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The Typical Advantage of Object-Based Attention Reflects Reduced Spatial Cost

Yaffa Yeshurun and Einat Rashal
University of Haifa

In Egly, Driver, and Rafal's (1994) seminal study, an attentional precue appeared either at the target location (valid), a different location within the same object (invalid-same), or on another object (invalid-different). Performance was best in the valid condition, reflecting the advance allocation of spatial-attention. In addition, performance was better in the invalid-same than invalid-different condition, reflecting object-based attention allocation. However, previous studies that used this paradigm did not include a baseline condition in which neither a specific object nor a specific location was indicated. It is, therefore, not clear whether this object-based effect reflects a 'genuine' performance benefit over baseline, or a reduction of the cost inflicted by allocating spatial attention to the wrong location. To examine these possibilities, the authors performed 3 experiments in which they added a neutral condition to the classical paradigm. The typical results were replicated, but performance was worse in the invalid-same than neutral condition. Hence, attending an object only reduced the cost of allocating attention to the wrong location. Importantly, because the different theoretical accounts of object-based effects generate different predictions regarding performance in the neutral condition, these findings pose various constraints on the different accounts.

Keywords: object-based attention, spatial cueing, neutral cue, benefit, cost

It is well known that spatial attention can be allocated to a location based on prior information (e.g., spatial precues), and that this could lead to both benefit and cost effects (e.g., Jonides, 1981; Posner, Nissen, & Ogden, 1978). The *benefit* refers to the improved performance observed when comparing the valid condition, in which the precue indicates the target location, with a neutral condition, in which no specific location is indicated. Typically, this benefit is attributed to the advance allocation of spatial attention to the target location afforded by the valid cue. The *cost* refers to the performance impairment observed when comparing the neutral condition with the invalid condition, in which the cue indicates a different location than that of the target. This cost is attributed to the need to disengage spatial attention from the invalid location or to inhibition of nonattended locations. A seminal study by Egly, Driver, and Rafal (1994) suggested that attentional precues can lead to the selection of an object, in addition to the selection of a location. In that study two rectangles were presented at the beginning of the trial. One of the rectangles' ends was then marked by a peripheral cue and a target followed the cue. The target could appear at the cued end of the rectangle (valid condition), the other end of the cued rectangle (invalid-same condition: different location within the same object) or at the equidistant end of the noncued rectangle (invalid-different condition: different location on a different object). Egly et al. (1994) found the fastest response times (RTs) in the valid condition, reflecting the benefit of spatial selection. Critically, RTs were faster in the invalid-same than invalid-different condition. This latter finding was taken as evidence of object-based selection. These results were replicated later on by many studies (e.g., Hecht & Vecera, 2007; Ho & Yeh, 2009; Macquistan, 1997; Martínez, Teder-Sälejärvi, & Hillyard, 2007; Moore, Yantis, & Vaughan, 1998; Pratt & Sekuler, 2001; Shomstein & Yantis, 2004; for reviews, see Chen, 2012, and Reppa, Schmidt, & Leek, 2012).

However, none of the previous studies that used a variant of this paradigm included a neutral condition in which no specific object is indicated. Hence, it is impossible to tell whether the improved performance found in the invalid-same condition (i.e., when the relevant object was selected in advance) reflects a benefit over a condition in which no specific object is selected in advance (neutral condition), or a smaller cost.

The question of whether the object-based effect reflects a benefit or a smaller cost is important because the different theoretical accounts of this effect provide different predictions regarding the neutral condition. Specifically, three main explanations were provided for the object-based effect. One of these explanations is attentional spreading or signal enhancement (e.g., Avrahami, 1999; Chen & Cave, 2006; Richard, Lee, & Vecera, 2008; Roelfsema & Houtkamp, 2011). According to this account, the advantage of the invalid-same condition over the invalid-different condition is due to spreading of attentional resources (e.g., signal enhancement) along the object from the cued location to the other locations of the same object. Areas to which attention has spread are better represented leading to better performance. Another possible object-based mechanism is attentional prioritization (e.g., Drummond & Shomstein, 2010; Shomstein & Yantis, 2002, 2004).

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Yaffa Yeshurun and Einat Rashal, Psychology Department and Institute of Information Processing and Decision Making, University of Haifa.

