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Static items are automatically prioritized in a dynamic environment

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Everyday experience provides us with the intuition that dynamic events guide or capture attention—something which has been confirmed in experimental studies. Recently, we showed that there are limitations to the extent to which dynamic items attract attention. In a visual search task where all items, except one, were dynamic, the dynamic items could be ignored and the static item could be efficiently detected. In the present study we investigated whether attention is automatically drawn to the static item. Three visual search experiments, in which the target and the static object were uncorrelated, revealed that the static item was nevertheless prioritized. This result is at odds with some of the current theories on attentional capture, including the "new object" hypothesis. The current study suggests that differences in dynamics, rather than dynamic features per se, determine where attention is allocated.

When you are looking for a friend in a crowd it helps when he or she waves. This example suggests that dynamic items attract attention. Research using visual search tasks has indeed confirmed that, within static environments, dynamic items can guide or capture attention (Franconeri & Simons, 2003; McLeod, Driver, & Crisp, 1988; Theeuwes, Kramer, Hahn, & Irwin, 1998; von Mühlenen, Rempel, & Enns, 2005; Watson & Humphreys, 1995; Yantis & Jonides, 1984).

Recently, Pinto, Olivers, and Theeuwes (2006) investigated the complementary question, namely whether in a dynamic environment, a static object is able to efficiently guide attention. Imagine everyone is frantically waving to people they know—would it be easier to find your friend if he or she is the only one who does not wave? Given that dynamic items attract attention,

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one might expect this to be quite difficult. However, Pinto et al. have found that when all items are blinking or moving except one, the dynamic items can be largely ignored and attention can be efficiently directed to the static target.

In Pinto et al.'s (2006) study the static item was always the target and participants were aware of this. In other words, the fact that it was static was a task-relevant feature of the target. Therefore, it is not clear if attention went to the static item because it matched the top-down settings of the participants, or whether attention was captured in an involuntary way. The present study intended to resolve this issue by using conditions in which the fact that an item was static was irrelevant to the task. For this purpose, we employed the irrelevant-feature search task developed by Yantis and Jonides (1984). As in a typical search task, participants search for a target item among a variable number of distractors. However, instead of the target always carrying the feature of interest, this feature is assigned to a randomly chosen item in the search display. Consequently, the object with the unique feature is the target in only 1/*n*th of the trials, with *n* indicating the number of items in the display. As the feature is uncorrelated with being the target, participants presumably have no top-down incentive to search for it since it is irrelevant to the task. Nevertheless, if the feature of interest draws attention automatically, one should still find improvements in search efficiency when the feature happens to coincide with the target. In other words, reaction times (RTs) as a function of search set size should be reduced. In our case, the unique feature of interest was being static.

Existing psychophysical theories offer two opposite predictions regarding the question whether or not a static object should automatically guide attention in a dynamic environment. Yantis and colleagues (e.g., Jonides & Yantis, 1988; Yantis & Egeth, 1999; Yantis & Hillstrom, 1994) suggest that the creation of a new perceptual object or group automatically draws attention. The abrupt onset of an object is a prime example of such a new object appearance, and has been found to capture attention, whereas a sudden increase in luminance of an existing object may be less effective (Yantis & Hillstrom, 1994). Franconeri and Simons' (2003) findings suggest that specific types of motion (such as looming) may also involuntarily draw attention, as long as these events are ecologically relevant to the organism. Finally, von Mühlenen et al. (2005) argue that in principle any dynamic change could capture attention, as long as there are no temporally neighbouring changes. Important for the current study is that all these views, which we will refer to as the *dynamic capture hypothesis*, predict that a static object does not automatically guide attention in a dynamic environment, since it does not indicate the appearance of a new object, it is not dynamic, and it does not undergo a change when the environment is stable (rather the reverse).

A different prediction can be derived from the views of, for example, Itti and Koch (2000), Nothdurft (1993), and Theeuwes (1992, 2004). In their view, attention is not driven by the specific quality of a feature (such as being dynamic), but by the difference between a feature and its (local) environment. The more salient a feature difference, the more likely that it draws attention. According to this saliency account a static item surrounded by dynamic items will automatically draw attention, since it carries a unique feature relative to its surroundings.

In the current study we investigated if a static object automatically guides attention in a dynamic background. We conducted three experiments in which the irrelevant-feature search task was employed.

