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Relax! Cognitive strategy influences visual search

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Two experiments evaluated whether visual search can be made more efficient by having participants give up active control over the guidance of attention. In Experiment 1 participants were instructed to search while either *actively* directing their attention to the target or by *passively* allowing the target to just "pop" into their minds. Results showed that passive instructions led to more efficient search on a hard task but not on an easy task. In Experiment 2 participants completed the search task either by itself or concurrently with a memory task. This yielded the same pattern of results as Experiment 1; a hard search was completed more efficiently when performed concurrently with a memory task than when performed alone. These findings suggest (a) that the efficiency of some difficult searches can be improved by instructing participants to relax and adopt a passive cognitive strategy and (b) the improved efficiency results from a reduced reliance on slow executive control processes and a greater reliance on rapid automatic processes for directing visual attention.

Visual search has become a model task for exploring the nature of attentional processes, as attested to by the other articles in this special issue. In a typical study, participants look for a target item that is presented along with a number of distractor items. The total number of items in a

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display is varied so that it is possible to examine the time it takes to find a target, or the accuracy of the search, as a function of the set size. The resulting function is often linear and its slope is taken as an index of the difficulty, or inversely the efficiency, of search. Shallow slopes reflect easy or efficient search; steep search slopes reflect hard or inefficient searches. Following Wolfe (1998) we use the term *search efficiency* as a theory-neutral term for how search for a target is influenced by adding distractor items to a search display.

Most studies of visual search have varied either the *display characteristics* or the *knowledge* (i.e., expectations) that participants bring to the task. Often-studied display characteristics include target–distractor similarity (Duncan & Humphreys, 1989), item density (Cohen & Ivry, 1991), retinal eccentricity (Carrasco & Yeshurun, 1998), and whether a simple feature or a conjunction of features defines the target (Triesman & Sato, 1990). Variations in task knowledge and expectations have included prior visual versus conceptual information about the target (Wolfe, Butcher, Lee, & Hyle, 2003), prior experience with specific display configurations (Chun & Jiang, 1998), and whether the target must be detected, identified, or localized (Bravo & Nakayama, 1992; Liu, Healey, & Enns, 2003).

Results from these studies have led to numerous theories regarding how attention is guided during search. Most theories propose that search is optimally efficient when it is guided by an appropriate balance of *automatic* or involuntary processes that analyse the visual display and *controlled* or voluntary processes that place the proper weight on the output of these automatic processes. A representative theory of this kind is Guided Search Theory (Wolfe, 1994), which proposes that search depends both on the extent to which target–distractor differences correspond to the organization of early visual processes *and* the extent to which the participant has actively tuned his/her control processes to optimize search for a given set of displays. The dimensional weighting theory of Müller and his colleagues (Found & Müller, 1996; Müller, Reimann, & Krummenacher, 2003) also emphasizes the balanced contributions of automatic and controlled processes in efficient search.

One issue that has been surprisingly neglected in this context is the extent to which search efficiency is influenced by the general cognitive strategy brought by the participant to the task. By cognitive strategy, we are referring to processes that are under the observer's voluntary control, but the term is intended to apply to cognitive control settings that are distinct from any specific knowledge the participant may have about the search items, the stimulus displays, or the responses that will be made in the search task.

One reason to suspect that cognitive strategy plays an important role in search is that it influences performance in other tasks involving categorization, memory, and perception. For example, in studies of categorization where items in different categories have very similar nondefinitional surface features, individuals are often more accurate at categorizing items when they adopt a feature-based (analytic) strategy compared to when they adopt a holistic (nonanalytic) strategy (Jacoby & Brooks, 1984; Whittlesea, Brooks, & Westcott, 1994). Similarly, in studies of memory where items from a number of different sources must be memorized, later recognition of items from a given source is much higher when participants base their judgements on retrieval of the previous study context, than when they base them on the familiarity of the items (see Jacoby & Brooks, 1984).

Studies of perception show that the context can bias participants undertaking a search to adopt either a singleton mode or a feature mode (Bacon & Egeth, 1994) and that singleton distractors defined by a different feature than the target interfere less with performance when participants search in feature mode than when they search in singleton mode (but see Theeuwes, 2004). In Lange's (1888) classic studies of speeded responding, average reaction times were found to be much faster (about 100–120 ms) when participants were instructed adopt an "extreme muscular mode" and focus on generating a response than when they were instructed to adopt an "extreme sensory mode" and focus on the incoming stimulus. Even in studies of perception without awareness, the strength of the unconscious influence of a briefly presented stimulus is greater when the participant allows the stimulus to "pop" into their mind, as opposed to actively looking for the stimulus (Marcel, 1983; Snodgrass, Shevrin, & Kopka, 1993a, 1993b; van Selst & Merikle, 1993).

Another reason to believe that cognitive strategy may influence search comes from anecdotes provided by researchers who regularly use this task. For example, Jeremy Wolfe believes that some conjunction searches can be made more efficient by instructing participants to relax and to observe the display passively rather than to search with a great deal of cognitive effort. He refers colloquially to this strategy as "using the force" (Wolfe, personal communication, 2004). Similarly, in our laboratories we have often instructed visual search participants to "let the search items come to you rather than looking hard to find them". We arrived at these instructions because we noted that experienced participants reported doing this spontaneously, whereas naïve searchers were expending great mental effort but searching less efficiently. Although anecdotes such as these have received wide circulation among researchers, there is little formal evidence supporting the effectiveness of the claim that searching "passively" is more efficient. A primary purpose of the present study was therefore to simply document the influence of this cognitive strategy on visual search.

