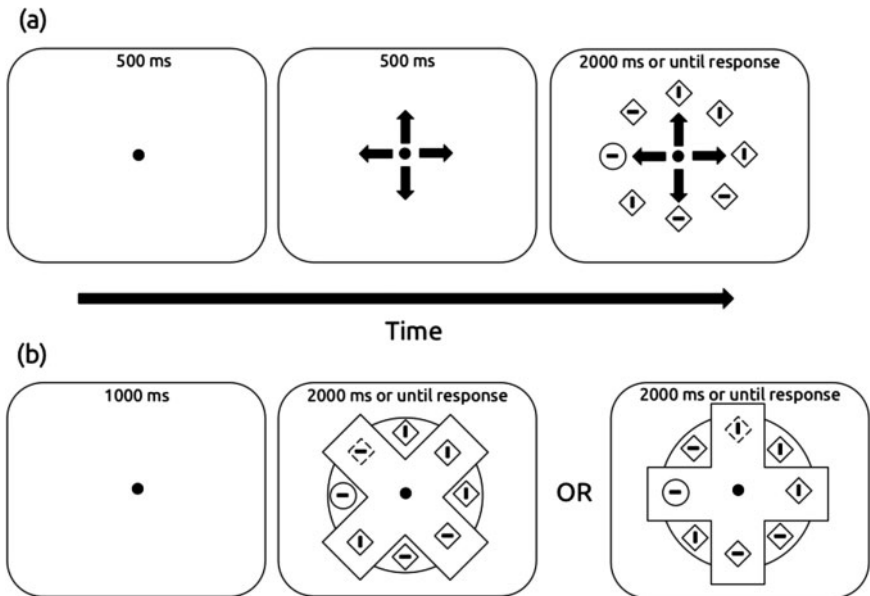


Figure 1. Sequence of events in Experiments 1 and 2. (a) In Experiment 1, a fixation dot appeared alone on the screen for 500 ms. Next, four arrows pointing to the relevant locations appeared along with the fixation dot for 500 ms. Following this, the search display onset and appeared for 2000 ms or until response. The cued locations were blocked. (b) In Experiment 2, a fixation dot appeared on the screen for 1000 ms followed by the two objects and the search array, which appeared for 2000 ms or until response. The target always appeared on the cued object. The orientation of the cross object changed pseudorandomly on each trial. In Experiments 1 and 2, a colour singleton appeared on 50% of the trials. The diamond outlined by a dotted line depicts the colour singleton.

spreading to locations outside the object. Specifically, we hypothesize that perceptual grouping cues might configure observers' attentional window, and observers will restrict their attention to locations contained by the cued object, even if this object occupies non-contiguous locations in a circular search display (see Figure 1b). Such results would be accounted for readily by attentional selection from a grouped array (Vecera, 1994; Vecera & Farah, 1994) by proposing that the attentional window conforms to perceptual groups and that featural selection occurs within the attended perceptual groups (i.e., objects or surfaces).

To evaluate if featural attention, and thus the attentional window, can be constrained to perceptual surfaces or objects, we used the additional singleton paradigm (Theeuwes, 1992). In the additional singleton paradigm, observers search for a shape singleton (circle) among homogenous distractors (diamonds). In half of the trials, all items are the same colour. In the other half, one of the diamond distractors is a different colour, making it a colour singleton distractor. Observers are consistently slower to respond to the target when the colour singleton distractor is present than absent. Importantly, regardless of whether one interprets this colour singleton distractor related slowing as attentional capture (Theeuwes, 1992), singleton search mode (Bacon & Egeth, 1994), or a filtering cost (Becker, 2007; Folk & Remington, 1998), any colour singleton related slowing indicates that the colour singleton is within the attentional window. No colour singleton related slowing indicates that the colour singleton is not within the attentional window.