EXPERIMENT 1: DOES A STATIC OBJECT AUTOMATICALLY GUIDE ATTENTION?

In Experiment 1, participants searched for a nontilted line segment among tilted line segments and indicated if the target was vertical or horizontal. Example displays are shown in Figure 1. We presented participants with two types of blocks. In the "irrelevant" block all line segments except one were continuously blinking on and off. The static element coincided with the target in 1/*n*th of the trials, with *n* indicating set size, and therefore was not predictive of the target. In the "relevant" block all elements except one were blinking, and now the static element was always the target. If the dynamic capture hypothesis is correct, then the static item should not capture

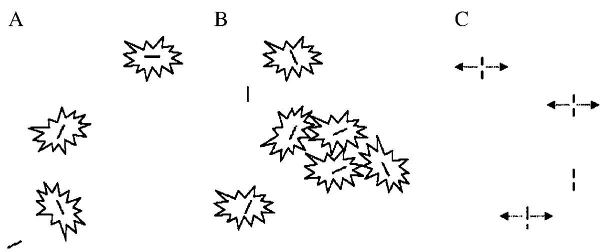

Figure 1. Typical examples of the search displays used in Experiments 1, 2 and 3. Panels A and B show examples of Experiments 1 and 2, in which participants searched for a vertical or horizontal line among slightly tilted lines. The flash surrounding an item indicates that it was blinking. Panel A depicts an example of a trial with set size 4, in which the target was one of the blinking items. The blinking objects randomly switched on and off after 150, 200, 250, or 300 ms. Chances of switching were equal for each lag and were not influenced by previous switching latencies. Panel B depicts an example of a trial with set size 8, in which the target was static. Panel C depicts an example of the search display used in the motion conditions of Experiment 3. Participants searched for a line with a gap above or below the middle. In this example all items except one were moving, the target was one of the moving items. In the actual experiments the lines were white and the background was black.

attention at all, and performance in the irrelevant block should be similar regardless of the target being static or dynamic. However, if the saliency account is correct then the static singleton should involuntarily draw attention and the target should be more efficiently found when it is static than when it is dynamic. Furthermore, if top-down factors play no role in directing attention to the static object, then performance for a static target should be similar regardless of whether being static is relevant or not.

Method

Participants. Eight participants, ranging in age from 18 to 22 years, average 19.6 years, took part as paid volunteers. All participants completed all of the conditions. All had normal or corrected-to-normal vision.

Apparatus and stimuli. The experiment was conducted on a computer with a Pentium IV processor, a 17-inch monitor, and a standard keyboard. The software package E-Prime was used for the layout and timing of the experimental trials. The stimulus field consisted of a 7×6 imaginary matrix ($12.68^\circ \times 8.26^\circ$ visual angle). In its cells white line segments (Commission Internationale de l'Eclairage [CIE] x, y coordinates: .283, .301) of size 0.76° were randomly placed. The distractors could appear anywhere on the matrix, the target could appear anywhere except in the middle (row 4, column 3 or 4). The luminance of the line segments was 65.62 cd/m^2, the luminance of the background was 0 cd/m^2, as measured with a Tektronix photometer. In each display there was a vertical or horizontal white line target, among white lines that were tilted 22.5° to either side of the horizontal or vertical plane.