Preliminary evidence that cognitive strategy influences search comes from a recent study by Smilek, Dixon, and Merikle (2006a). Simple differences in the pretask instructions given to participants were reported to influence search for items that had recently been associated with meaningful verbal labels. In a first phase of the study, participants learned to associate verbal labels with simple shapes (e.g., vertical and right oblique were both called an "elephant" and left oblique was called a "pencil"). Counterbalancing the labels used by different groups of participants ensured that the visual similarity of the items was controlled. In one condition, target and distractor shapes were from the same category, so that participants had to search for an "elephant" among "elephants". In another condition, target and distractor shapes were from different categories, so that now a "pencil" had to be found among "elephants".

The critical manipulation in the study involved instructing one group of participants to search for the target by *actively* directing their attention to the target; the other group of participants was told to let the target "pop" *passively* into their mind. The results showed that the categorical relationship between target and distractors influenced search only when participants adopted a passive search strategy. Specifically, when target and distractors differed in category membership, search was much more efficient for participants following *passive* instructions than for those given *active* instructions. These results were interpreted to suggest that the conceptual categories of targets and distractors influences search only when participants adopt a *passive* strategy.

Although the Smilek et al. (2006a) study demonstrates that cognitive strategy can influence search, several important questions remain. First, it is not known whether cognitive strategies will influence search when no newly acquired meanings have been linked to the display items. It is possible that the search task of Smilek et al. required participants to base their search on a more conceptual and abstract representation of the items in the displays. Conceptual representations may simply be more susceptible to strategic influence than representations of spatial and geometric characteristics (Pylyshyn, 2003). On the other hand, it is possible that control processes are able to influence attentional guidance at the earliest stages and therefore influence search based on a simple visual discrimination.

Another question that remains unanswered is whether cognitive strategies interact with the overall difficulty of the search task. If instructions have an influence at the level of altering the decision criteria used by participants to select a response, with passive instructions simply leading to a more relaxed decision rule, then the instructions should have a similar influence on search tasks of all levels of difficulty. On the other hand, if instructions influence the cognitive control processes of participants, and more difficult searches bias participants to attempt to exert greater cognitive control over the task, then one would expect instructions to have a greater influence only on more difficult searches. This prediction is consistent with anecdotes that a passive search strategy is particularly effective for conjunction searches and that experienced searchers have learned that a passive strategy is most effective.

EXPERIMENT 1

The goals of Experiment 1 were twofold. First, we asked whether search efficiency is influenced by active and passive search instructions when the search task involves only geometric visual discriminations. Second, we evaluated whether the influence of instructions depends on the relative difficulty of the search.

Participants searched for a circle that had a gap either on the left side or on the right side, among circles that had a gap on both the left and right side. They were required to respond by indicating as quickly and accurately as possible whether the target gap was on the left or the right. Search difficulty was varied by testing participants in an *easy* discrimination (target gap was large) and a *hard* discrimination (target gap was small) in separate blocks of trials. *Active* and *passive* search instructions were given to two different groups of participants. Search efficiency was indexed by measuring search slopes for response time and accuracy over three different levels of set size: Two, four, and six display items.

Method

Participants. Twenty-four undergraduate students reporting normal or corrected-to-normal vision participated in a 30-minute session for extra course credit at the University of British Columbia. Twelve participants were randomly assigned to each instructional group.

Stimuli. Examples of the visual search displays are shown in Figure 1. Each display consisted of a target (circle with gap on left or right) and one, three, or five distractors (circle with a gap on the left and the right). Each

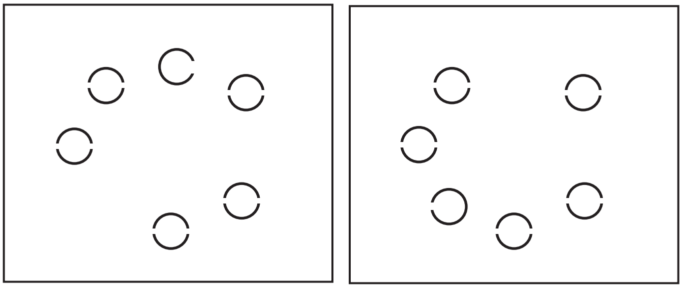

Figure 1. Examples of easy (left) and hard (right) search displays used in Experiments 1 and 2.

item occupied one of eight possible locations, equally spaced on an imaginary circle centred on fixation. Item location was selected randomly. The size of the gap in the target circle was varied between blocks to vary the overall difficulty of the search: Easy (large gap) and hard (small gap). Examples of the easy and hard search displays are shown on the left and right sides of Figure 1, respectively.

Displays were presented on an Apple iMac computer running VScope experimental software (Enns & Rensink, 1992). The monitor resolution was 800×600 pixels and the refresh rate was 112 Hz. At this resolution, items in the search display measured 0.8 cm in diameter and subtended 0.8 degrees visual angle at a viewing distance of 57 cm. The gaps in the distractor items, the targets with the small gaps and the targets with the large gaps measured 0.1 cm (0.1°), 0.15 cm (0.15°), and 0.3 cm (0.3°), respectively. The imaginary circle on which the items were placed had a radius of 4.0 cm (4.0°).

