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Eye movements and time-based selection: Where do the eyes go in preview search?

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Abstract

In visual search tasks, presenting one set of distractors (previewing them) before a second set which contains the target, improves search efficiency compared to when all items appear simultaneously. It has been proposed that this preview benefit reflects an attentional bias against old information and towards new information. Here we tested directly whether there was such a bias by measuring eye movement behavior. The main findings were that fixations were biased against, and overall dwell times were shorter on, old stimuli during search in the preview condition. In addition, the initial onset of search was delayed in the preview condition and saccades made during the preview period did not disrupt the ability to prioritize new items. The data demonstrate directly that preview search results in an attentional bias towards new items and against old items.

Keywords: visual search, visual marking, preview search, time-based selection, eye movements, saccades, overt attention.

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For behavior to be efficient it is essential to be able to select the most relevant information quickly. Often this involves prioritizing newly appearing information over old already processed stimuli. Such time-based selection has been demonstrated using the preview paradigm in which one set of stimuli is presented (previewed) before a second set which contains the target information. Provided that the old items are presented alone for 400ms or more it appears to be possible to fully ignore them and restrict search to a set of subsequently presented new stimuli.

Although the preview benefit has been shown to be a robust phenomenon, the mechanism(s) responsible for it remains controversial. According to Watson and Humphreys (1997) the preview benefit reflects the operation of a top-down, limited-capacity inhibitory mechanism (called visual marking) that coordinates and applies inhibition to the locations or features of the old to-be-ignored stimuli (Watson & Humphreys, 1997, 1998, 2000, 2002, 2005; Watson, Humphreys & Olivers, 2003; Braithwaite et al, 2005). This active old item inhibition then results in a selection advantage for newly arriving information by biasing the allocation of attention away from the locations of the old stimuli. In contrast to the visual marking account, Donk and Theeuwes (2001, 2003; Donk, 2005) proposed that the preview benefit arises because the luminance onsets accompanying the new items capture attention automatically, thus leading to their prioritization in search. Finally, according to the temporal asynchrony account (Jiang, Chun & Marks, 2002; Jiang & Wang, 2004) stimuli can be grouped together on the basis of their time of arrival and then attention can be selectively applied to the most relevant group.

Irrespective of the mechanism(s) responsible for the preview benefit, to date, the proposed attentional bias against the old and towards the new has been inferred from relatively indirect measures. For example, one method compares search efficiency in the preview condition to that obtained in a full-element baseline (FEB) in which all the elements appear simultaneously, and a half-element baseline (HEB) in which only the second set of stimuli from the preview condition is presented. Typically search in the preview condition is more efficient than in the FEB and matches that of the HEB suggesting that search can be restricted to the new elements. Another method for inferring attentional bias has been to compare the detection of luminance probes presented at either old or new locations (Watson & Humphreys, 2000; Olivers & Humphreys, 2002; Braithwaite et al., 2005). When set to prioritize new stimuli probe detection on old elements is impaired compared to when there is no incentive to, or when a load task reduces the ability to, prioritize new stimuli. Although these measures are consistent with an attentional bias against the old and/or towards the new items, they are nonetheless indirect in that they provide little, if any, information on the spatio-temporal aspects of visual search. For example, the slower detection of a probe dot at the location of a single old stimulus does not provide direct evidence that those stimuli are less likely to be examined during a visual search task.

Accordingly, given the close coupling between eye movements and visual attention (e.g., Deubel & Schneider, 1996), the main goal of the present work was to analyze eye movements to provide the first direct measure of any attentional bias against old previewed items and towards new stimuli. As Zelinsky and Sheinberg (1997; see also Zelinsky et al., 1997; Greene & Rayner, 2001; Williams et al., 1997) point out, eye movements can reveal much more about visual search behavior than can be obtained from simple visual search RTs which may be composed of a number of search steps. For example, there may be a reduced probability of fixating an old element and/or fixation durations and overall dwell times might be shorter on old elements in the preview condition compared to a FEB in which there is no opportunity for temporal selection mechanisms to operate.