Procedure. Participants sat at approximately 90 cm from the monitor, with their fingers resting on the "z" and "m" keys, which were used as the response buttons. The experiment consisted of 12 blocks, each containing 48 trials. In the *relevant* condition participants looked for a static horizontal or vertical white line among tilted white lines that blinked on and off. The tilted lines randomly switched on or off with an equal chance of switching after 150, 200, 250, or 300 ms. The chances of an item switching on or off were independent of the other items, and independent of the item's previous switch times. The *irrelevant* condition was the same as the *relevant* condition, except that now the static object was the target in 1/*n*th of the trials and a distractor on all other trials, with *n* indicating set size (i.e., if there were four items in the display the static object was the target in 25% of the cases and a distractor in 75% of the cases). Thus, there were two kinds of blocks: In the relevant blocks, the static item was always the target and all distractors were blinking; in the irrelevant blocks the target was mostly a blinking item (with one of the distractors being static), but in 1/*n*th of the trials the target happened to be the item (and all the distractors were blinking). Therefore, there were two types of trials in the irrelevant block. *Irrelevant, static target* refers to these trials in the irrelevant block, where the target happened to be static. *Irrelevant, blinking target* refers to these trials in the irrelevant block, where the target was a blinking item among other blinking items. In all conditions set sizes varied randomly within a block, between 4 and 8 (i.e., three or seven distractors plus one target). Within each block, on two-thirds of the trials set size was 8 and on one-third of the trials set size was 4. This was done in order to have equal numbers of static target trials for both set sizes in the irrelevant, static target condition. The order of the blocks was repeated every four blocks. In each sequence of four blocks there was one relevant block, and three irrelevant blocks. For half of the participants the relevant block was the first of the four blocks, for the other half the relevant block was the last of the four blocks. The task was to determine the orientation of the target element. Participants pressed "z" for vertical, and "m" for horizontal lines. The task was assumed to require focal attention to be directed to the target element. Before every block started, there appeared a text on the screen instructing the participants either to attend to the static object (since it was always the target), or that attending the static object was not beneficial (since the static item and the target only coincided at chance level). Participants were instructed that both speed and accuracy were important. The first four blocks were disregarded as practice. The other eight blocks were included in the analyses. The experiment took approximately 45 minutes, with breaks between the blocks.

Results

Error percentages were overall low (see Table 1), and an ANOVA revealed no significant effects; there were no signs of a speed–accuracy tradeoff. We will therefore concentrate on the mean RTs of the correct trials.

Trials on which RTs were two and a half standard deviations away from the mean were excluded from analysis, resulting in a loss of approximately 3% of the trials. See Figure 2 for a graphical depiction of the findings. A two-way ANOVA on mean RT for each participant with condition (relevant, irrelevant, static target or irrelevant, blinking target) and set size (4 or 8) as factors revealed a main effect of condition, $F(2, 14) = 29.95$, $MSE = 6139.13$, $p < .001$, a main effect of set size, $F(1, 7) = 37.36$, $MSE = 12{,}881.27$, $p < .001$, and a significant interaction, $F(2, 14) = 9.06$, $MSE = 2945.35$, $p < .005$. RTs increased with set size in all conditions and this will not be reported on further. Separate comparisons between conditions revealed that RTs were faster, and search slopes were shallower in both the relevant condition and

TABLE 1
Average error percentages for the different conditions and the different set sizes of Experiments 1–3

	Set size	
Condition	*4*	*8*
Experiment 1		
Relevant	13.68	6.78
Irrelevant, static target	9.17	13.03
Irrelevant, blinking target	8.52	9.28
Experiment 2		
Static target	3.08	4.18
Blinking target	2.71	3.15
Experiment 3		
Moving		
Relevant	6.44	6.07
Irrelevant, static target	3.96	2.34
Irrelevant, dynamic target	5.76	5.29
Blinking		
Relevant	3.92	4.53
Irrelevant, static target	4.74	4.84
Irrelevant, dynamic target	6.78	6.52

the irrelevant, static target condition than in the irrelevant, blinking target condition: Effects of condition, $F(1, 7) = 63.30$, $MSE = 5760.43$, $p < .001$; $F(1, 7) = 14.47$, $MSE = 8482.34$, $p < .01$; and Condition × Set size, $F(1, 7) = 15.46$, $MSE = 3168.50$, $p < .01$; $F(1, 7) = 8.26$, $MSE = 3412.91$, $p < .05$, respectively. RTs were overall faster in the relevant condition than in the

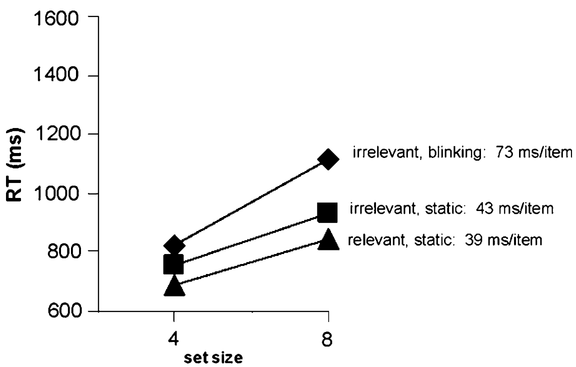

Figure 2. Mean RTs for each condition of Experiment 1 (relevant, irrelevant, static target and irrelevant, dynamic target) as a function of set size. For each condition, the mean search slopes are provided.

irrelevant, static target condition, $F(1, 7) = 15.39$, $MSE = 4174.63$, $p < .01$. Importantly, there was no significant difference in search slopes, between the relevant condition and the irrelevant, static target condition, $F(1, 7) = 1.26$, $MSE = 2254.63$, $p = .3$.