Correspondence concerning this article should be addressed to Yaffa Yeshurun, Psychology Department and Institute of Information Processing and Decision Making, University of Haifa, Haifa 3498838, Israel. E-mail: yeshurun@research.haifa.ac.il

According to this account, when there is a need to search for the target, object-based effects reflect the higher priority in search order given to locations within the cued object. With this account, locations within the selected object are not better represented but are searched before locations within other objects. The third explanation is the attentional shifting account (Brown & Denney, 2007; Lamy & Egeth, 2002), suggesting that the object-based effect is due to the higher cost involved in shifting attention between objects than within objects. Specifically, Brown and Denney (2007) demonstrated that RTs in the invalid-different condition were slower because this condition entailed a costly disengagement from the attended object, which was not required with the invalid-same condition. The first two accounts—attentional spreading and attentional prioritization—have a similar prediction regarding a design that includes a neutral condition. If the advantage of the invalid-same condition is brought about by signal enhancement that spreads to the target location from the cued location, then better performance should be found with the invalid-same than neutral condition. This is because with the neutral condition no specific object is selected and thus there should be no enhancement of the target. Likewise, if the faster RTs in the invalid-same than invalid-different condition are due to a bias to search first locations within the attended object, then RTs should also be faster in the invalid-same than neutral condition. Again, this is because with the neutral condition no specific object is selected and therefore there is no bias to search one object over another. In contrast, the attentional shifting account generates a different prediction. According to this account, performance is better in the invalid-same than invalid-different condition because the latter involves attentional disengagement from a selected object. Thus, there should be no advantage for the invalid-same over the neutral condition because with both conditions there is no need for attentional disengagement from an object, either because no object is selected or because the target appeared in the same object as the cue. Note that if the invalid-same condition has no advantage over the neutral condition in terms of object-based allocation of attention, performance should be better in the neutral than invalid-same condition due to allocation of space-based attention. That is, with the neutral condition there is also no need to disengage attention from an attended location because no location was selected, whereas with the invalid-same condition attention has to disengage from the invalidly cued location.

To test these different predictions we conducted three experiments using a similar paradigm to that of Egly et al. (1994), but in addition to the cueing conditions used in the original study, we also included a neutral condition in which neither a specific location nor a specific object was indicated (i.e., this condition did not afford an advance selection of a specific location or a specific object). If the previously reported improved performance in the invalid-same condition reflects a benefit, as expected according to the attentional spreading and attentional prioritization accounts, better performance should be found in the invalid-same condition compared to the neutral condition. In contrast, if the reported improved performance reflects a smaller cost due to the lack of an object-based attention disengage operation, as expected according to the attentional shifting account, the opposite pattern of results should be found—better performance should be observed in the neutral compared with the invalid-same condition, where a space-based attentional disengagement would still be required.

Experiment 1

This experiment was designed to test whether the typical object-based effect observed with the Egly et al. (1994) paradigm reflects a performance benefit over baseline, or a reduction of the cost brought about by the allocation of spatial attention to the wrong location. To that end, we added a neutral condition to the original paradigm. Specifically, in addition to the cueing conditions used in the original study (i.e., valid, invalid-same, invalid-different; Figure 1A, 1C, and 1D), in which a peripheral cue indicated a specific location, we also included a neutral condition in which a cue appeared at each end of each rectangle (i.e., four cues appeared simultaneously; Figure 1B). Thus, like the peripheral cue, this neutral cue indicated the onset of the upcoming target ensuring temporal preparations were equal in all cueing conditions. However, unlike the peripheral cue, the neutral cue did not indicate a specific location nor a specific object, and therefore did not allow an advance selection of a specific location or a specific object. Moreover, because the neutral cue involved stimulation at all four rectangles' ends, it ensured optimal conditions for the emergence of a reliable object-based effect as it encouraged the observers to spread their attention rather than focusing it on the center. That is, Goldsmith and Yeari (2003) demonstrated that the extent of the initial focus of attention plays an important role in modulating object-based effects. They found that the emergence of a stable object-based effect required that prior to the appearance of the cue, observers' attention was spread across the rectangles. Such spreading of attention was encouraged by the fact that the

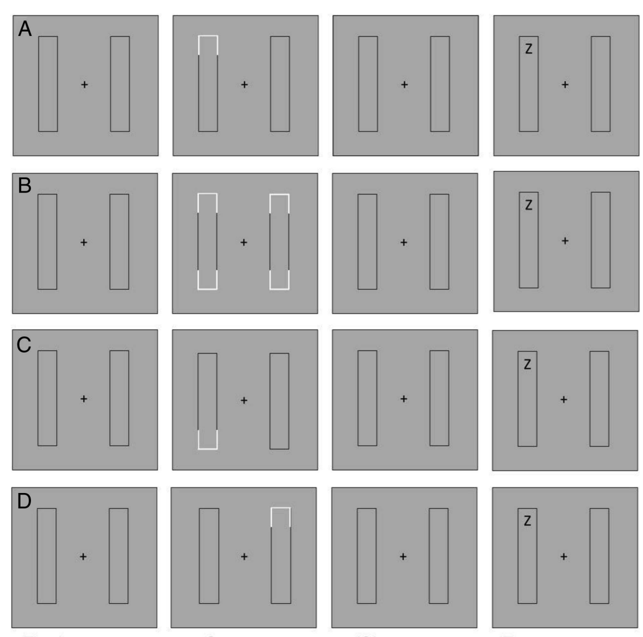

Figure 1. A schematic depiction of the sequence of events in a single trial of Experiment 1, in each of the cueing conditions: (A) valid; (B) neutral; (C) invalid-same; (D) invalid-different. The target was either an *N* or a Z.