In Experiment 1, we replicated a result from Kerzel and colleagues (2012), in which arrows cued observers to the relevant locations as the search display onset. Kerzel and colleagues (2012) found that colour singletons at both cued and uncued locations slowed RTs to the target and, thus, they concluded that observers could not configure the attentional window to these non-contiguous locations. We cued observers to possible target locations before the onset of the search display, which may be a stronger cue than used by Kerzel and colleagues, because central cues, such as arrows, are not instantly effective (Jonides, 1981; Müller & Rabbit, 1989; Posner et al., 1980). Thus, our replication of Kerzel and colleagues is an even stronger test of whether observers can configure the attentional window to non-contiguous locations via central cues alone. If observers can configure the attentional window to non-contiguous locations without support from perceptual groups, then observers will respond slower when the colour singleton appears at a cued location than when the colour singleton appears at an uncued location. However, if observers need perceptual grouping cues to configure the attentional window to non-contiguous locations, then, because the relevant locations are not perceptually grouped, exclusive selection of these cued locations will fail in Experiment 1, and observers will respond slower when the colour singleton appears at both cued and uncued locations. This latter result would replicate Kerzel and colleagues.

EXPERIMENT 1

Method

Participants

Fourteen University of Iowa undergraduates participated for course credit. All reported having normal or corrected-to-normal vision. Two observers were excluded for low accuracy (below 90% correct).

Stimuli and procedure

A Macintosh Mini using MATLAB and the Psychophysics Toolbox (Brainard, 1997) presented stimuli and collected responses. The displays appeared on a 17 inch CRT screen with observers sitting approximately 60 cm from the screen.

The stimulus set was composed of eight coloured shapes equally spaced around the circumference of a centred imaginary circle with a radius of 8.12° . The fixation point was a small blue dot (RGB 0, 0, 255), with a radius of 0.15° . In each display, there were seven diamonds and one circle. The side of each diamond was 0.9° . The circle had a radius of 0.9° . All distractor items contained randomly tilted lines, which measured $0.65^\circ \times 0.15^\circ$. The circle contained a vertical or horizontal line that also measured $0.65^\circ \times 0.15^\circ$. Whether the circle contained a vertical or horizontal line was decided pseudorandomly on each trial. The target circle was red (RGB 255, 0, 0; 37.8 cd/m^2 ; CIE Yxy 37.8,0.562,0.323) and appeared on every trial. On half of the trials, the colour singleton was absent from the display and all of the distractor diamonds were red. On the other half, the colour singleton was present and it was a green diamond (RGB 20, 215, 0; 115.5 cd/m^2 ; CIE Yxy 115.5,0.291,0.558). The colour singleton's location was chosen randomly from locations not already occupied by the target. The search array appeared on a grey background (RGB 125, 125, 125).

The procedure appears in [Figure 1a](#). The fixation dot appeared alone for 500 ms followed by four arrow cues for 500 ms. The arrows were 2.4° long and 0.6° wide at the base. The head of the arrow was 1.2° wide at the widest point, which was 0.6° from the tip of the arrow. The base of each arrow was positioned 1.25° from the centre of the screen. These arrow cues either pointed to the cardinal positions or diagonal positions of the search display. The arrows stayed visible throughout the entire trial. The position that the arrows pointed towards was counterbalanced across blocks and served as a 100% valid cue. Before each block, observers were informed with 100% validity about the possible target locations. The position of the target was chosen pseudorandomly on each trial from the four cued locations. All search items appeared on the screen simultaneously and remained visible for 2000 ms or until response. If observers did not respond within 2000 ms, they were encouraged to respond faster and the

trial was marked as incorrect. An error beep alerted observers to incorrect responses.

Observers were given the task of reporting the orientation of the line within the target circle. Observers reported line orientation using the “m” and “z” keys. Observers were informed that their target was the red circle and that they should ignore differently coloured items since these items would never be the target. Eye movements were not monitored, but observers were encouraged not to move their eyes. Finally, observers were instructed to respond as quickly and accurately as possible.

Observers began the experiment with 64 practice trials to acquaint them with the task. In 32 of the trials, the target appeared at the cardinal locations and in the other 32 trials, the target appeared at the diagonal locations. The cued locations switched every block and order was counterbalanced across observers. Following the practice trials, observers completed 896 trials divided into eight blocks of 112. Before each block, observers were encouraged to take a self-paced break and informed about the relevant locations.

Results and discussion

Reaction times (RTs) above 1500 ms and below 300 ms and incorrect RTs were excluded from the data analysis. This trimming eliminated less than 2% of the data.