It is also important to look at intertrial priming. Maljkovic and Nakayama (1994) showed that features associated with the target on the previous trial attract attention on the current trial. Changing the proportions of different trial types (as we did here) not only changes presumed top-down settings, but also changes intertrial contingencies (see Olivers & Humphreys, 2003, for a more extensive argument). Although such effects are still automatic, they are not the type of attentional guidance we are interested in here. To investigate this possibility, we repeated the analyses with the exclusion of static target repititions in the irrelevant block. Although, numerically, effects were somewhat weakened, an analysis of the data with *inclusion* as a factor (two levels: Target repetitions included vs. target repetitions excluded), revealed no significant interactions of search slopes with this factor in this or subsequent experiments (all Fs < 1.6, all ps $> .24$). Thus, with respect to search slopes, the overall pattern of results remained the same whether static target repetitions were included or excluded.

Discussion

Experiment 1 shows that participants benefit from the target being static in the irrelevant blocks, even though in this condition they presumably have no top-down incentive to prioritize static items. Furthermore, the search slopes for the static target are similar in the relevant and the irrelevant blocks. These findings not only indicate that the static object automatically guides attention, but also that adding a top-down incentive to actively go and look for it does not add anything to the efficiency of search. Nevertheless, participants are overall slower to react when they are automatically guided by the static target, compared to when they voluntarily attend to it. This suggests that top-down settings may affect nonselection processes, such as response factors (e.g., after several trials with a dynamic target, the "surprise" that the target is static might slow down the response).

Note however that search slopes were overall quite high and far from efficient even in the relevant conditions (i.e., around 40 ms/item), especially when compared to the equivalent conditions in Pinto et al. (2006; typically between 10 and 20 ms/item). In this sense it is difficult to argue for strong bottom-up attentional capture by static objects. Instead, we argue for prioritization or guidance. We will return to this point in the General Discussion.

Another important objection to the conclusion that the static object automatically guides attention may be that the inclusion of a relevant block may have given participants the incentive to pay attention to static items, even in the irrelevant blocks. To investigate if the attentional guidance observed in Experiment 1 was due to such top-down factors, Experiment 2 was conducted.

EXPERIMENT 2: THE ATTENTIONAL GUIDANCE IS NOT DUE TO CARRYOVER EFFECTS

Experiment 2 investigated whether the attentional guidance observed in Experiment 1 could be the result of residual top-down effects. Although in the irrelevant blocks of Experiment 1 participants were explicitly told that attending to the static item was not beneficial, it may be that because participants were set to search for the static object in the relevant block they were inclined to do so also in the irrelevant blocks. To control for such possible carry-over effects of top-down settings from the relevant blocks to the irrelevant blocks, we replicated Experiment 1, but without the relevant blocks. If the observed attentional guidance in Experiment 1 was due to carryover effects, then in Experiment 2 we expect to see no difference in performance whether the target is static or dynamic. However, if the attentional guidance in Experiment 1 was the result of automatic processes, then we expect search slopes again to be shallower when the target happens to be static than when it is dynamic.

Method

Eleven new participants, ranging in age from 18 to 35 years, average 22.7 years, took part as paid volunteers. Everything was identical to Experiment 1, except that now there was no *relevant* condition. The experiment consisted of nine blocks of 48 trials. The first three blocks were disregarded as practice. The other six blocks were included in the analyses. The experiment took approximately 35 minutes, with breaks between the blocks.

Results and discussion

Error percentages were overall low (see Table 1), and an ANOVA revealed no significant effects; nor were there any signs of a speed–accuracy tradeoff. We will therefore concentrate on the mean RTs of the correct trials.