Procedure. Each participant was tested in a single experimental session consisting of 8 practice trials and two blocks of 144 experimental trials. Order of search difficulty (easy, hard) was counterbalanced across participants. Within each block, the three set sizes (2, 4, and 6) and two targets (gap on left, gap on right) yielded six possible conditions, which were repeated 24 times, with each display configuration determined randomly.

Each trial began with a fixation cross at the centre of the screen for 500 ms. Following a blank interval of 400 ms, a search display was presented and remain on view until response or until 1800 ms had elapsed. Participants' index fingers rested on the "z" key (gap on left) and the "/" key (gap on right), which they depressed when they identified the target. Participants were instructed to respond as rapidly as possible without sacrificing accuracy for speed. Responses made after the end of the 1800 ms period in which the visual search display was presented were recorded as errors.

The two groups of participants differed only in the instructions given prior to the search task. The *passive* group instructions were:

> The best strategy for this task, and the one that we want you to use in this study, is to be as receptive as possible and let the unique item "pop" into your mind as you look at the screen. The idea is to let the display and your intuition determine your response. Sometimes people find it difficult or strange to tune into their "gut feelings"—but we would like you to try your best. Try to respond as quickly and accurately as you can while using this strategy. Remember, it is very critical for this experiment that you let the unique item just "pop" into your mind.

The *active* group instructions were:

> The best strategy for this task, and the one that we want you to use in this study, is to be as active as possible and to "search" for the item as you look at the screen. The idea is to deliberately direct your attention to determine your response. Sometimes people find it difficult or strange to "direct their attention"—but we would like you to try your best. Try to respond as quickly and accurately as you can while using this strategy. Remember, it is very critical for this experiment that you actively search for the unique item.

Results

Correct response time (RT). Before examining the RT data of each participant, the outliers in each condition were removed using a recursive procedure (see van Selst & Jolicoeur, 1994). The data were then evaluated by a mixed analysis of variance (ANOVA) that assessed the between-group factors of instruction (active, passive) and order (hard search first, easy search first), and the within-participant factors of search difficulty (easy, hard) and set size (2, 4, and 6).

Figure 2 shows the mean correct RT. This pattern of results points to two main conclusions, which were corroborated by ANOVA. First, simply instructing participants to search actively or passively influences the efficiency of their search, with a passive strategy resulting in greater efficiency. Second, the passive strategy is effective only when the search is relatively difficult.

ANOVA showed that mean correct RT increased linearly with set size, $F(1, 20) = 246.74$, $MSE = 3744.9$, $p < .001$, as is the case in many studies of visual search. Also, the slopes of the search functions were steeper in the difficult search condition than in the easy search condition, $F(2, 40) = 39.96$, $MSE = 1241.0$, $p < .001$, indicating that variation of the target's gap size was effective in influencing search difficulty. Most importantly, the slopes of the search functions were shallower when participants adopted a passive strategy than when they adopted an active strategy, $F(2, 40) = 7.081$, $MSE = 2401.2$, $p < .003$, pointing to the role of cognitive strategy in search efficiency. However, whether strategy influenced the slopes also depended on the difficulty of search, $F(2, 40) = 11.617$, $MSE = 1241.0$, $p < .001$. Testing order had no influence on search strategy, $F < 1$, nor on its interaction with hard and easy search conditions, $F(2, 40) = 1.287$, $MSE = 1241.0$, $p = .287$.

To further examine how instructions interacted with search difficulty, we examined the data separately in the hard and easy search conditions. These analyses revealed that instructions had a substantial effect on the search slope when search was hard, $F(2, 40) = 12.477$, $MSE = 2503.3$, $p < .001$, but

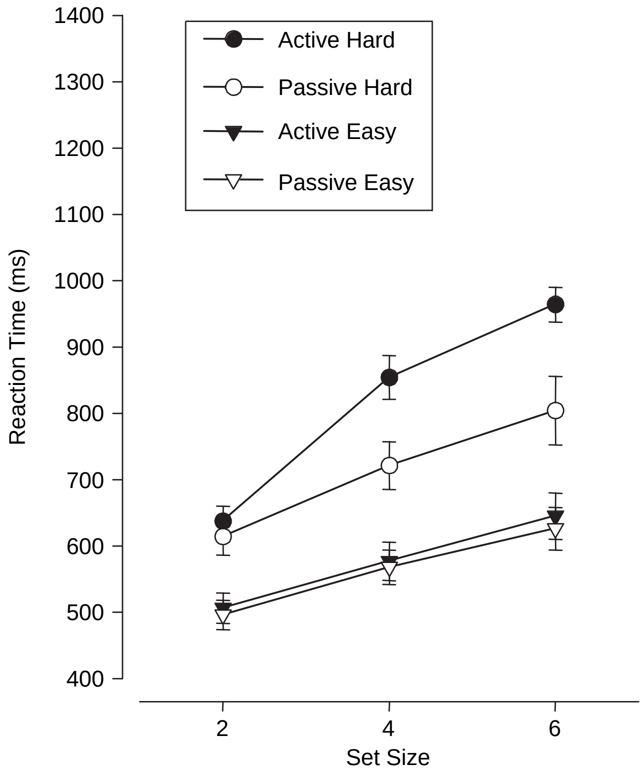

Figure 2. Mean correct response times for identifying the target in Experiment 1. The error bars represent one standard error of the mean.

not when search was easy, $F < 1$. In the hard search condition, the difference between active and passive search slopes was nominally greater when hard search was done after the easy search (slope difference of 45 ms/item) than when hard search was done before easy search (slope difference of 23 ms/item), but this interaction did not reach statistical significance, $F(2, 40) = 1.207$, $MSE = 2503.3$, $p = .310$.