peripheral cue could appear at any end of the rectangles. When their observers adopted a narrow attentional focus on the center of the display there was no significant difference between the different invalid conditions. In light of the importance of the attentional spread prior to cue onset, and given that our observers could not know in advance which cue is about to appear, it was important to ensure that both cue types (peripheral and neutral) encouraged the spreading of attention across the rectangles rather than focusing it centrally. As detailed above, the critical question tested in this experiment was whether or not performance in the invalid-same condition will be better than performance in this neutral condition.

Method

Observers. Twenty-one students from the University of Haifa participated in this experiment. The number of participants was determined based on previous successful demonstrations of object-based effects (e.g., Avrahami, 1999; Goldsmith & Yeari, 2003; Hecht & Vecera, 2007; Law & Abrams, 2002). All the observers had normal or corrected-to-normal vision, and all of them were naive to the purpose of the study. This study adhered to the Declaration of Helsinki.

Stimuli and apparatus. The stimuli were presented using PsyScope (Cohen, MacWhinney, Flatt, & Provost, 1993) on a 21" monitor of a PowerMac G4 computer. As in Egly et al. (1994), each display consisted of two black rectangles (1.7° × 11.4°; Figure 1) with a line stroke of 0.2°, presented on a gray background on both sides of a black fixation cross (0.7° × 0.7°). The rectangles were centered at an eccentricity of 4.8°, and their orientation was either vertical or horizontal. The target was either the letter Z or *N* (1° × 1°, line stroke − 0.2°). The peripheral cue was a brief brightening of three sides (1.7° each) of one end of one of the rectangles. The neutral cue was a multi-element cue that included four cues identical to the peripheral cue, each appearing at one of the rectangles' ends.

Procedure. Each trial started with the fixation cross and two rectangles. After 1,000 ms, the cue was presented for 70 ms. The target appeared after interstimulus interval (ISI) of 50 ms and was presented for 100 ms. These values were chosen in an attempt to keep the overall time between cue onset and target offset short, to prevent eye movements (e.g., Mayfrank, Kimmig, & Fischer, 1987). The rectangles' orientation and target identity were chosen randomly for each trial, but occurred equally often throughout the experimental session. The peripheral cue was presented on 80% of the total trials, and the other 20% included a neutral cue. On trials with a peripheral cue, the target appeared at the cued location (i.e., valid condition) on 75% of the trials (60% of total trials); at the other end of the rectangle on which the cue appeared (i.e., invalid-same condition) on 12.5% of the trials (10% of total trials); and at the end of the other rectangle, which was equidistant from the cued end (i.e., invalid-different condition) on 12.5% of the trials (10% of total trials). On the neutral trials the target appeared equally often at each end. The observers had to report the identity of the target and an auditory feedback followed their response. Each observer participated in 160 practice trials and 960 experimental trials.

Results and Discussion

A repeated-measures two-way analysis of variance (ANOVA)—Rectangles Orientation (vertical vs. horizontal) × Cueing Condition (valid, invalid-same, invalid-different, neutral)—was performed on both correct RTs (see Figure 2) and accuracy data. RTs shorter than 150 ms or larger/smaller than 2 standard deviations from the mean of each observer were removed from the analyses (this resulted in the removal of 2.8% of the trials). The RT analysis revealed a significant main effect of cueing condition, $F(3, 60) = 106.47$, $p < .0001$; $\eta_p^2 = 0.84$, Figure 2. Planned comparisons revealed the expected benefit for the valid cue: the mean RT in the valid condition was significantly shorter than the mean RT in the neutral condition, $t(20) = 7.78$, $p < .0001$. This finding is consistent with previous studies of spatial attention that demonstrated the adequacy of a multi-element neutral cue (e.g., Carrasco, Williams, & Yeshurun, 2002; Talgar, Pelli, & Carrasco, 2004; Yeshurun, 2004; Yeshurun & Hein, 2011; Yeshurun & Marom, 2008; Yeshurun & Sabo, 2012). The expected object-based effect was also found: mean RT was significantly shorter in the invalid-same than invalid-different condition, $t(20) = 3.78$, $p < .0007$. This finding further supports the adequacy of the multi-element neutral cue because evidently it did not prevent the initial wide spread of attention required for the emergence of object-based effects (Goldsmith & Yeari, 2003). Critically, when we compared performance in the invalid-same condition to the neutral condition, the opposite effect was found: Mean RT was significantly shorter in the neutral condition than in the invalid-same condition, $t(20) = 5.02$, $p < .0001$. Importantly, this pattern of results was consistent for most of the participants. Figure 3 depicts the data points of all the participants for the three main comparisons: valid versus neutral, neutral versus invalid-same, and invalid-same versus invalid-different. As is clear in the figure, with all three comparisons most of the data points fall below the equality diagonal, reflecting the fact that for the majority of the participants RTs were faster in the former than latter component of each comparison. Thus, these findings are not a mere artifact of averaging.