A second aim was to determine whether the onset of search in the preview condition was delayed relative to standard search conditions. It is often found that even though search efficiency in the preview condition matches that of the HEB in terms of search slopes, the overall RTs are longer. Watson and Humphreys (1997) suggested that this was because there was a delay in the initial onset of search in the preview condition (due to the additional load of inhibiting the old items). If so, then we would expect the saccadic onset latency for the first saccade in the preview condition to be increased relative to the FEB.

Finally we were interested in whether or not participants spontaneously made saccades during the preview period and what, if any, effect this had on the preview benefit. Watson and Humphreys (1997) showed that saccades to the old items are not necessary to obtain a preview benefit and Olivers et al., (2002) showed that searching through the old elements actually disrupted the benefit. However, even though participants are typically told to maintain fixation on a central dot throughout the preview period it is not known whether they spontaneously make saccades and if so what effect these have on preview search efficiency.

In summary we asked 5 main questions: 1) what is the relationship between search RTs and saccadic frequency, 2) are fixations and overall dwell time biased against the old and towards the new items in preview search, 3) do the fixation durations differ between old and new distractors in preview search compared to when all items appear simultaneously, 4) is the onset of search delayed in the preview condition relative to the baselines, and 5) do eye movements in the preview period disrupt the preview benefit?

Method

Participants

Twelve students (6 male) from the University of Warwick aged 21-37 years (M=27.3) participated for payment of £8.

Stimuli and apparatus

The target was a blue H (H_b, CIExy 0.210, 0.268, lum = 27.2cd/m^2) and the distractors were green Hs (H_g, CIExy 0.244, 0.438, lum = 43.6cd/m^2) and blue As (A_b) created from a box-figure 8 measuring 0.57° wide × 0.98° high presented against a dark grey background (CIExy 0.324, 0.321, lum= 3.1cd/m^2). Displays were presented on a Pentium based PC attached to a 19” Sony CRT monitor (800×600 pixels) placed at eye level and viewed from a chin rest 70cm away. Eye movements were recorded using an Eyelink I (SR Research) eye tracker sampling from the right eye at 250Hz. Search displays were generated by placing the stimuli into the cells of a 6 × 6 invisible grid with inter-element spacing of 2.29°. No stimuli could fall in the center 4 cells and the position of the target was constrained to fall into columns 1, 2, 5 or 6 so that when detected it was relatively easy to determine whether it was to the left or right of the display center. Distractors were placed in the remaining cells with the constraint that there was an equal number of each type of distractor on each side of the display. When the target was present it took the place of one of the A_b distractors. In the FEB and preview conditions there were 4, 8 or 16 elements (half green, half blue). The HEB condition was identical to the FEB except that the H_g distractors were not present (and thus display sizes were half those of the FEB). Responses were made via a 12-button PC game pad.

Design and procedure

Each trial started with a blank screen (1000ms) followed by a light grey (CIExy 0.288, 0.300, lum = 48.5 cd/m^2) central fixation dot (0.25° × 0.25°), which served as a drift correction for the eye tracker. Observers fixated the dot and pressed a key on the response pad to start a trial. In the preview condition, after 750ms a display containing H_g distractors appeared for 1000ms followed by the blue items, which contained the H_b target when present. Participants indicated whether the H_b target was to the left or the right of the display center by pressing the left or right shoulder button on the response pad. On target absent trials they made no response and 5s later the next trial began automatically. Participants were asked to maintain fixation on the central dot until the final search display appeared.

The FEB and HEB conditions were the same except that all the stimuli appeared simultaneously and the H_g distractors were not present in the HEB. Each participant completed one block of 99 trials for each of the conditions preceded by a short (27 trial) practice block. Each full block contained 90 target present trials with an equal combination of target side by display size trials. The remaining 9 trials were target absent catch trials that discouraged observers from responding by processing only one side of the display. Trial order was randomized within a block and block order was completely counterbalanced. The eye tracker was calibrated and validated with a 9-point display directly before each block of trials.

Results

Eye movement data were analyzed with DataViewer v1.7.95 (SR Research) configured to ignore spanned events and with saccade and fixation thresholds of 0.5° and 50ms respectively.