The RTs for the relevant conditions appear in [Figure 2](#). To evaluate the effect of the colour singleton and if the effect of the colour singleton was dependent on whether it was at a cued or uncued location, RTs were submitted to a within subjects one-way ANOVA with the factors: colour singleton absent, colour singleton present at cued location, and colour singleton present at uncued location. The ANOVA found a significant main effect, $F(2, 22) = 5.88, p < .01$. As expected, a planned comparison found RTs were slower when the colour singleton appeared at a cued location (710 ms) than when it was absent (691 ms), $t(11) = 3.40, p < .01$ (see [Figure 2](#)). Critically, planned comparisons failed to find slower RTs when the colour singleton was present at an uncued location (701 ms) than when it was absent, $t(11) = 2.07, p = .063$, and when the colour singleton appeared at cued than uncued location, $t(11) = 1.51, p = .158$. The fact that colour singletons at cued locations did not slow RTs more than colour singleton at uncued locations replicates Kerzel and colleagues (2012) and indicates that observers failed to configure the attentional window around only cued locations.

Error rates appear in the corresponding bars of [Figure 2](#). Observers generally made few errors (< 5%). Error rates were submitted to the same ANOVA as the RTs. The ANOVA found no effect, $F < 1$. It is likely the ANOVA failed to find an effect because errors were rare.

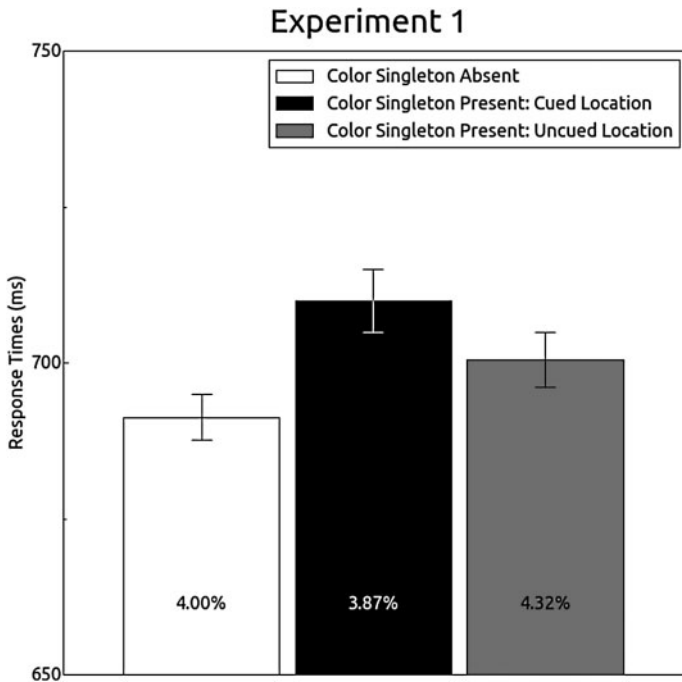


Figure 2. Experiment 1 response times (ms) to the target as a function of colour singleton location (absent, present at a cued location, and present at an uncued location). Error rates of each condition are reported at the base of the bars. Error bars represent 95% within subject confidence intervals (Cousineau, 2005; Loftus & Masson, 1994; Morey, 2008).

The current results replicated Kerzel and colleagues (2012) in finding that RTs did not differ when colour singletons appeared at cued and uncued locations, which demonstrates that the attentional window was not precisely configured to cued locations. In Experiment 2, we tested if object surfaces and boundaries provide a stronger constraint on attention and allow attention to be configured precisely to non-contiguous locations. We placed the target and distractors on a cross super imposed upon a circle, creating the perception that the search items appeared on two separate objects (see Figure 1b). Before each block of trials, observers were cued to which of the two objects the target would appear upon. Additionally, to ensure that observers constrained their attentional window to the objects and not the spatial locations of those objects, the objects' orientations rotated pseudorandomly between trials so that any of the locations in the search array could be occupied by either object on any given trial. We predict that if observers can constrain their attentional window to perceptually grouped items (object surfaces in this case), then the singleton distractor will only slow RTs when it appears on the cued object. Conversely, if the attentional window cannot

be constrained to the cued object, then the singleton distractor will slow RTs to the target both when it is on the cued object and when it appears on the uncued object.