Error data. The conclusions derived from the RT data are only valid if the error data indicate that participants are not trading response speed for accuracy. The error rates for each condition are shown in Table 1 and they indicate that speed–accuracy trading relations are not a concern for out interpretation. In particular, there was no evidence that the differences in the slopes of the RT functions associated with two instructional sets were the result of participants trading speed for accuracy.

TABLE 1
Mean percentages of errors in Experiment 1

	Set size		
	2	*4*	*6*
Active			
Hard	3.1	4.9	15.5
Easy	3.0	2.1	2.6
Passive			
Hard	9.7	10.7	20.8
Easy	5.2	6.9	9.0

These data were analysed in the same way as the RT data. ANOVA revealed that participants made more errors when search was hard than when search was easy, $F(1, 20) = 35.036$, $MSE = 0.00368$, $p < .001$, that errors increased linearly with set size, $F(1, 20) = 35.300$, $MSE = 0.00308$, $p < .001$, and this increase was greater in the hard search condition than in the easy search condition, $F(2, 40) = 15.000$, $MSE = 0.00243$, $p < .001$. Although there were more errors in the passive search condition than in the active search condition, $F(1, 20) = 8.472$, $MSE = 0.1166$, $p < .01$, there was no measurable influence of search strategy on the slopes of the error functions, $F < 1$, and this did not differ across hard and easy search conditions, $F < 1$.

Inefficiency scores. Speed–accuracy trading relationships can be subtle and difficult to detect when error rates are low (Pachella, 1974; Wickelgren, 1977). One sensitive way to assess whether they are playing a role in the data is to combine RT and errors in single measure of *search inefficiency*, by dividing mean correct RT for each participant in each condition by the mean proportion correct (Townsend & Ashby, 1983). This is a measure that corrects the RT measure by its appropriate level of accuracy in a very intuitive way: if accuracy is perfect in a condition, the inefficiency score will be identical to mean RT; as accuracy is decreased the inefficiency score will increase in proportion to the level of errors being made. The main assumption underlying the interpretation of these scores is that mean correct RT increases linearly as mean proportion accuracy decreases. This was supported in the present data by a correlation of $-.29$, $p < .001$.

The inefficiency scores for Experiment 1 are shown on the left side of Figure 5 (see later). Their pattern makes it clear that the benefit of the passive instructions was not the result of shifting participants' response criteria. Instead, using a passive strategy resulted in greater search efficiency in the hard search condition and had no measurable influence on the easy search. ANOVA conducted on the inefficiency scores showed the identical pattern of results as reported for the correct mean RT data.

EXPERIMENT 2

Having established that instructing participants to adopt an active or a passive strategy influences the efficiency of search, we sought to explore the reasons that passive search leads to more efficient search. One possibility is that these instructions influence the extent to which participants employ executive control mechanisms to direct their attention during search. Specifically, it is possible that active search instructions increase participants' propensity to employ cognitive control, whereas passive search instructions decrease their efforts to use such control. On this view, search is less efficient when following active instructions because exerting executive control over search is inefficient, relative to allowing search to proceed on the basis of the rapid and automatic mechanisms that are involved in passive search.

Tentative support for this hypothesis comes from a recent study of the effects of memory load on visual search performance (Woodman, Vogel, & Luck, 2001). In one of the experiments in this report, participants completed a relatively difficult search task either as a single or dual task. The dual-task condition was designed to interfere as much as possible with the short-term memory requirements that might be shared in both tasks. As such, participants were required to remember an array of four visual items that were very similar in appearance to the search items, prior to completing the search task. Upon completion of the search, they were required to indicate whether a test memory display was the same of different from the studied memory display.

The results showed that search was overall much slower in the dual-task condition than in the single task condition. However, the slope of the search function in the dual-task condition was slightly shallower than the slope in the single task condition (though the difference in search slopes did not reach statistical significance in that experiment). As such, the authors concluded that search efficiency is unaffected by memory load. However, we believe the data is suggestive for our claim that search may be accomplished *more* efficiently when participants are unable to exert strong executive control during the search. If so, then increasing the difficulty of the memory task might actually improve the efficiency of search task, in much the same way as following passive instructions, provided the memory task also requires executive control functions.

In Experiment 2 participants performed a concurrent memory task with visual search, in a test of this hypothesis. As in Experiment 1, participants completed the hard and easy search tasks in separate blocks of trials. However, instead of varying search instructions across participants, we varied executive processing demands by having some participants complete the search task as a single task, and others as part of a dual task, together with a demanding visual memory task.