The basic preview benefit. Mean RTs and numbers of saccades for correct target present trials are shown in Figure 1 and search slope statistics in Table 1. As in previous research (Watson & Humphreys, 1997), search slopes in the HEB were calculated using the same number of display items (4, 8, and 16) as in the FEB and preview conditions. Thus the HEB slopes represent the search rate that would be obtained if search in the preview condition could be fully restricted to the new (blue) items. The preview benefit was determined by comparing the preview condition with the HEB and FEB conditions using within-subjects ANOVAs.

HEB vs Preview RTs: RTs were longer overall in the preview condition, $F(1,11) = 7.33$, $MSE = 12780.64$, $p < 0.05$, and increased with display size $F(2,22) = 55.51$, $MSE = 6969.61$, $p < 0.001$, however the Display Size × Condition interaction was not significant, $F(2,22) = 1.78$, $MSE = 1528.06$, $p = .192$, indicating that search efficiency did not differ between conditions.

HEB vs Preview Saccades: The number of saccades increased with display size, $F(2,22) = 70.17$, $MSE = .148$, $p < 0.001$, however, neither the main effect of condition nor the Condition × Display Size interaction reached significance, both Fs<1.

FEB vs Preview RTs: RTs were longer in the FEB, $F(1,11) = 18.30$, $MSE = 10164.27$, $p = 0.001$, increased with display size, $F(2,22) = 69.43$, $MSE = 11933.47$, $p < 0.001$, and RTs increased more with display size in the FEB, $F(2,22) = 31.36$, $MSE = 1965.47$, $p < 0.001$.

FEB vs Preview Saccades: More saccades were made in the FEB, $F(1,11) = 21.88$, $MSE = .500$, $p = 0.001$, their frequency increased with display size, $F(2,22) = 64.97$, $MSE = .289$, $p < 0.001$, and the increase with display size was greater in the FEB, $F(2,22) = 11.90$, $MSE = 0.079$, $p < 0.001$.

Errors. Errors were infrequent (<1.5%) and a 3 (condition) × 3 (display size) within-subjects ANOVA revealed no significant main effects or their interaction, all Fs<1.

Distractor bias. A fixation was coded as being at the location of a distractor stimulus if it fell within a circular region (radius 1.06°) around that item. Bias towards and against each type of distractor was determined by calculating the ratio of the total dwell time and fixation frequency on the H_g and A_b distractors within a block of trials for each participant individually. The average H_g:A_b dwell time ratio was significantly greater in the FEB (0.338) than in preview condition (0.151), t(11) = 4.66, $p = 0.001$, as was the ratio of the number of fixations, (FEB = 0.338, preview condition = 0.158), t(11) = 4.30, $p = 0.001$.[1] The dwell time and fixation frequency ratios were very close because there was no reliable difference between the average duration of a single fixation across distractor types: The overall mean duration of fixations falling on H_g and A_b distractors in the FEB and preview conditions ranged from 153ms to 159ms with no significant main effect of condition, stimulus or their interaction (all Fs < 1).

Catch trials[2]. Errors on catch trials (false hits) were low overall <7.5% and were not analyzed further. The eye movement data were analyzed in the same way as for search trials. Figure 2 shows the mean saccadic frequency as a function of condition and display size.

HEB vs Preview saccades: Saccadic frequency increased with display size, $F(2,20) = 29.57$, $MSE = 6.52$, $p < 0.001$, however, neither the main effect of condition, $F(1,10) = 1.55$, $MSE = 9.50$, $p = 0.242$, nor the Condition × Display Size interaction, $F(2,20) = 1.66$, $MSE = 1.865$, $p = 0.215$, approached significance.

FEB vs Preview saccades: Saccadic frequency increased with display size, $F(2,20) = 82.98$, $MSE = 3.17$, $p < 0.001$, and more saccades occurred in the FEB,

$F(1,10) = 7.19$, $MSE = 17.70$, $p < 0.05$, however, the condition × display size interaction was not significant, F<1.