EXPERIMENT 2

Methods

Participants

Thirteen University of Iowa undergraduates participated for course credit. All reported having normal or corrected-to-normal vision. One observer was excluded for low accuracy (below 90% correct).

Stimuli and procedure

The stimuli and procedure were the same as Experiment 1 except for the following exceptions. The circle and diamonds were placed upon two background objects, a cross superimposed on a circle. The length of the cross was 19.5° and the radius of the circle was 7.45° . Each object was bevelled using Photoshop to enhance the perception of two separate objects in depth. On each trial the cross could be white (RGB 255, 255, 255) and the circle could be black (RGB 0, 0, 0) or vice versa. This was decided pseudorandomly on each trial. The cross and circle were placed on a grey background (RGB 125, 125, 125).

The procedure appears in [Figure 1b](#). Before each block, observers were cued with 100% validity which of the two background objects would contain the target. The cued background object switched each block and starting cued object was counterbalanced across observers. To ensure that observers could not search specific locations, the orientation of the cross was varied pseudorandomly between trials. This means that on 50% of the trials, the cross was positioned in the canonical vertical orientation; and in the other 50% of trials, the cross' orientation was rotated 45° so that it looked like an "X". Each trial began with the fixation point alone on the screen for 1000 ms. After this, the large cross, large circle, and all search items appeared on the screen simultaneously and remained visible for 2000 ms or until response.

Results and discussion

The same RT trimming procedures were used as in Experiment 1. This led to trimming of less than 1.5% of the data.

The RTs across relevant conditions appear in [Figure 3](#). To evaluate if the effect of the colour singleton was dependent on whether or not it appeared on the cued object, RTs were submitted to a within subjects one-way ANOVA with the factors: colour singleton absent, colour singleton present on the cued object,

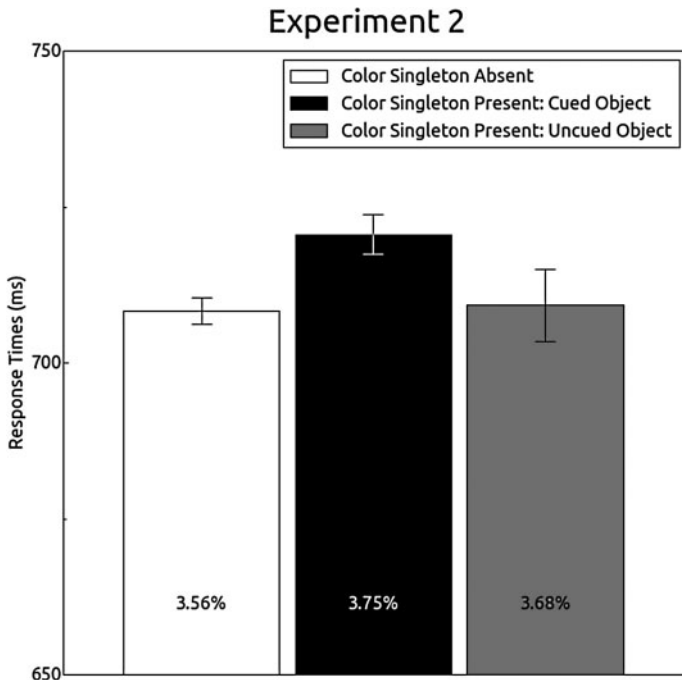


Figure 3. Experiment 2 response times (ms) to the target as a function of colour singleton location (absent, present at a cued object, and present at an uncued object). Error rates of each condition are reported at the base of the bars. Error bars represent 95% within subject confidence intervals (Cousineau, 2005; Loftus & Masson, 1994; Morey, 2008).

and colour singleton present on uncued object. The ANOVA found a significant main effect, $F(2, 22) = 8.02, p < .005$. A planned comparison found RTs were slower when the colour singleton was on the cued object (721 ms) than absent (708 ms), $t(11) = 3.78, p < .005$. Critically, planned comparisons confirmed RTs were not slower when the colour singleton appeared on the uncued object (709 ms) than when absent, $t < 1$, and demonstrating that the attentional window configures to object boundaries, RTs were slower when the colour singleton appeared on the cued object than the uncued object, $t(11) = 2.80, p < .05$. When the colour singleton appeared on an uncued object, it was as if the colour singleton was absent. These results demonstrate that colour singletons only slowed RTs to the target when they appeared on the cued object, indicating that the attentional window was precisely constrained to the cued object. These results suggest that observers can dynamically configure the shape of their attentional window to fit perceptually grouped locations.