The main effect of orientation and its interaction with cueing condition did not reach statistical significance (with both: $p > .1$). Accuracy was very high ($M = 0.94$, $SD = 0.24$) and the analysis of the accuracy data revealed no significant effects (with all: $p > .1$).

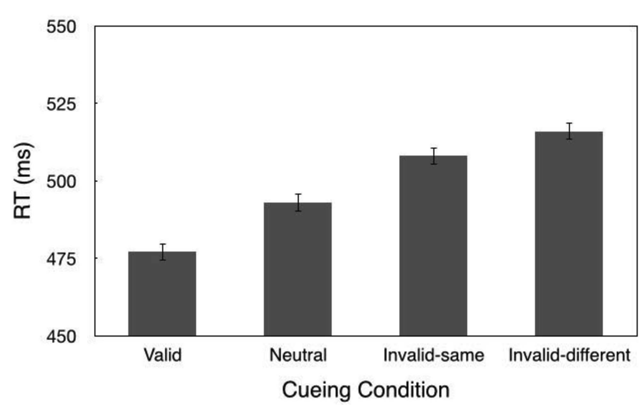

Figure 2. Response time (RT; ms) as a function of cueing condition in Experiments 1. Error bars correspond to ±1 SEM.

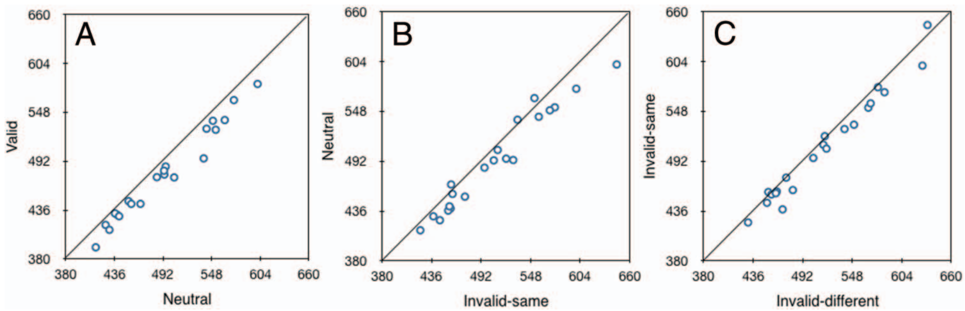

Figure 3. Response time (RT) in ms for each participant of Experiment 1 in the three main comparisons: (A) valid versus neutral; (B) neutral versus invalid-same; and (C) invalid-same versus invalid-different. See the online article for the color version of this figure.

Hence, in accordance with the prediction of the attentional shifting account of object-based attention (Brown & Denney, 2007; Lamy & Egeth, 2002), RTs were faster in the neutral condition than the invalid-same condition, suggesting that the typically reported object-based advantage is in fact a decrement of the cost inflicted by the allocation of space-based attention to the wrong location. In Experiment 2 we examined whether this finding was due to the specific cue-target ISI and target duration used in this experiment.

Experiment 2

The pattern of results observed in Experiment 1 suggests that the allocation of attention to an object does not reflect performance benefit over a baseline condition in which no specific location or a specific object was indicated; rather it only reduces the cost of allocating attention to an invalid location. This experiment was designed to test whether the results of Experiment 1 will be replicated with a longer cue-target ISI. We varied this factor because previous studies suggested that it may be relevant for the emergence of object-based effects (e.g., Avrahami, 1999; Chen & Cave, 2008; Law & Abrams, 2002) and we wanted to verify that the pattern of results observed with the neutral cue does not depend on the specific values chosen for this factor. Hence, the procedure of this experiment was identical to that of Experiment 1 except for the employment of a longer ISI (130 ms in comparison to 50 ms of Experiment 1). In addition, the lengthening of the ISI necessitated shortening of target duration to prevent eye movements (50 ms in comparison to 100 ms of Experiment 1). If the findings of Experiment 1 do not depend on the specific ISI and target duration used in that experiment they should be replicated here.

Method

Observers. Twenty-one students from the University of Haifa participated in this experiment. All the observers had normal or corrected-to-normal vision, and all of them were naive to the purpose of the study. None of these observers participated in Experiment 1.

Stimuli, apparatus, and procedure. The stimuli, apparatus, and procedure were the same as in Experiment 1 except for lengthening the ISI to 130 ms and shortening target duration to 50 ms.