Catch trial distractor bias: The H_g:A_b dwell time ratio was greater in the FEB (0.418) than in the preview condition (0.206), t(10) = 3.312, $p < 0.01$, as was H_g:A_b fixation frequency, (FEB = 0.391, Preview = 0.195), t(10) = 2.72, $p < 0.05$.[3]

Saccadic onset latency. We determined the onset latency of the first saccade when the search display appeared for correct target-present trials, and these are shown in Figure 3. Overall onset latencies were slowest in the preview condition (221.2ms) compared to the HEB (188.5ms) or the FEB (189.1ms), $F(2,22) = 10.11$, MSE = 1243.03, $p = 0.001$, onset latencies also increased with display size $F(2,22) = 19.68$, $MSE = 128.16$, $p < 0.001$. Numerically the increase in onset latency with display size was greatest in the preview condition (2.05 ms/item) compared with the two baselines (HEB =0.69 ms/item, FEB baseline =0.94 ms/item). However, the Condition × Display Size interaction was not significant $F(4,44) = 1.46$, $MSE = 161.92$, $p = 0.232$.

If we restricted the analysis to trials on which the starting point of the initial fixation was within 15 pixels of the display center (removing trials on which participants may have been fixating a blank region or an old distractor when the new were added) then a similar pattern emerged. Overall onset latencies were slower in the preview (228.2 ms) compared to the two baselines (HEB 195.5ms, FEB 193.7ms), $F(2,22) = 13.00$, $MSE = 1039.83$, $p < 0.001$, latencies increased with display size, $F(2,22) = 7.05$, $MSE = 487.47$, $p < 0.005$, however, the Condition × Display Size interaction was now also significant $F(4,44) = 3.04$, $MSE = 279.612$, $p < 0.05$, with onset latencies increasing by 0.57, 0.80 and 3.03 ms/item for the HEB, FEB and Preview conditions respectively.

Saccadic frequency during the preview period and its effect on preview search efficiency. Despite being asked to maintain fixation throughout the preview period, participants made eye movements during a relatively large number of trials. The percentage of trials on which at least one saccade was made during the preview period varied across participants from 5.7 to 92.1% (M= 51.8) and tended to increase with display size (47.5%, 52.3%, and 55.5% for display sizes of 4, 8 and 16 items), $F(2,22) = 3.39$, $MSE = 57.49$, $p = 0.052$. To determine whether making saccades in the preview period affected the ability to ignore the old items we re-analyzed the preview RT search data on the basis of whether or not at least one saccade had been made during the preview period display. This showed that preview search slopes were numerically smaller when saccades were made in the preview period (20.5 ms/item) than when they had not been made (24.0 ms/item) but this difference proved non-significant, $t(11) = 1.17$, $p = 0.266$.

Even with a stricter saccadic threshold of 2.5°, trials on which at least one saccade had been made in the preview period remained relatively high (32.4%) and again increased with display size (29.0, 31.2 and 37.1% for display sizes 4, 8 and 16), $F(2,22) = 4.59$, $MSE = 46.10$, $p < 0.05$). However, there was still no difference in preview search efficiency between trials on which one or more saccades had been made in the preview period (21.2 ms/item) compared to none (25.3 ms/item), $t(11) = 1.41$, $p = 0.187$.

Discussion

The main aim of this study was to examine the spatio-temporal aspects of overt attentional selection in preview search. Firstly, we obtained a standard preview benefit. In terms of search slopes, search in the preview condition was more efficient than in the FEB and matched that of the HEB. This pattern was mirrored in the eye movement data, demonstrating the close correspondence between the RT and the number of saccades required to locate the target (see also Zelinsky & Sheinberg, 1997, for a related finding with standard visual search tasks).

The second finding was that even in the FEB there was some indication of bias against the H_g distractors, consistent with there being some color-based attentional guidance (Wolfe, 1994; Shen, Reingold & Pomplun, 2000; Williams et al., 1997) to likely target items. However, both the overall dwell time and probability of making a saccade to a H_g distractor was much lower (approximately half) in the preview condition when the H_g distractors appeared first, compared with the FEB where all items appeared simultaneously. This provides the first direct evidence that preview search results in an overt attentional bias against the old items and towards the new. Perhaps somewhat surprisingly, this bias was maintained throughout the relatively long 5s period on no-target catch trials and thus did not seem to wear off over time. Despite the bias, fixation durations were relatively constant across all distractor types and conditions.