The sequence of displays used in Experiment 2 consisted of a memory study display, a visual search display, and, finally, a memory test display. Examples of the memory study and test displays are shown in Figure 3. In the single task, participants were required to simply complete the search task and to ignore the two memory displays. In the dual task, participants were required to first memorize the study display, complete the search task, and then report whether the memory test display was same as or different to the memory study display. To ensure that the memory task was difficult and required considerable executive control, we followed Woodman et al. (2001) in designing memory study and test displays that were highly confusable with each other, as well as being confusable with the targets in the search display.

We expected that, as in Woodman et al. (2001), search should generally take longer when it is done as a dual task than when it is done as a single task. However, if passive instructions lead to more efficient search because they encourage participants to exert less executive control over search, then preventing participants from using executive control during search, by having them perform a concurrent memory task, should have a similar impact on search as did the passive instructions. Specifically, this would mean that search slopes in the dual task should be shallower than those for the single task when search is hard, but not when search is easy. On the other hand, if the influence of passive search observed in Experiment 1 is not a matter of decreasing the use of executive control mechanisms, then the slopes

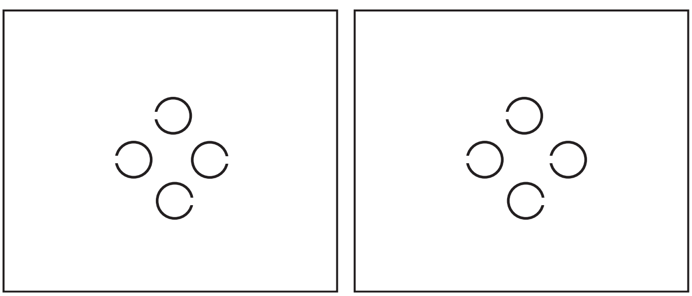

Figure 3. Examples of the memory study (left) and memory test (right) displays used in Experiment 2.

of the search functions should be equivalent across single and dual tasks for both easy and hard search.

Method

Participants. Twenty-four undergraduate students reporting normal or corrected-to-normal vision participated in a 45 minute session for extra course credit at the University of British Columbia. Twelve participated were randomly assigned to either the single- or the dual-task condition.

Stimuli. The search displays in Experiment 2 were identical to those in Experiment 1. In addition, Experiment 2 also included memory study and memory test displays. An example of a study display is shown in Figure 3. Each display consisted of four circles, each of which had a gap either on the left or on the right, with the constraint that not all of the circles had a gap on the same side. The circles were 2.0 cm (2.0 deg) above, below, to the left, and to the right of fixation. Figure 3 also shows an example of a memory test display. On half of the trials the memory test display on a given trial was identical to the study display; on the other half of the trials the orientation of one of the items in the test display differed from its counterpart in the study display.

Procedure. The main change in the procedure was that all participants were given neutral search instructions in Experiment 2. Participants were simply instructed to find the unique item in each display and, using their left hand, to press the "z" key if the gap was on the left or the "x" key if the gap was on the right. What did vary between observers was whether search was done as a single or a dual task. This meant that the sequence of displays used on each trial of Experiment 2 included a fixation cross presented for 500 ms, a blank interval for 400 ms, a memory study display for 1800 ms, a visual search display presented until response or until 2700 ms elapsed, a blank interval for 400 ms, and, finally, a memory test display presented for 2500 ms.

In the dual-task condition, participants were required to first memorize the items in the study display, complete the visual search task, and, finally, report whether the memory test display was same as or different to the memory study display by using their right hand to press either the "." key or the "/" key, respectively. The response to the visual search display was speeded as in Experiment 1, but the response to the memory test display was not. In contrast, participants in the single-task condition were required to complete the search task and ignore the memory study and test displays. They simply pressed the "/" key to advance to the search display each time the memory test display was presented.

Results and discussion

Response times. As in Experiment 1, a recursive procedure was used to remove the outliers in each cell before the RTs for the correct responses were analysed. The data were then submitted to a mixed ANOVA that assessed the between-group factors of task (single, dual) and order (hard search first, easy search first) and the within-participant factors of search difficulty (easy vs. hard) and set size (2, 4, and 6).

The mean correct RT is shown in Figure 4. With the exception of the overall slowing in responses in the dual-task condition relative to the single task condition, the pattern of results is strikingly similar to that of Experiment 1. Like the passive search instructions in Experiment 1, performing search with a concurrent memory task led to more efficient search when search was hard, but no reliable influence when search was easy.

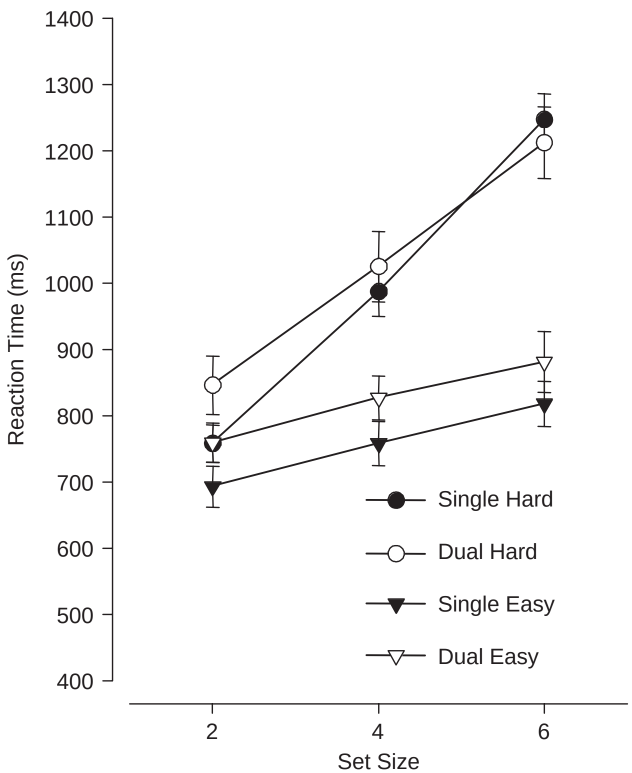

Figure 4. Mean correct response times for identifying the target in Experiment 2. The error bars represent one standard error of the mean.