Results and Discussion

As in the previous experiment, we performed a repeated-measures 2-way ANOVA—Rectangles Orientation (vertical vs. horizontal) × Cueing Condition (valid, invalid-same, invalid-different, neutral)—on both correct RTs and accuracy data. RTs shorter than 150 ms or larger/smaller than 2 standard deviations from the mean of each observer were removed from the analyses (this resulted in the removal of 3.3% of the trials). Like before, the RT analysis revealed a significant main effect of cueing condition, $F(3, 60) = 83.39$, $p < .0001$; $\eta_p^2 = 0.81$, Figure 4, and planned comparisons revealed the typical advantage of the valid condition: RTs were significantly faster in the valid than neutral condition, $t(20) = 7.84$, $p < .0001$. Similarly, an object-based effect was also found here: RTs were significantly faster in the invalid-same than invalid-different condition, $t(20) = 3.38$, $p < .002$. Most importantly, even though a longer ISI was used in this experiment, performance was still better in the neutral than invalid-same condition: RTs were significantly faster in the neutral than in the invalid-same condition, $t(20) = 3.64$, $p < .001$. The main effect of orientation and its interaction with cueing condition did not reach statistical significance (with both: $p > .1$). Thus, the pattern of results that emerged in Experiment 1 was not due to the specific values of ISI and target duration used in that study, as it was replicated here with different values. Finally, as was the case with

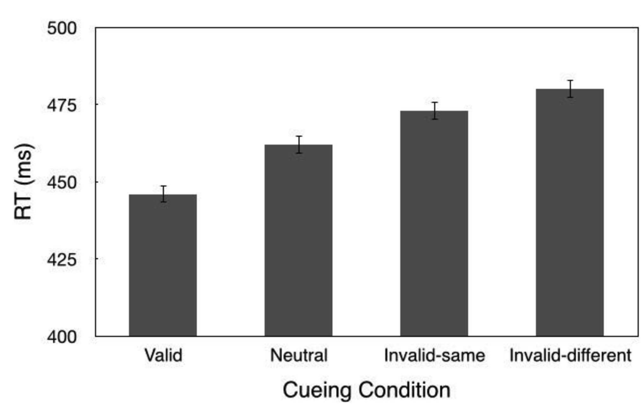

Figure 4. Response time (RT; ms) as a function of cueing condition in Experiments 2. Error bars correspond to ±1 SEM.

Experiment 1, this pattern of results was consistent for most of the participants (see Figure 5) demonstrating the robustness of these results.

Accuracy was also very high in this experiment (M = 0.94, SD = 0.23), however unlike Experiment 1, in this experiment the analysis of the accuracy data revealed a significant main effect of orientation, $F(1, 20) = 4.43$, $p < .05$; $\eta_p^2 = 0.18$: Accuracy was higher when the rectangles were vertical (M = 0.95, SD = 0.23) than when they were horizontal (M = 0.94, SD = 0.24). Most relevant for the goal of our study, the main effect of cueing condition and its interaction with orientation did not reach statistical significance (with both: $p > .1$).

Experiment 3

The results of both Experiments 1 and 2 suggest that the typical object-based effect found with Egly et al.'s (1994) paradigm cannot be interpreted as performance benefit over a baseline condition in which no specific location or object is indicated. One may wonder, however, whether the current findings are unique to the multi-element neutral cue used here. We do not find this possibility highly likely because several previous studies have already demonstrated that similar effects of attention are observed when different kinds of neutral cues are used, including multi-element cues like the one used here (e.g., Carrasco et al., 2002; Montagna, Pestilli, & Carrasco, 2009; Talgar et al., 2004; Yeshurun, 2004; Yeshurun & Carrasco, 2008; Yeshurun & Marom, 2008). Still, all of these studies examined space-based allocation of attention, whereas here we are examining object-based allocation of attention, and there might be some unintended effects of this multi-element cue that are relevant only to object-based selection. Therefore, we performed Experiment 3 to ensure that the lack of object-based advantage over the baseline condition was not due to the specific neutral cue used in Experiments 1 and 2. This experiment was identical to Experiment 1 except for the following: (a) A brief sound was presented in all conditions, prior to target onset, with the same stimulus onset asynchrony (SOA) as the visual cue. This sound served as a temporal warning signal announcing that the target is about to appear, and it ensured that temporal preparations are identical in all the experimental conditions. (b) The baseline condition included no visual cue - only the rectangles and the fixation were presented prior to the target. If better performance in the neutral than invalid-same condition will also be found in this experiment, when there is no multi-element or any other kind of visual cue, this will indicate that the performance advantage of the neutral condition is not due to the specific cue used in Experiments 1 and 2.