A third finding related to the overall RT difference between the preview and FEB conditions. A typical finding is that preview search RTs can be longer overall than in the HEB even though, in terms of search slopes, search efficiency may not differ (Watson & Humphreys, 1997). This result was found here in the RT data but not in the saccadic frequency data. Thus the overall RT difference does not appear to be due to a fixed increase in the number of saccades made in the preview condition. We did however find that the saccadic onset latency of the first search saccade was delayed in the preview condition compared with the HEB and FEB. Thus at least some of the overall preview-HEB RT difference is attributable to an initial delayed onset of search in the preview condition. Moreover, there was some evidence that this delay increased as the number of old preview items increased. Interestingly this increase (approx 2-3ms/item) was very close to the (non-significant) difference in search slope between the FEB and preview condition observed here and in some previous work. This delay might be caused by the need to apply attentional resources to the old items in order to inhibit them which then delays the onset of search through the new items (Watson & Humphreys, 1997). Moreover, the present data (tentatively) suggest that the amount of effort (and hence delay) may increase as the number of old to-be-ignored distractors increases. Alternatively, the delay may arise from an increased difficulty in disengaging attention from the fixation dot as a result of trying to prevent eye movements to the old items. Whatever the cause, the present data suggest that search onset is delayed in the preview condition which contributes to the longer RTs often observed in preview search.

A final finding was that observers made eye movements in the preview period on a relatively large number of trials despite being asked to maintain central fixation. Nonetheless, a full preview benefit was still obtained and such saccades did not disrupt preview search efficiency (in fact numerically the opposite was true). Previously Olivers et al., (2002) showed that intentionally searching the old items disrupted the preview benefit and so we might have expected preview-period saccades to have the same effect. Clearly this was not the case. This suggests that spontaneously generated saccades that are not associated with an active search through the old set do not disrupt their inhibition. Alternatively, the majority of saccades may have been made early in the preview period allowing sufficient time (400ms or more) to prioritize the new. An additional informal analysis provided some support for this possibility. We split the preview period into 4 time bins (250ms duration) and found that saccadic frequency initially increased and then decreased within the preview period. With a saccadic threshold of 0.5° the average total number of saccades within a block equaled 25.9, 34.2, 21.5, 12.8 across the 4 intervals. With a stricter 2.5° threshold they were 18.0, 18.3, 11.4 and 6.4 respectively. Whatever the cause of the lack of disruption the data suggest that making some saccades in the preview period has little impact on the preview benefit illustrating the general robustness of intentional time-based selection. Determining exactly when and what kinds of eye movements disrupt time-based selection will be a valuable goal for future research.

References

Braithwaite, J.J., Humphreys, G.W., & Hulleman, J. (2005). Color-based grouping and inhibition in visual search: Evidence from a probe detection analysis of preview search. *Perception & Psychophysics, 67,* 81-101.

Deubel, H., & Schneider, W.X. (1996). Saccade target selection and object recognition: Evidence for a common attentional mechanism. *Vision Research, 36,* 1827-1837.

Donk, M. & Theeuwes, J. (2003) Prioritizing selection of new elements: Bottom-up versus top-down control. *Perception & psychophysics, 65, 1231-1242.*

Donk, M. (2005). Prioritizing selection of new elements: On the time course of the preview effect. *Visual Cognition, 12,* 1373-1385.

Donk, M., & Theeuwes, J. (2001). Visual marking beside the mark: Prioritizing selection by abrupt onsets. *Perception & Psychophysics, 63,* 891-900.

Greene, H.H. & Rayner, K. (2001). Eye movements and familiarity effects in visual search. *Vision Research, 41,* 3763-3773.

Jiang, Y. & Wang, S.W. (2004). What kind of memory supports visual marking? *Journal of Experimental Psychology: Human Perception and Performance, 30,* 79-91.

Jiang, Y., Chun, M.M., & Marks, L.E. (2002). Visual marking: Selective attention to asynchronous temporal groups. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 717-730.

Olivers, C.N.L, & Humphreys, G.W. (2002). When visual marking meets the attentional blink: More evidence for top-down, limited-capacity inhibition. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 22-42.

Olivers, C.N.L., Humphreys, G.W., Heinke, D., & Cooper, A.C.G. (2002) Prioritization in visual search: Visual marking is not dependent on a mnemonic search. *Perception & Psychophysics, 64,* 540-560.