The findings suggest that preventing participants from using executive control during search, by having them do a concurrent memory task, has a similar impact as the passive instructions. Assuming that a concurrent memory task influences the same factors as do the passive search instructions, the findings imply that passive instructions increase search efficiency by encouraging participants to give up executive control during search and instead rely on more rapid automatic processes.

These conclusions were supported by the ANOVA. As in Experiment 1, RT increased linearly with set size, $F(1, 22) = 449.731$, $MSE = 4057.3$, $p < .001$, and the slopes of the search functions were much steeper in the difficult search condition than in the easy search condition, $F(2, 40) = 92.424$, $MSE = 3008.2$, $p < .001$. Although RT for the dual task was higher than for the single task, this main effect did not reach statistical significance, $F(1, 20) = 1.128$, $MSE = 76{,}453.9$, $p = .301$. Most importantly, however, the results revealed that search slopes were shallower in the dual-task condition than in the single-task condition, $F(2, 40) = 4.274$, $MSE = 2803.4$, $p = .021$, indicating that the presence of a concurrent memory task influenced the efficiency of search. Furthermore, the extent to which the dual task influenced the search slopes depended on the difficulty of search, $F(2, 44) = 3.604$, $MSE = 2955.0$, $p = .036$. Neither of these latter two findings depended on the order of the hard and easy search conditions, both Fs < 2.605, both ps $> .09$.

To evaluate how the influence of the dual task depended on the difficulty of search, the data for the hard and easy search conditions were further analysed separately. This revealed that the dual task had a substantial effect on slopes for hard search, $F(2, 40) = 6.351$, $MSE = 3557.1$, $p < .005$, but did not have any measurable influence for easy search, $F < 1$. Though the difference between single and dual task search slopes in the hard search condition was greater when hard search was done after the easy search (slope difference of 45 ms/item) than when hard search was done before easy search (slope difference of 15 ms/item), this effect of order did not reach statistical significance, $F(2, 40) = 2.661$, $MSE = 3557.1$, $p = .082$.

Overall, the RT search slopes in Experiment 2 are steeper than those in Experiment 1, as seen in a comparison of Figures 2 and 4. A similar comparison of the errors in Tables 1 and 2 reveals that these slopes were shallower in Experiment 2 than in Experiment 1. This pattern of findings suggests that participants responded with a different criterion in the two experiments. There are two possible reasons for such a criterion shift between experiments. One is that participants strategically adopted a stricter criterion in Experiment 2 because they had to complete an additional memory task. Another possible reason is that participants failed to respond more often before the visual search display timed-out in Experiment 1 than in Experiment 2. Indeed, the maximum exposure duration of the displays

TABLE 2
Mean percentages of errors in Experiment 2

	Set size		
	2	*4*	*6*
No load			
Hard	3.4	0.8	2.3
Easy	1.8	0.5	0.8
Load			
Hard	2.1	3.5	2.6
Easy	2.6	4.2	2.9

was made longer in Experiment 2 (2700 ms) than in Experiment 1 (1800 ms), to accommodate the increase in task difficulty in Experiment 2. Because responses that occurred after the display timed-out were recorded as errors this difference between the two experiments would be similar to participants adopting different criteria across experiments. To demonstrate that these two possibilities do not cause a problem for our interpretation of the RT data, and to facilitate comparison across experiments, we analysed both the errors and the inefficiency scores.

Error data and inefficiency scores. We first considered the possibility that the RT results might be due in part to the trading relationship between speed and accuracy. The error rates for each condition in Experiment 2 are shown in Table 2 and they indicate that speed–accuracy tradeoffs pose no problems for our interpretation of the RT data. Error rates were relatively low overall and there was no evidence that the differences in the slopes of the RT functions associated with the single and dual tasks were the result of participants trading speed for accuracy. These conclusions were corroborated by a mixed ANOVA similar to the one used to analyse the RT data. The analysis revealed no significant main effects or interactions, all Fs < 3.894, all ps $> .06$.

To bolster our conclusion that trading relations between speed and accuracy do not contaminate the RT data, we calculated the inefficiency scores, as shown on the right side of Figure 5. This shows that when RT and errors are combined, the pattern of data is the same as the pattern revealed by considering the RT data alone. Namely, the dual task led to increased search efficiency in the hard search condition but had no measurable influence in the easy search condition.