Method

Observers. Twenty-four students from the University of Haifa participated in this experiment. All the observers had normal or corrected-to-normal vision, and all of them were naive to the purpose of the study. None of these observers participated in the previous experiments.

Stimuli, apparatus, and procedure. The stimuli, apparatus, and procedure were the same as in Experiment 1 apart from the following: The stimuli were presented using PsychoPy (e.g., Peirce, 2007) on a 21" monitor of a Mac Pro computer; in all conditions, 120 ms prior to target onset, a 220 Hz tone was presented for 100 ms; the neutral condition included no visual cue—the rectangles and fixation appeared at the start of the trial and 1,120 ms afterward the target was presented; the auditory feedback was replaced with "+" and "−" black symbols.

Results and Discussion

Four participants were excluded from further analysis because of a too high error rate (≥20%). The data of the remaining 20 participants were analyzed as in the previous experiments: We performed a repeated-measures two-way ANOVA—Rectangles Orientation (vertical vs. horizontal) × Cueing Condition (valid, invalid-same, invalid-different, neutral)—on both correct RTs and accuracy data. RTs shorter than 150 ms or larger/smaller than 2 SDs from the mean of each observer were removed from the analyses (this resulted in the removal of 3.5% of the trials). Like before, the RT analysis revealed a significant main effect of cueing condition, $F(3, 57) = 36.09$, $p < .0001$; $\eta_p^2 = 0.66$, Figure 6A. Planned comparisons revealed the typical advantage of the valid condition: RTs were significantly faster in the valid than neutral condition, $t(19) = 8.38$, $p < .0001$. Critically, RTs were significantly faster in the neutral than in the invalid-same condition, $t(19) = 2.27$, $p < .02$, even though no visual cue was used in the neutral condition of this experiment. The fact that a similar effect emerges with a multi-element neutral cue and a no-cue condition is consistent with the various studies demonstrating similar space-

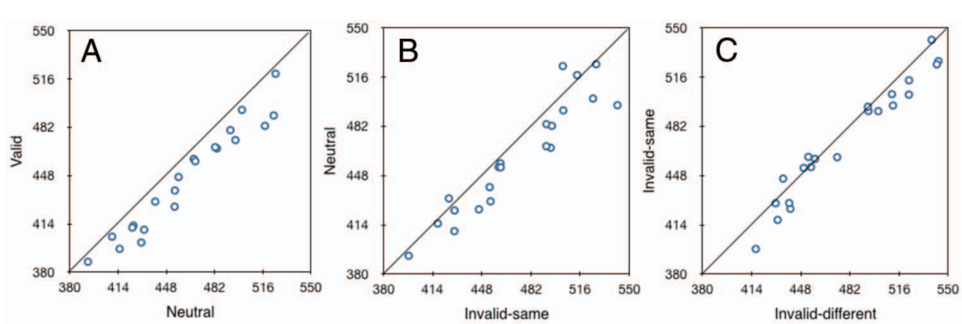

Figure 5. Response time (RT) in ms for each participant of Experiment 2 in the three main comparisons: (A) valid versus neutral; (B) neutral versus invalid-same; and (C) invalid-same versus invalid-different. See the online article for the color version of this figure.

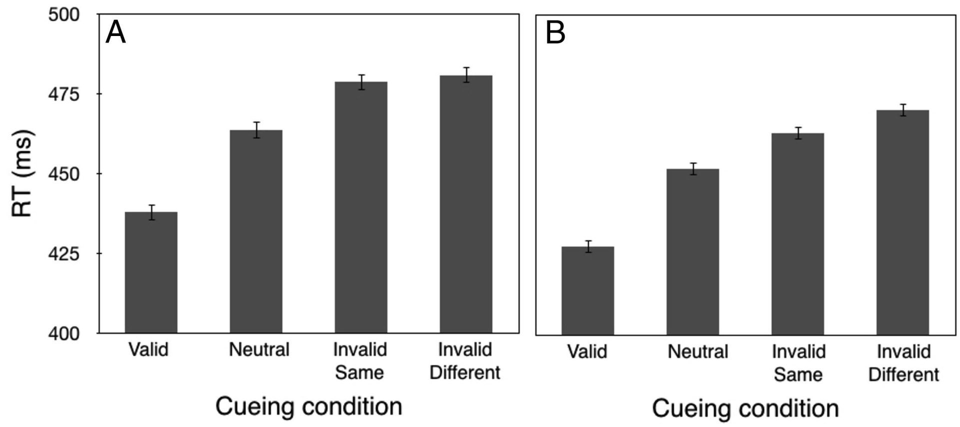

Figure 6. Response time (RT; ms) as a function of cueing condition in Experiments 3: (A) When all observers with error rate smaller than 20% are included. (B) Without one anomalous observer (see text and Figure 7). Error bars correspond to ±1 SEM.

based attentional effects regardless of the type of neutral cue (e.g., Carrasco et al., 2002; Montagna et al., 2009; Talgar et al., 2004; Yeshurun, 2004; Yeshurun & Carrasco, 2008; Yeshurun & Marom, 2008), and it further suggests that this also holds for object-based attentional effects. Most important for the goal of this experiment, the fact that the neutral advantage over invalid-same emerged even when the neutral condition did not include any visual cue suggests that this neutral advantage is not specific to the multi-element cue used in the previous two experiments.