Trials on which RTs were two and a half standard deviations away from the mean were excluded from analysis, resulting in a loss of approximately

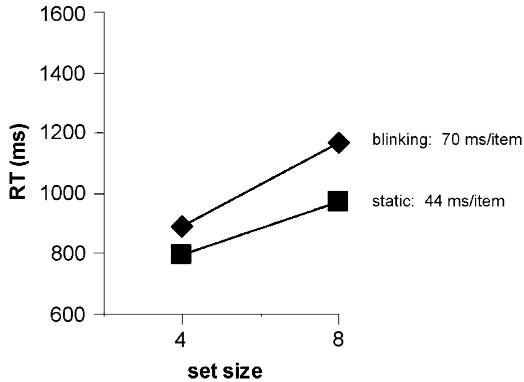

Figure 3. Mean RTs for each condition of Experiment 2 (static target and blinking target) as a function of set size. For each condition, the mean search slopes are provided.

3% of the trials. See Figure 3 for a graphical depiction of the findings. A two-way ANOVA on mean RT for each participant with condition (static target or blinking target) and set size (4 or 8) as factors revealed that RTs were elevated in the blinking target condition compared to the static target condition, $F(1, 10) = 28.26$, $MSE = 8085.51$, $p < .001$, and that RTs increased with set size, $F(1, 10) = 24.63$, $MSE = 22{,}913.65$, $p = .001$. There was also a significant interaction reflecting the steeper search slope in the blinking target condition compared to the static target condition, $F(1, 10) = 12.26$, $MSE = 2421.12$, $p < .01$.

The results of Experiment 2 allow for a straightforward interpretation. The exclusion of the relevant block left the results virtually unchanged relative to Experiment 1. The prioritization of the static object found in Experiment 1 is again found in Experiment 2, and since there were no relevant blocks this cannot be explained by the carryover of top-down effects.

EXPERIMENT 3: AUTOMATIC ATTENTIONAL GUIDANCE OF A STATIC OBJECT IN OTHER DYNAMIC ENVIRONMENTS?

Experiments 1 and 2 have shown that a static object involuntarily guides attention when it is surrounded by blinking items. However, it is unclear if these results generalize to other dynamic stimuli. Pinto et al.'s (2006) results hint at this generalization, since in their study a static target was efficiently found among both blinking and moving distractors (with search slopes around 15 ms/item in both cases). However, it could be that the efficient search for a static object among blinking distractors is automatic, but the efficient search for a static item surrounded by moving items is the result of other, top-down, mechanisms. To investigate whether search for a static item among blinking objects represents a special case, Experiment 3 investigated if a static object also guides attention when it is surrounded by items featuring apparent motion. If the same mechanisms underlie search for a static object in a blinking or a moving environment, then we expect attentional guidance to be similar in both conditions. However, if top-down processes play a larger role when searching for a static among moving than for a static among blinking, then we expect attentional guidance to be reduced, or even absent in the motion conditions (when all items except one are moving).

Method

Eight participants ranging in age from 18 to 22 years, average 19.9 years, took part as paid volunteers. One participant was replaced, due to exceptionally large error rates of approximately 35%. Everything was identical to Experiment 1, except for the following changes. The experiment consisted of 18 blocks of 48 trials. Figure 1C shows an example display. Using the exact Pinto et al. (2006) displays was no option, because in their study, moving items flipped back and forth between two 90 degrees rotated positions. Applied to the current case, this would imply that the target on most trials would be flipping back and forth, making it impossible to determine whether it is vertical or horizontal. Therefore, in the current experiment we used stimuli that allowed for discrimination of the target even if it was moving. The stimulus field consisted of white line segments (size 0.87°) with a gap in the middle (size 0.26°) and one white line segment with a gap above or below the middle (distance from the middle 0.17°). The task was to find the only object with a gap not located in the middle, and to indicate if the gap was above or below the middle by pressing the "k" and "m" keys respectively. There were two types of dynamics and three relevance conditions (relevant, irrelevant, static target and irrelevant, dynamic target as in Experiment 1). When the dynamics were set to blinking all items except one were blinking. When the dynamics were set to moving, all items were moving horizontally back and forth (over a distance of 0.46° per movement, rate of motion was the same as the blinking rate) except one. Neither direction (left or right) nor moment of change were correlated between the items. The order of the blocks was repeated every six blocks. In every sequence of six blocks there were four possible orders (which remained the same throughout the experiment, but differed per participant). First, blocks alternated between blinking and moving, with either starting first. Second, within these two types of sequences, either the first or the last two blocks were the relevant blocks, the other four the irrelevant blocks. The same number of participants was assigned to each of the four orders. The first six blocks were disregarded as practice. The other 12 blocks were included in the analyses. The experiment took approximately 60 minutes, with breaks between the blocks.