Shen, J., Reingold, E.M., Pomplun, M. (2002). Distractor ratio influences patterns of eye movements during visual search. *Perception, 29,* 241-250.

Watson, D.G. & Humphreys, G.W. (1997). Visual Marking: Prioritizing selection for new objects by top-down attentional inhibition of old objects. *Psychological Review, 104,* 90-122.

Watson, D.G. & Humphreys, G.W. (1998). Visual marking of moving objects: A role for top-down feature based inhibition in selection. *Journal of Experimental Psychology: Human Perception and Performance, 24,* 946-962.

Watson, D.G. & Humphreys, G.W. (2000). Visual marking: Evidence for inhibition using a probe-dot paradigm. *Perception & Psychophysics, 62,* 471-481.

Watson, D.G. & Humphreys, G.W. (2005). The effects of irrelevant changes on preview search. *Perception & Psychophysics, 67,* 418-434.

Watson, D.G., & Humphreys, G.W. (2002). Visual marking and visual change. *Journal of Experimental Psychology: Human Perception and Performance, 28,* 379-395.

Watson, D.G., Humphreys, G.W., & Olivers, C.N.L. (2003). Visual marking: Using time in visual selection. *Trends in Cognitive Sciences, 7,* 180-186.

Williams, D.E., Reingold, E.M., Moscovitch, M., & Behrmann, M. (1997). Patterns of eye movments during parallel and serial visual search tasks. *Canadian Journal of Experimental Psychology, 51,* 151-164.

Wolfe, J.M. (1994). Guided search 2.0: A revised model of visual search. *Psychonomic Bulletin & Review, 1,* 202–238.

Zelinsky , G.J., & Sheinberg, D.L. (1997). Eye movements during parallel-serial visual search. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 244-262.

Zelinsky, G.J., Rao, R.P.N., Hayhoe, M.M., & Ballard, D.H. (1997). Eye movements reveal the spatiotemporal dynamics of visual search. *Psychological Science, 8,* 448-453.

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Footnotes

[1] The overall average dwell time on H_g and A_b distractors per trial for the FEB were 35.5ms and 114.2ms respectively and for the preview condition they were 9.7ms and 74.3ms. The average number of fixations per trial on each distractor type in the FEB were 0.226 (H_g) and 0.730 (A_b) and for the preview condition they were 0.060 (H_g) and 0.487 (A_b).

[2] The catch trial data from one participant were not analyzed because for one block of trials they pressed a third response key to indicate target absence rather than withholding their response.

[3] The overall average dwell time on H_g and A_b distractors per trial were 433.8ms and 1075.4ms (FEB) and 205.3ms and 948.6ms (preview). The mean number of fixations on each distractor type in the FEB were 1.875 (H_g) and 5.101 (A_b) and in the preview condition 0.860 (H_g) and 4.406 (A_b).

Table 1. Search slope statistics based on mean correct RTs and mean saccadic frequency as a function of condition. HEB = Half element baseline, FEB = Full element baseline, PRE = preview condition.