Unexpectedly, in this experiment, the typical object-based effect did not reach statistical significance ($p = .25$). Examining individual data (see Figure 7) suggests that this is likely due to a single participant with particularly slow RTs in the invalid-same condition. Other observers demonstrate a similar pattern of results to that found before. Indeed, if this observer is taken out of the analysis, the object-based effect is significant [$t(18) = 2.55$, $p < .02$]. The other two comparisons also remain significant: The valid condition is still significantly faster than the neutral condition, $t(18) = 8.66$, $p < .0001$, and importantly the neutral condition is still significantly faster than the invalid-same condition, $t(18) = 1.96$, $p < .04$. The means of these conditions without the anomalous observer are presented in Figure 6B.

Finally, as in the previous experiments, the main effect of orientation and its interaction with cueing condition did not reach statistical significance (with both: $p > .1$). Also like before, accuracy was very high ($M = 0.95$, $SD = 0.22$), and the analysis of the accuracy data revealed no significant effects (with all: $p > .1$).

General Discussion

Egly et al. (1994) have demonstrated in their influential study that attentional precues can lead to both space-based and object-based selection. The former is evidenced by the fastest RTs found when the target appears at the same location as the cue. The latter is evidenced by the faster RTs found when the target appears at a different location than the cue but in the same object in comparison to when the target appears in a different location and object. In our current study both outcomes were replicated. However, unlike Egly et al., our study also included a neutral cue that neither indicated a specific location nor a specific object. This allowed us to test whether the performance improvement associated with object-based selection reflects a true benefit over a situation in which advance attentional selection is not possible, or a smaller

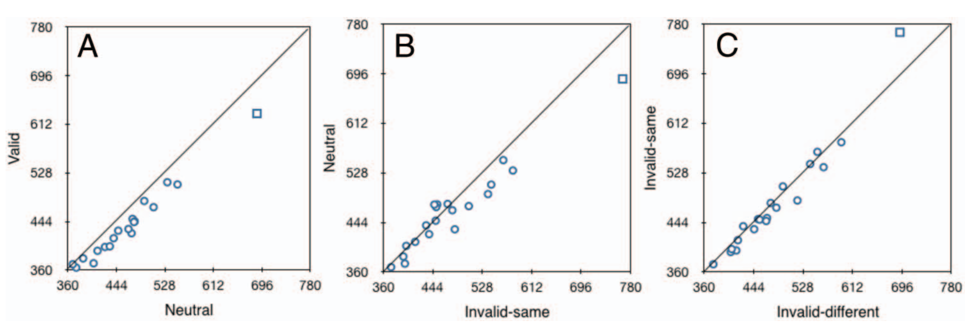

Figure 7. Response time (RT) in ms for each participant of Experiment 3 in the three main comparisons: (A) Valid versus Neutral; (B) Neutral versus Invalid-same; and (C) Invalid-same versus Invalid-different. An anomalous observer is marked with a square (see text). See the online article for the color version of this figure.

cost in comparison to a situation in which the wrong object and location were selected. The fact that in all three experiments, regardless of the ISIs and whether or not the neutral condition included a visual cue, RTs were faster in the neutral than the invalid-same condition suggests that the typical performance difference between invalid-same and invalid-different condition reflects a smaller cost rather than a benefit.

These findings have important implications for the various interpretations suggested thus far for object-based selection. Specifically, these findings are consistent with the predictions of the attentional shifting account (Brown & Denney, 2007; Lamy & Egeth, 2002), but not with those of the attentional spreading/signal enhancement account (e.g., Avrahami, 1999; Chen & Cave, 2006; Richard et al., 2008; Roelfsema & Houtkamp, 2011) or those of the attentional prioritization account (e.g., Drummond & Shomstein, 2010; Shomstein & Yantis, 2002, 2004). Contrary to the outcomes of the current three experiments, both the attentional spreading and attentional prioritization accounts predict better performance in the invalid-same than neutral condition. This is because in comparison to the neutral condition, according to the former account target representation in the invalid-same condition should be better due to the spreading of enhancement to the target location, and according to the latter account target location in the invalid-same condition should have higher priority in search order. In contrast, according to the attentional shifting account, the target in the invalid-same condition should have no advantage over the target in the neutral condition. This is because in both conditions there is no need to disengage attention from a wrongly selected object. Additionally, because with the neutral condition there is also no need to disengage attention from a wrongly selected location, performance in this condition should be better, as was indeed found in all our experiments. Thus, the addition of a neutral condition allowed us to determine which of the various object-based explanations can provide a better account of object-based effects found with the Egly et al. (1994) paradigm.