Results and discussion

Error percentages were low overall (see Table 1), and an ANOVA revealed no significant effects, nor were there signs of a speed–accuracy tradeoff. We will therefore concentrate on the mean RTs of the correct trials.

Trials on which RTs were two and a half standard deviations away from the mean were excluded from analysis, resulting in a loss of approximately 2% of the trials. See Figures 4 and 5 for a graphical depiction of the findings. A three-way ANOVA on mean RT for each participant with type of dynamics (blinking or moving), relevance condition (relevant, irrelevant, static target, or irrelevant, dynamic target) and set size (4 or 8) as factors revealed that RTs were overall elevated in the blinking conditions compared to the moving conditions, $F(1, 7) = 81.62$, $MSE = 4439.57$, $p < .001$, RTs were overall higher in the irrelevant than in the relevant blocks, $F(2, 14) = 26.47$, $MSE = 42{,}318.20$, $p < .001$, and RTs increased with set size, $F(1, 7) = 271.17$, $MSE = 5996.42$, $p < .001$. There was a significant interaction between relevance condition and set size reflecting the steeper search slopes when the target was dynamic compared to when the target was static, $F(2, 14) = 9.46$, $MSE = 9663.44$, $p < .005$. There were no significant interactions between type of dynamics and relevance condition or type of

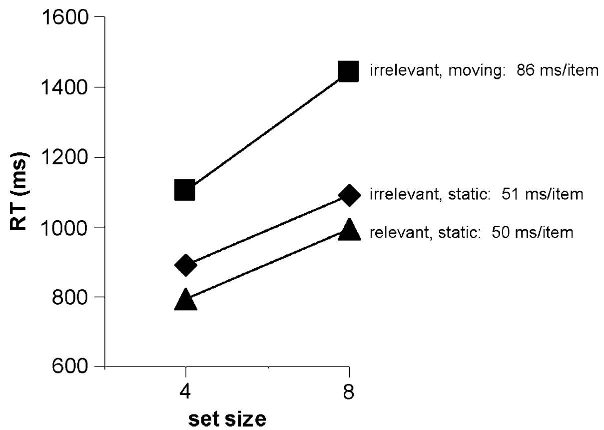

Figure 4. Mean RTs for each condition of Experiment 3 (relevant, irrelevant, static target and irrelevant, dynamic target) as a function of set size when the dynamics were set to moving. For each condition, the mean search slopes are provided.

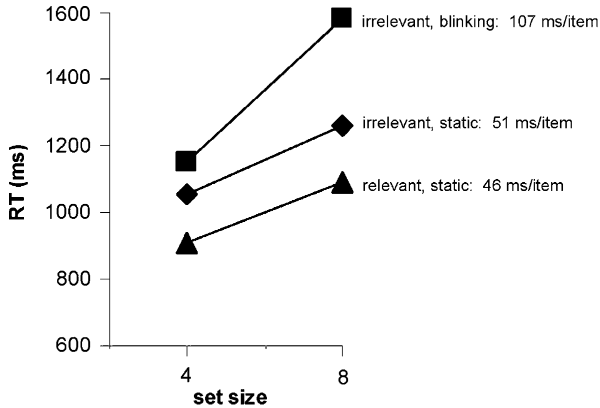

Figure 5. Mean RTs for each condition of Experiment 3 (relevant, irrelevant, static target and irrelevant, dynamic target) as a function of set size when the dynamics were set to blinking. For each condition, the mean search slopes are provided.