Error rates appear in the corresponding bars of Figure 3. Observers made few errors ($< 4\%$). Error rates were submitted to the same ANOVA as the RTs. The

ANOVA found no effect, $F < 1$, because errors were rare. However, we do note that accuracies followed the same pattern of data as the RTs.

Although Experiment 2 demonstrates that observers can precisely configure their attentional windows to non-contiguous locations, the similarity between the results of Experiments 1 and 2 prevents us from concluding that objects bring about this ability. Specifically, spatially cuing attention to non-contiguous locations does influence the effect of a singleton distractor, although this influence is not as robust as directing attention to a perceptual object. To strengthen our argument, in Experiment 3, we replicated both Experiments 1 and 2 in a within-subjects design. Not only will this replicate our results, but it will also increase the statistical power of our comparisons between cuing attention by arrows and objects.

EXPERIMENT 3

Methods

Participants

Twenty-four University of Iowa undergraduates participated for course credit. We doubled the number of observers to compensate for halving the number of trials in each critical condition. All observers reported having normal or corrected-to-normal vision.

Stimuli and procedure

The stimuli were the same as Experiments 1 and 2. The procedure roughly mirrored Experiments 1 and 2 with the following minor exceptions. Observers were cued to the target's location via either arrows (as in Experiment 1) or objects (as in Experiment 2). Cue type pseudorandomly changed between blocks. Observers performed a practice block of 12 trials with each cue type before beginning the experiment. Observers performed 16 blocks of 64 trials rather than eight blocks of 112 trials. To best equate our experiment with that of Kerzel and colleagues (2012), the arrow cue appeared simultaneously with the search display. This also helps equate the arrow and object cueing conditions. Finally, target colour was randomly assigned in each trial (red or green). The colour singleton's colour was always the opposite of the target.

Results and discussion

The same RT trimming procedures were used as in Experiments 1 and 2. This trimming eliminated less than 2.2% of the data.

RTs across the relevant conditions appear in Figure 4. The results are remarkably similar to those from Experiments 1 and 2. To evaluate the effect of cue type and distractor location, RTs were submitted to a within subjects 2×3