It is worthwhile to keep in mind that it might be possible to modify the attentional spreading and attentional prioritization accounts to accommodate the current results, but this will require the adoption of additional assumptions. In particular, these accounts will have to assume that the effects of space-based selection and the effects of object-based selection are mediated by independent mechanisms, and that the effects brought about by the space-based mechanism are considerably larger than those brought about by the object-based mechanism. That is, in the invalid-same condition the cue indicates the correct object but the wrong location. If the object-based benefit generated by selecting the correct object co-occurs with a space-based cost invoked when a wrong location is selected, and the magnitude of the object-based benefit is smaller than that of the space-based cost, then the object-based benefit may not be apparent even though it took place. This is the case regardless of whether the benefit reflects signal enhancement or prioritization. For instance, let us assume that directing spatial attention to a location leads to both facilitated processing at the selected location, and active inhibition at the other nonselected locations (e.g., to reduce noise), regardless of whether or not these nonselected locations are within the same object. Such active inhibition may lead to slower processing of targets presented at any nonselected location (i.e., invalid-same or invalid-different). Let us also assume that locations within the selected object are searched before locations within a nonselected object. With such priority-bias, on average, the invalid-same location will be searched before a neutral location. Still, if the amount of time that is saved for targets in the invalid-same location due to this bias is smaller than the amount of time added to the processing of these targets due to the active inhibition of unattended locations, then worse performance should be found with the invalid-same than neutral condition. Thus, under such conditions both accounts can accommodate worse performance in the invalid-same than neutral condition. However, thus far there is no empirical evidence to support these various assumptions. As detailed above, the attentional shifting account, unlike these two explanations, can easily accommodate the current findings without a need to adopt any additional assumptions.

There is another way with which the attentional spreading and attentional prioritization accounts can accommodate the current results, but again this will require the adoption of additional assumptions. Particularly, it is possible to assume that in the neutral condition spatial attention is spread across all four possible locations, resulting in simultaneous facilitation at all locations rather than no facilitation. Of course, given the improved performance observed with the valid condition in comparison to the neutral condition, this multiple locations facilitation must be smaller than the facilitation established when spatial attention can be narrowly focused on a single location based on the peripheral cue. Hence, to reconcile the current findings with the attentional spreading and attentional prioritization accounts an additional assumption is required. Specifically, both accounts will have to also assume that the advantage brought about by the object-based selection (whether it is enhancement or prioritization) is rather small, as it has to be smaller than the already small facilitation brought about by simultaneous space-based selection of four locations. Also, the assumption that with the neutral condition attention is spread across both rectangles cannot simply rest on evidence supporting the zoom-lens theory of attention (e.g., Eriksen & St. James, 1986), because according to this body of evidence the effect of attention weakens as the size of the attentional window increases. This would predict better performance in the invalid-same condition than neutral condition because the size of the attentional window can be half the size with the former than the latter (i.e., with the invalid-same condition attention needs to cover one rectangle, whereas with the neutral condition it has to cover two rectangles). Hence, one needs to assume here that the facilitation brought about by spreading space-based attention over twice as large region is still larger than the facilitation brought about by the object-based selection of a single object. This assumption awaits empirical testing.

In contrast, the attentional shifting account can easily explain the current results, because even with this 'multiple facilitation' view of the neutral condition the expected outcome is better performance in the neutral than invalid-same condition. That is, according to this account with both conditions there is no need to disengage from an object, but with the neutral condition there is some space-based facilitation, resulting in higher performance with the neutral condition. Given that with both views of the neutral condition the attentional shifting account can accommodate the current findings without a need to adopt any additional assumptions to those that were already tested (e.g., Brown & Denney, 2007), whereas the other accounts require several assumptions that need to be tested empirically, the current study is in favor of the attentional shifting account of object-based attention. Of course, the attentional shifting account of object-based attention cannot explain object-based effects that do not involve shifts of attention (e.g., Chen & Cave, 2006; Kramer & Jacobson, 1991).

To summarize, in this study we added to the classical Egly et al.'s (1994) paradigm a neutral condition, with which neither a specific object nor a specific location was indicated. This addition of a baseline condition revealed that the well-known object-based effect does not reflect a performance benefit but rather a smaller performance cost. That is, mean RT in the invalid-same condition was shorter than mean RT in the invalid-different condition, but was nevertheless longer than mean RT in the neutral condition. This finding is most naturally consistent with the shifting attention account of object-based attention, though with some additional assumptions the other accounts can also accommodate these findings.

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