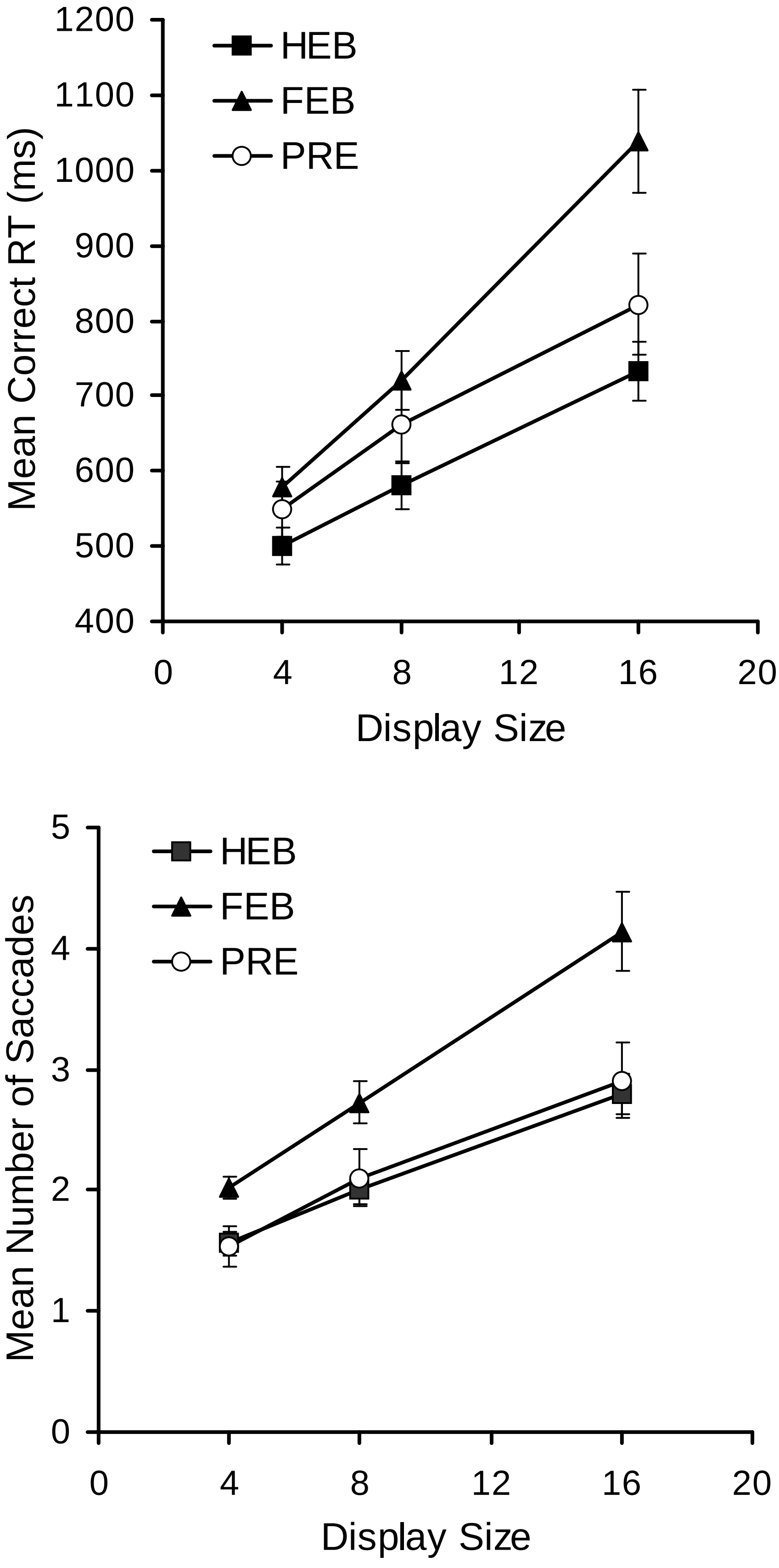
Condition	Slope (ms/item)	Intercept (ms)	r^2
RTs HEB	19.2	425.4	1.000
RTs FEB	38.6	419.0	0.999
RTs PRE	22.2	469.6	0.992
	Slope (saccades/item)	Intercept (saccades)	
Saccades HEB	0.103	1.164	0.999
Saccades FEB	0.177	1.312	1.000
Saccades PRE	0.113	1.129	0.991

Figure captions

Figure 1. Mean RTs and number of saccades for correct target present trials as a function of condition and display size. Error bars represent ± 1SE of the mean.

Figure 2. Mean saccadic frequency on correct-response catch trials as a function of condition and display size. Error bars represent ± 1SE of the mean.

Figure 3. Mean saccadic onset latency of the first search saccade in preview search as a function of condition and display size. Error bars represent ± 1SE of the mean.