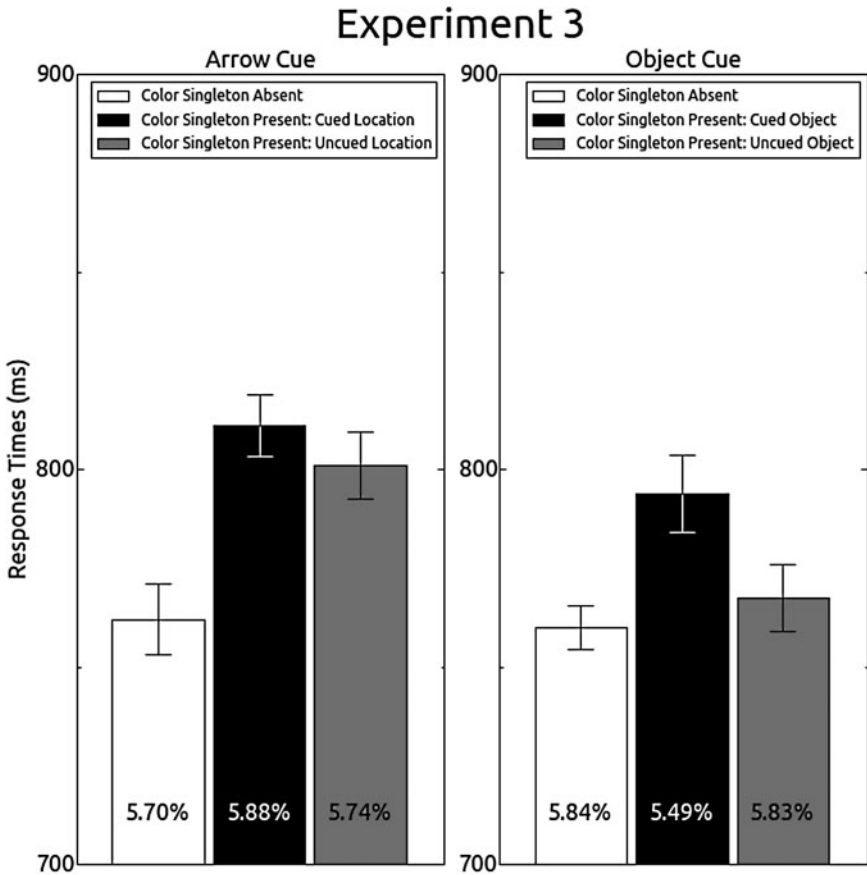


Figure 4. Experiment 3 response times (ms) to the target as a function of colour singleton location (e.g., absent, present at a cued object, and present at an uncued object). The left panel depicts data from blocks using an arrow cue. The right panel depicts data from blocks using an object cue. Error rates of each condition are reported at the base of the bars. The left panel depicts data from blocks using an arrow cue. The right panel depicts data from blocks using an object cue. Error bars represent 95% within subject confidence intervals (Cousineau, 2005; Loftus & Masson, 1994; Morey, 2008).

ANOVA with the factors Cue Type (arrow; object) and Colour Singleton Location (colour singleton absent; colour singleton present on the cued object; colour singleton present on uncued object). The ANOVA found a significant main effect of Cue Type, $F(1, 23) = 5.07, p < .005$, and Colour Singleton Location, $F(2, 46) = 26.57, p < .001$. Critically, these main effects were subsumed by a significant interaction, $F(2, 46) = 8.16, p < .001$, demonstrating that colour singletons affected RTs differently when observers were cued with arrows and objects.

To understand this interaction we analyzed RTs from both cue types independently. First, we used planned comparisons to understand how colour singleton location affected RTs when arrows cued the relevant locations. Observers responded slower when the colour singleton appeared at a cued location (811 ms) than when absent (762 ms), $t(23) = 7.01$ $p < .001$. Observers also responded slower when the colour singleton appeared at an uncued location (801 ms) than when absent, $t(23) = 5.22$ $p < .001$. Observers responded equally slow when the colour singleton appeared at a cued location and at an uncued location, $t(23) = 1.54$, $p = .138$. These results replicate Kerzel and colleagues (2012) and demonstrate that colour singletons at both cued and uncued locations distract observers. Critically, this indicates that when cued by arrows, observers could not configure their attentional windows precisely to cued locations.

Next, we used planned comparisons to understand how colour singleton location affected RTs when objects cued the relevant locations. Observers responded slower when the colour singleton appeared on the cued object (794 ms) than when absent (760 ms), $t(23) = 5.23$, $p < .001$. Observers responded equally fast when the colour singleton appeared on the uncued object (767 ms) and when absent, $t(23) = 1.46$, $p = .158$. Observers responded slower when the colour singleton appeared on the cued object than when the colour singleton appeared on the uncued object $t(23) = 3.16$, $p < .01$. These results demonstrate colour singletons on the cued object slowed RTs while colour singletons on the uncued object did not. This indicates that objects enable observers to configure their attentional windows precisely to the cued locations.

Error rates appear in the bases of the bars in Figure 4. Error rates were submitted to the same ANOVA as the RTs. The ANOVA found no main effect of Cue Type, $F < 1$, and no main effect of Colour Singleton Location, $F < 1$. The ANOVA also did not find a significant interaction, $F < 1$. We suspect near floor error rates prevented us from finding any significant effects.

GENERAL DISCUSSION

Our ability, or inability, to restrain attention to task relevant information has been debated over the past 25 years (Bacon & Egeth, 1994; Folk et al., 1992; Theeuwes, 1992; see Vecera, Cosman, Vatterott, & Roper, 2014, for a summary). Most of this work concentrates on the role of features in the control of attention and ignores how the configuration of spatial attention interacts with featural selection. The attentional window account theorizes that salient, irrelevant stimuli demand attention only within an “attentional window”, that is, the spatial region broadly attended in the course of performing a task (Belopolsky et al., 2007). The current project used the additional singleton paradigm to measure how precisely observers configured this attentional window. In Experiment 1 we replicated Kerzel and colleagues’ (2012) original demonstration that observers

cannot configure the attentional window to non-contiguous locations. In Experiment 2 we kept the same target/distractor locations, but used object surfaces to perceptually group the locations, so that items fell on the same or different surfaces or groups. In Experiment 2 we found that observers configured their attentional window very precisely to perceptually grouped, non-contiguous locations.