Having calculated the inefficiency scores for both Experiments 1 and 2, it is now possible to directly compare the results of the two experiments

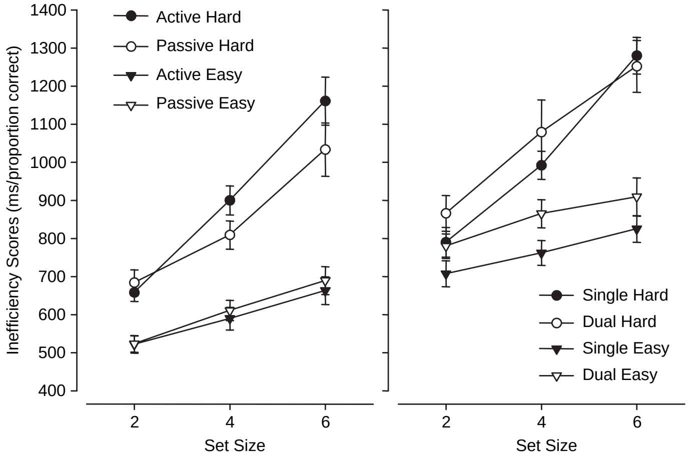

Figure 5. Mean search inefficiency scores (correct RT/proportion correct) for identifying the target in Experiment 1 (left) and Experiment 2 (right). The error bars represent one standard error of the mean.

because the inefficiency scores eliminate differences in response criterion between experiments. Note that the slopes of the inefficiency functions for Experiment 2 (right side of Figure 5) are very similar to those of Experiment 1 (left side of Figure 5). This further indicates that performing a concurrent memory task has the same impact on search efficiency as does instructing participants to search passively through the displays, once the different baseline rates of error in the two experiments have been factored in.

Memory data. The memory task was completed with an overall accuracy of 84.5%. The percentages of correct responses for the easy search condition were 80.4, 83.9, and 88.3, for set sizes 2, 4, and 6, respectively. The corresponding percentages for the hard search condition were 84.8, 82.8, and 87.0. The accuracy scores were evaluated using a mixed ANOVA, which assessed the between-group factor of order (hard search first, easy search first) and the within-participant factors of search difficulty (hard, easy) and set size (2, 4, and 6). The analysis revealed that memory performance increased with set size, $F(1, 11) = 22.616$, $MSE = 0.001322$, $p < .001$. No other main effects or interactions reached significance, all $F\text{s} < 2.301$, all $p\text{s} > .126$.

A consideration of the visual search data together with the memory data suggests that our interpretation of the visual search slopes is not compromised by a tradeoff between tasks. If the shallower search slopes in the dual-task condition been accompanied by a decrease in memory performance as set size increased, it could be interpreted as a tradeoff between tasks. Such a pattern could be explained by positing that the shallower search slopes in the dual-task condition occurred because, as set size increased, resources were progressively shifted from the memory task to the search task. However, the pattern of data just described was not found in this experiment. Rather, memory performance increased with set size. Thus, any task tradeoff would actually lead to an underestimation of the influence of memory load on search efficiency and would further support our interpretation of the search findings.

GENERAL DISCUSSION

There is considerable anecdotal evidence that some visual search tasks can be made more efficient by instructing participants to simply relax, that is, to take a passive cognitive approach to an otherwise difficult task. In Experiment 1 we tested this possibility formally by instructing participants to complete a search task either by *actively* directing their attention to the target or by *passively* allowing the target item to just "pop" into their minds. The results showed that passive search instructions led to greater efficiency when the search task was hard but these instructions had no observable influence when the search task was easy. Our tentative hypothesis was that the passive instructional set induced participants to rely less on their control processes and to rely more on the unconscious processes that are able to distinguish the target from the distractors.

This hypothesis was put to the test in Experiment 2 where the amount of executive control available during the search task was reduced by having participants complete the search task while concurrently holding similar visual items in short-term memory. The results were strikingly similar to those in Experiment 2. As with passive search instructions, completing search concurrently with a memory task led to more efficient search when search was hard but had no observable influence on search efficiency when search was easy.

Taken together, these results support the following conclusions. First, visual search can be made more efficient by instructing participants to adopt a passive cognitive strategy, consistent with previous anecdotal evidence. This increase in efficiency is not simply the result of a tradeoff between speed and accuracy; both response times and errors agree that search is more efficient with passive instructions. Second, passive instructions influence searches that are relatively hard but do not influence searches that are relatively easy. This is consistent with passive instructions having their influence primarily on tasks on which participants are likely to try to exert strong cognitive control. It also shows in another way that passive instructions do not simply alter the decision criteria used by participants, since that effect should be evident in both hard and easy searches. Third, the similarity in the search results for passive instructions (Experiment 1) and for a difficult concurrent memory task (Experiment 2) is consistent with the improved efficiency deriving from a reduced reliance on slow executive control processes and a forced reliance on more rapid automatic processes for directing attention during search.

The present findings extend the work showing that active and passive cognitive strategies influence search for items associated with conceptual categories (Smilek et al., 2006a). A potential criticism of this work, considered in isolation, was that conceptual or abstract representations might be more susceptible to strategic influences than basic visual discriminations. The present findings show that this is clearly not the case. Cognitive strategy is able to influence attentional guidance at early stages of perception, where only acuity-based visual discriminations are required.