dynamics and set size (Fs < 1.6, ps > .24). There was a significant three-way interaction between type of dynamics, relevance condition, and set size, $F(2, 14) = 4.91$, $MSE = 1382.32$, $p < .05$. Further analysis revealed that this three-way interaction was mainly the result of a higher search slope in the irrelevant block when the target was blinking compared to when it was moving, $F(1, 7) = 5.53$, $MSE = 3103.00$, $p = .051$. Separate comparisons between relevance conditions for each type of dynamics revealed the following. With dynamics set to blinking, in the irrelevant, static target condition RTs were faster, and search slopes were shallower than in the irrelevant, dynamic target condition: Effects of condition, $F(1, 7) = 7.26$, $MSE = 47{,}165.20$, $p < .05$; Condition × Set size, $F(1, 7) = 9.95$, $MSE = 10{,}150.05$, $p < .05$. Furthermore, in the relevant condition RTs were faster than in the irrelevant, static target condition, $F(1, 7) = 12.73$, $MSE = 15{,}934.0$, $p < .01$. Importantly there was no significant interaction between relevance condition and set size, indicating that search slopes in these conditions did not differ significantly from each other ($F < 0.25$, $p > .6$). The same pattern was found with dynamics set to moving. RTs were faster and search slopes were shallower in the irrelevant, static target condition than in the irrelevant, dynamic target condition: Effects of condition, $F(1, 7) = 33.92$, $MSE = 18{,}009.28$, $p = .001$; Condition × Set size, $F(1, 7) = 6.20$, $MSE = 5715.60$, $p < .05$. In the relevant condition RTs were faster than in the irrelevant, static target condition, $F(1, 7) = 12.91$, $MSE = 5481.0$, $p < .01$, but again there was no significant interaction between relevance condition and set size, indicating that search slopes in both conditions were not significantly different from each other ($F = 0.01$, $p > .9$).

As in the previous experiments, static targets received priority even when static items were not relevant to the task. Experiment 3 shows that this result generalizes to motion stimuli. For both blinking and moving environments, search for a static target was more efficient than for a dynamic target regardless of whether static was a relevant feature or not. The only difference between the relevant and irrelevant static target search was an overall RT effect, again suggesting that top-down factors affect postselection processes, rather than the saliency of the static item per se.

GENERAL DISCUSSION

In the present study we employed the irrelevant-feature search task to investigate if static items automatically guide attention in a dynamic environment. All three experiments suggested that, to some degree, static objects involuntarily guide attention. Experiments 1 and 3 showed that making the static object task relevant did not make search more efficient than when the static object was task irrelevant. Experiment 2 demonstrated that this was not due to inadvertent carryover effects between task-relevant and task-irrelevant conditions. Furthermore, Experiment 3 showed that a static object is equally effective in guiding attention among moving as among blinking objects.

In all experiments search slopes were considerably shallower when the target was static than when it was dynamic, but at a rate of 40 ms/item, search was still far from parallel. Obviously then, the automatic guidance by static items here was not an all-or-none phenomenon. It may have been the case that the static item drew attention on some, but not all, trials, or that that the attentional weight assigned to the static item was insufficiently strong to immediately receive priority over all other items in the display (see Todd & Kramer, 1994, for a similar argument). Note that relatively high slopes have not precluded the conclusion of automatic attentional guidance in the past (e.g., Yantis & Hillstrom, 1994). Higher slopes mean that the static item is not always optimally salient, but when it is, it is prioritized automatically.

The question then is why the static item may occasionally evade capture. The answer may lie in the fact that, in the current study, the target is most often a dynamic object in a dynamic environment, and therefore hard to find. This may have caused participants to adopt a conservative, serial, search mode, using a relatively small attentional window (e.g., Belopolsky, Zwaan, Theeuwes & Kramer, 2007). Alternatively, participants may have adopted a specific feature search mode (looking for specific orientation) instead of a more global singleton search mode (Bacon & Egeth, 1994). In turn, such a narrowed spatial window or search mode may then have hindered search when the target was static. This suggestion is also supported by the results of Pinto et al. (2006), who found search for a static target in a dynamic surrounding to become less efficient when in some other blocks within the same experiment the target was actually dynamic and therefore hard to find.

To see if such context indeed plays a role, we ran another experiment in which participants searched for a static target amongst dynamic distractors (using the same displays as in Experiments 1 and 2), but now without the irrelevant blocks (i.e., the static item was always the target). On average across six participants, for the set sizes employed here (i.e., 4 to 8), search slopes dropped below 10 ms/item again (8.5 ms/item; not significantly different from zero, $p = .2$, but significantly different from the search slopes of the relevant condition in Experiment 1, $p < .05$), confirming the idea that the inclusion of an irrelevant block may induce a different type of search mode. Note that this suggestion implies that given the right circumstances, i.e., when the static object is the target in *all* blocks, participants can adopt a search strategy that allows them to increase search efficiency. This means that there still is some top-down contribution to the efficient detection of a static object, albeit a relatively crude version: The top-down control is in the overall spatial distribution of attention, not in the selective prioritization of a static/dynamics feature.