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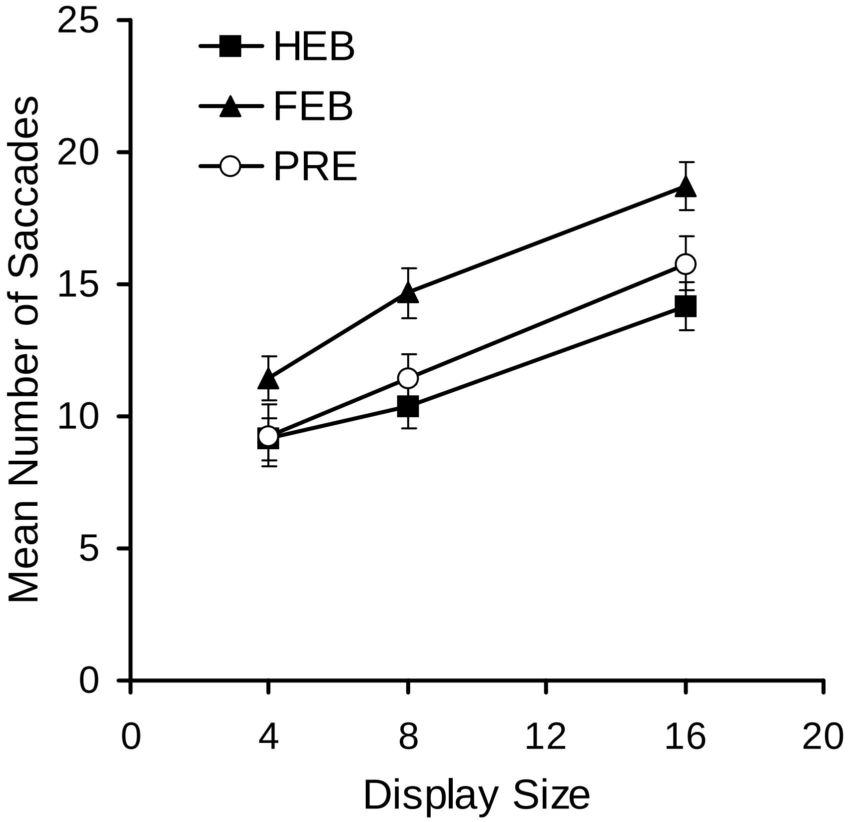

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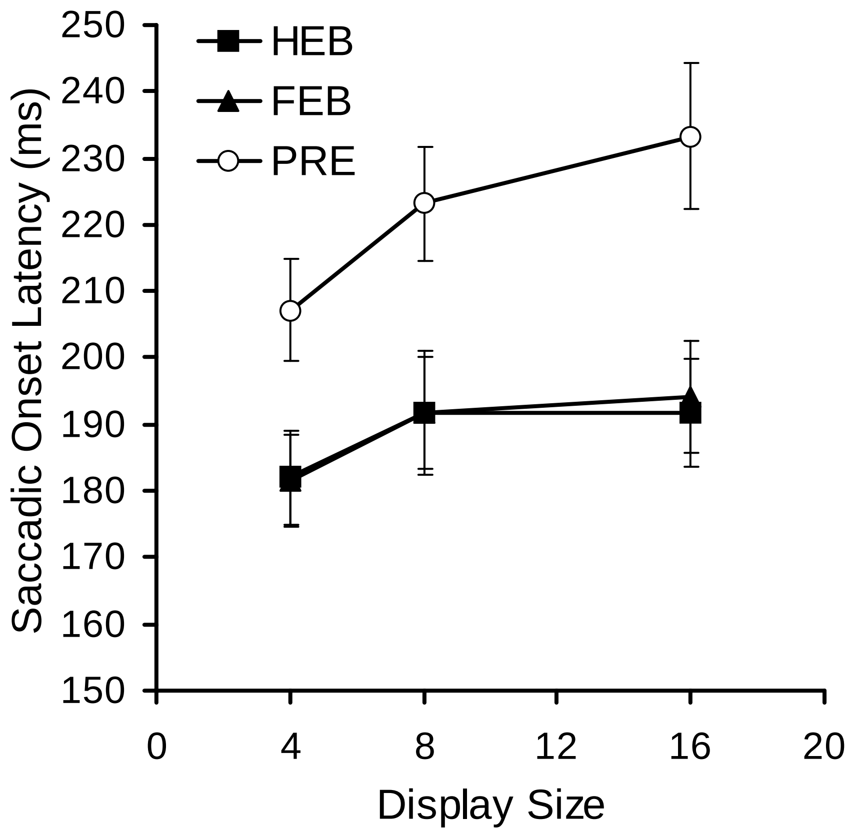

Figure 3. Mean saccadic onset latency of the first search saccade in preview search as a function of condition and display size. Error bars represent ± 1SE of the mean.