Our results bear relevance to the debate over whether stimulus-driven inputs or goal-driven inputs primarily drive attentional control (Folk et al., 1992; Theeuwes, 1992). Our results show that stimulus-driven inputs only influence attentional control when salient items appear upon task-relevant surfaces. This finding constrains the stimulus-driven attentional control account. That is, stimulus-driven attentional control only occurs on task-relevant surfaces. This interpretation of our results requires that we interpret slower RTs when the colour singleton is present than absent as attentional capture (Theeuwes, 1992), but this interpretation has been questioned (Folk & Remington, 1998). We do not make any strong claims about the interpretation of colour singleton related slowing and instead note that all accounts predict observers will respond slower when the colour singleton falls within observers' attentional window. Thus, whether colour singletons in the additional singleton paradigm slows RTs due to search mode (Bacon & Egeth, 1994), a filtering cost (Becker, 2007; Folk & Remington, 1998), or capture (Theeuwes, 1992), our results demonstrate that observers can precisely configure the attentional window around perceptual groups, a configuration that is substantially less precise without perceptual groups (Kerzel et al., 2012). This means that irrelevant, salient distractors only influence attentional control when on a relevant surface.

The attentional window hypothesis speculates that spatial selection acts as a gatekeeper for featural selection, which is also interesting because some studies find featural attention modulates task-relevant features across the entire visual field (Moher, Lakshmanan, Egeth, & Ewen, 2014; Serences & Boynton, 2007; Zhang & Luck, 2008). This implies that when we direct attention towards feature values, the effects of featural attention should occur independent of any spatial selection. Work supporting the attentional window suggests that featural selection is constrained to relevant locations (Kerzel et al., 2012). This seems at odds with past demonstrations of featural attention across the visual array. Future work will have to evaluate why featural selection can be restricted to particular locations in some experiments yet spreads across the visual field in other experiments. It is possible that the perceptual groups in some experiments and lack of perceptual groups in others mediate these incongruent experimental findings.

Our results bear relevance to the object-based attention literature. Object-based attention refers to the cost of either switching (Egely, Driver, & Rafal, 1994; Vecera, 1994) or spreading (Hollingworth et al., 2012; Richard et al., 2008) attention from one object to another versus maintaining attention within a single

object. Our current finding that objects enable observers to precisely configure their attentional windows represents the other side of the coin: objects benefit observers by increasing selectivity and allowing participants to allocate attention to task-relevant locations only (see Cosman & Vecera, 2012, for a related finding). Thus, our finding unites the attentional window and object-based attention literatures.

Our demonstration that observers can configure the attentional window to perceptual groups helps integrate the attentional control literature with real-world search tasks. In the real world, observers often constrain search to relevant objects or surfaces (Torralba, Oliva, Costelhana, & Henderson, 2006). For example, when searching for one's pen, one does not simply search the entire office. Instead, one will constrain search to relevant objects such as the surface of one's desk. Our results suggest that when one is searching for a pen on one's desk, a highlighter on the floor will not capture attention, but a highlighter on the desk will. Studies using real world scenes should follow up these results for a more conclusive demonstration, but the finding that contextual cueing only occurs on relevant surfaces (Brooks, Rasmussen, & Hollingworth, 2010) is certainly encouraging by suggesting that scene and surface structure constrains the allocation of spatial attention.

The finding that observers can configure the attentional window to non-contiguous locations demonstrates the intelligence (i.e., configurability) of the attentional window. Many researchers debate the importance of top down (Folk, Remington, & Wright, 1994) and bottom up or salience-based (Theeuwes, 1992) inputs for attentional control, and an intelligent attentional window illustrates the importance of top-down inputs. Even if attentional control is purely based on bottom-up inputs within the attentional window (Belopolsky et al., 2007), the ability to dynamically configure the attentional window according to task-relevant groups highly constrains the importance of bottom-up inputs in real-world search tasks. Thus, this demonstration of a highly configurable attentional window highlights the importance of top-down inputs for real-world search.

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