A special role for dynamic capture?

Several researchers have used the irrelevant-feature search task to investigate which features involuntarily capture attention. This has yielded a couple of influential accounts, such as the new object hypothesis (Jonides & Yantis, 1988; Yantis & Hillstrom, 1994) and the unique event hypothesis (von Mühlenen et al., 2005). Although the accounts differ, they all claim that dynamics are essential for capturing attention. The current result, that a static object involuntarily draws attention in a dynamic setting, provides a clear example of a nondynamic property automatically guiding attention in the irrelevant-feature search task. Thus, the present findings seem to pose a problem for any account that suggests that features essentially need to be dynamic in order to draw attention.

According to the saliency account (e.g., Theeuwes, 1991, 1992), whether or not an object attracts attention depends on the relative feature difference between the object and its background. The current results seem to fit neatly into the saliency account, since the static object was unique relative to its surrounding, and therefore more salient than the other items. According to this account, the static/dynamic distinction is no more special than a very distinctive colour, shape, or any other feature. An interesting corroboration of this conclusion comes from Pashler and Harris (2001). They found that when participants were to describe or aesthetically judge a display, a unique item was most likely to be reported. This was true when the unique item was a flashing item in a static environment, but importantly the reverse also held. When the unique object was a static object surrounded by flashing objects, it was still the most reported item.

However, note that both Theeuwes (1991, 1992) and Pashler and Harris (2001) used a somewhat different paradigm than the irrelevant-feature task employed here and elsewhere. In fact, whenever the irrelevant-feature paradigm has been applied to features other than dynamic properties, no evidence of attentional capture has been found (Jonides & Yantis, 1988; Yantis & Egeth, 1999; Yantis & Hillstrom, 1994). This discrepancy may be (and has been) explained in terms of different search modes (Bacon & Egeth, 1994) or differently sized attentional windows (Theeuwes, 2004). But, in any case, on the basis of the task used here, we cannot exclude the possibility of a special status for the static/dynamic distinction.

Perhaps then, both the saliency account and the dynamic capture hypotheses are both partly true. The saliency account correctly suggests that not features per se, but feature differences determine which items capture attention. The dynamic capture hypotheses might be correct in stating that the dynamics dimension is intrinsically more important than other dimensions, and that feature differences within the dynamics dimension are even more effective than other feature differences in capturing attention. Thus, new objects capture attention, but static items in a dynamic environment do as well, since they are both unique with regard to their dynamic properties (cf. von Mühlenen et al., 2005).

This hybrid view above also accounts for what appears to be a search asymmetry (Treisman & Gormican, 1988). Search for a static object surrounded by blinking items yields search slopes significantly higher than 0 ms/item, whereas the reverse case, the search for a blinking item in a static background, probably yields search slopes that are close to 0 (this, to our knowledge, has never been explicitly tested; see Watson & Humphreys, 1995, for a manipulation that comes close).

Thus, although any salient difference may attract attention, there appears to be an attentional bias on top of that towards dynamic items. This may be due to lifelong experience, in which dynamic objects are usually the ones to look out for. Interestingly, a similar asymmetry disappears with extensive training. Untrained participants are more efficient at detecting a motion-form conjunction among static distractors than a static-form conjunction among dynamic distractors. However after approximately 1000 practice trials, search for these latter conjunction targets becomes equally efficient (Müller & von Mühlenen, 1999).

Another influences on search efficiency was the earlier mentioned finding that search for a static target in a dynamic environment becomes less efficient, when the task is interlevelled with blocks containing a very difficult search task (such as a blinking target among blinking distractors). It seems unlikely that adding a difficult block would affect entirely efficient pop-out search (such as a green target among red distractors) in the same way it affects search for a static target in a dynamic background here. However, since search for a static target among dynamic distractors is not completely efficient to begin with, this may make the task more sensitive to difficulty (or search mode) manipulations, than a task that allows for obvious pop-out from start.

CONCLUSION

We found that a static object involuntarily draws attention when it is surrounded by dynamic items, regardless of the type of dynamics (i.e., moving or blinking). This finding is a clear example of a static feature being prioritized within the irrelevant-feature search task and therefore necessitates a modest revision of current theories on automatic attentional guidance. We conclude that feature differences in general, but especially dynamic feature differences, are essential for the involuntary guidance of attention.

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