We must also emphasize that our conclusions regarding the influence of a concurrent memory task on search efficiency differ considerably from the conclusion reached by Woodman et al. (2001). These authors concluded that a concurrent memory task has no influence on the efficiency of visual search. Their conclusion was based on the fact that they failed to find a statistically significant *increase* in the slopes of the search functions under dual task conditions. However, in their Experiment 2, when the memory task was particularly difficult, the search slope in the dual-task condition was actually shallower than the slope in the single-task condition, although not significantly so. In our study, this trend was statistically significant when the search task was made sufficiently difficult. This finding therefore leads us to conclude that performing a concurrent memory task can in fact influence search efficiency; but it does so by *improving* the efficiency of difficult searches.

The present findings are consistent with a recent report by Olivers and Nieuwenhuis (2005), who showed that the temporal dynamics of attention is influenced by inducing a “distributed state of mind” in participants. In their study, participants were required to report two successively presented visual targets. As is typically the case in such studies, participants were much poorer at reporting the second target when the two targets are presented in close succession than when the targets were widely separated in time, a finding known as the attentional blink. The important new finding, however, was that this dual-task deficit was completely eliminated when participants were presented with rhythmic music simultaneously with the visual stream of items. The authors argued that under normal circumstances, participants focus on the first of the two targets and that this effortful focusing of attention leads to the exclusion of the second target, thus yielding the AB deficit. In contrast, when rhythmic music is played, participants are placed into a “distributed sate of mind” allowing both the first and second target to be processed, which eliminates the typical AB deficit. We find these results relevant because, in our view, music might have a similar influence as our passive search instructions in that they both lead participants to relinquish executive control and to rely more heavily on automatic, and perhaps implicit, processes. As such, it would be interesting to see whether our active and passive instructions also influence the size of the AB deficit and whether playing music during search improves search efficiency.

Do passive instructions always benefit performance?

Although adopting a passive cognitive strategy improved search in the present study, it is conceivable that a passive strategy may be detrimental in other situations. Indeed, in other domains, such as conceptual categorization, it is well known that a nonanalytic approach can either help or hurt performance relative to an analytic approach (see Whittlesea et al., 1994). The same is likely true of active and passive cognitive strategies on perception. Specifically, we predict that any task that requires participants to analyse a display into its component parts would be done more effectively using an active rather than a passive cognitive strategy.

One situation in which adopting a passive cognitive strategy seems to hurt perception is when participants judge the clarity of coarse quantized images (e.g., a face of Abraham Lincoln). Typically, when participants view such images they rate the clarity of a quantized image overlaid with a screen as higher than the same image viewed without a screen, a finding that we refer to as the *illusion of clarity* (Smilek, Rempel, & Enns, 2006b). The illusion of clarity occurs because participants actively segregate the screen from the quantized image and, in the process, they attribute the high frequency edges created by quantization to the screen rather than to the face. The end result is a clearer view of the face. In this task, our findings indicate that adopting a passive cognitive strategy decreases the perceived clarity of images, relative to when an active strategy is adopted. This demonstrates that there is at least one case in which a passive strategy impairs a perceptual process. We believe there will be others, even in search, provided that the search task requires an active segmentation or individuation of component features of the display.

Implications of the present findings

A prediction that follows from this interpretation is that passive search instructions should magnify the extent to which attention is oriented on the basis of information processed only implicitly, or without awareness. This follows from our conclusion that passive instructions encourage participants to rely less on conscious control processes. This prediction was recently tested in a study of contextual cueing (Lleras & von Mühlenen, 2004). Contextual cueing refers to the guidance of attention by implicit memory of previously encountered search displays (Chun & Jiang, 1998). In an initial attempt to obtain contextual cueing, Lleras and von Mühlenen failed to replicate the findings of Chun and Jiang; participants searched as efficiently on new search displays as on those they had previously encountered. Based on the present findings, Lleras and von Mühlenen hypothesized that a passive cognitive strategy may be critical to obtaining guidance by implicit memory. In a subsequent experiment, they therefore instructed participants to search either actively or passively through displays, using the same instructional sets used in the present study. The results showed a robust contextual cueing effect for individuals instructed to search passively, but no contextual cueing effect for individuals who were instructed to search actively. This is consistent with the hypothesis that passive instructions induce less reliance on conscious control processes.

Another prediction that emerges from our interpretation is that individuals with deficits in executive control functions should be able to search more efficiently under some conditions than individuals with unimpaired executive control functioning. This prediction is supported by findings showing that children with autism, who are known to have deficits in executive control, perform difficult visual search tasks more efficiently than normally developing children (O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001). However, not all individuals with reduced executive control capacities show generally enhanced search efficiency. For instance, the elderly (Trick & Enns, 1998), young children (Plude, Enns, & Brodeur, 1994), and individuals with frontal damage (Kumada & Humphreys, 2002) all tend to show substantial reductions in visual search efficiency when compared to young healthy adults. One reason why these individuals may show reduced search efficiency is that they are actually trying to exert control over their search, and in their case, their control is poor or inappropriately matched to the task. If so, the search efficiency of these individuals might actually increase if they relaxed and gave up trying to exert conscious control, relying instead on their implicit processes. On the other hand, these individuals may also have other deficits, such as a reduced functional field of view that contributes to the reduction of their search efficiency for other reasons. Clearly more research is needed to understand fully how instructional sets can alter the guidance of visual attention. The findings to date on this issue suggest that this may well be a fruitful avenue of study.

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