The role of priming in conjunctive visual search

Árni Kristjánsson[a,*], DeLiang Wang[b], Ken Nakayama[a]

[a]*Vision Sciences Laboratory, Department of Psychology, Harvard University, Cambridge, MA, USA*
[b]*Department of Computer & Information Science and Center for Cognitive Science, The Ohio State University, Columbus, OH, USA*

Abstract

To assess the role of priming in conjunctive visual search tasks, we systematically varied the consistency of the target and distractor identity between different conditions. Search was fastest in the standard conjunctive search paradigm where identities remained constant. Search was slowest when potential target identity varied predictably for each successive trial (the 'switch' condition). The role of priming was also demonstrated on a trial-by-trial basis in a 'streak' condition where target and distractor identity was unpredictable yet was consistent within streaks. When the target to be found was the same for a few trials in a row, search performance became similar to that when the potential target was the same on *all* trials. A similar pattern was found for the target absent trials, suggesting that priming is based on the whole search array rather than just the target in each case. Further analysis indicated that the effects of priming are sufficiently strong to account for the advantage seen for the conjunctive search task. We conclude that the role of priming in visual search is underestimated in current theories of visual search and that differences in search times often attributed to top-down guidance may instead reflect the benefits of priming. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

The importance of priming in various cognitive tasks is well known and has been researched extensively. Its role in visual search, however, has been poorly understood and relatively neglected. In a typical visual search task observers search for the same target repeatedly among a set of distractors. Yet, in some variants of the task, the identity of the target and distractors can change from one trial to the next. Although the effects of target

variation have been demonstrated (Maljkovic & Nakayama, 1994, 1996, 2000; Schneider & Shiffrin, 1977) current theories of visual search do not address the issue of repeating targets or distractors (Duncan & Humphreys, 1989; Grossberg, Mingolla, & Ross, 1994; Palmer, 1995; Treisman & Gelade, 1980; Wolfe, 1994).

The characteristics of repetition effects in visual search have been documented by Maljkovic and Nakayama (1994, 1996). They found short-term priming for features and locations of the target in a feature ("pop-out") search task. Thus, if the target had the same features, or appeared in the same location as on the previous trial, search was faster than otherwise. These priming effects were very strong, effective over a number of trials, and not subject to voluntary control or expectation.

Why should priming of this sort be important for theories of visual search? Firstly, the empirical basis of many such theories is experiments in which the same target is to be found repeatedly among the same distractors. Secondly, priming effects may be large enough to contaminate the theories themselves, for example when differences in search rates between experiments where the target varies and where it remains the same are not attributed to this difference in target identity, but are instead spuriously attributed to some other difference between the two experiments. Thirdly, organisms do not normally spend their time scanning the visual environment for completely novel objects from one moment to the next but instead the targets tend to be relatively stable over time. In fact, when engaged in a simple task requiring input from the visual system we seem to make surprisingly many eye movements to the same targets. In one informative experiment observers' eye movements were monitored while they were engaged in copying a pattern of colored chips (Ballard, Hayhoe, Li, & Whitehead, 1992). Their subjects did not seem to memorize the layout of the chips they were to copy but made frequent eye movements back and forth between the copying pattern and the area where the copied pattern was to be placed. Maljkovic and Nakayama (1994) suggested that the priming of pop-out played a role in this process by allowing fast return of gaze to previously inspected areas or features. Similarly, in the wild, a predator tracking the movement of potential prey would benefit greatly from being able to reorient quickly to the tracked prey.

Given the strength of priming and its neglect in theoretical accounts of visual search, a study of its role is undertaken here. Our goals were three-fold: first, to assess the degree to which performance in visual search can be influenced by and accounted for by priming; second, to assess the nature of priming itself; and third, to investigate what role priming should play in theoretical accounts of visual search.

1.1. What is priming?

It is useful before proceeding further to delineate what we mean by the term priming. We think of priming as constituting an altered representational state for a feature that results in more efficient processing of this feature than otherwise. Thus, in visual search experiments a primed feature associated with a target will be found faster than others. Similarly, it is conceivable that primed distractors can be more easily rejected on subsequent occasions as the research on "negative" priming (see Tipper, 1985, 1992) suggests. The priming pattern should then be observable from differences in reaction times to repeated vs. unrepeated features. Furthermore, priming effects can last for some time,

but the largest priming effects seen in visual search experiments are relatively short lived, extending over thirty seconds or less (Maljkovic & Nakayama, 1994).

Priming as we have defined it differs significantly from putative top-down processing. First, it does not require conscious effort or explicit knowledge. Second, it is impervious to prior knowledge or expectation (Maljkovic & Nakayama, 1994). Priming is also distinct from perceptual learning. This latter phenomenon is retinotopic, or confined to particular locations (see e.g. Dosher & Lu, 1999; Goldstone, 1998; Karni & Sagi, 1993), whereas priming operates in object-based rather than retinotopic coordinates (Maljkovic & Nakayama, 1996; see also Kristjánsson, Mackeben, & Nakayama, 2001; Kristjánsson & Nakayama, 2002). Interestingly, Sireteanu and Rettenbach (2000) showed that learning in visual search tasks affects structures at relatively high levels of the processing stream, since the learning they observed generalized between visual fields, over different locations and between the two eyes of their subjects. Their effects, however, were observed over months of training, so the relevance to the present studies is at present unknown, since our following study addresses between-trial priming in a visual search task.

1.2. The experiment

To investigate the role of priming in visual search, we compared performance in several variants of a conjunctive visual search task. In conjunctive search, there is no single feature property that defines the target. The identity of the target is determined by the conjunction of two features (Treisman & Gelade, 1980). In our baseline condition, which we call conjunctive search, the target and distractor identities were stated to the observer and were consistent over a whole trial block. The features we used are horizontal vs. vertical and red vs. green. Thus, a target could, for example, be a red vertical bar among horizontal red and vertical green distractor bars. Three variants of conjunctive search were also used, designed to reveal the presence and characteristics of possible priming effects. (1) In the "switch" condition the potential target always changed orientation from one trial to the next. (2) In the "streak" condition the potential target retained its orientation for longer stretches of adjacent trials. (3) In the "random" condition, the potential target orientation changed randomly from one trial to the next.

The target was always a red horizontal or vertical bar. As in all conjunction tasks, the orientation of the target defined the distractors. Thus, when the target was horizontal, the red distractors were vertical, and the green distractors were horizontal. When the target was vertical, the distractors were red horizontal and green vertical bars. Fig. 1 presents a typical search array and Fig. 2 shows a representative sequence of the target identity on ten consecutive trials under the conjunction, switch and streak conditions.

1.3. Theoretical predictions

Our operative assumption is that priming plays a significant and perhaps decisive role in conjunctive visual search. We can thus make a number of predictions as to the relative efficiency of visual search in the various conditions outlined. In the baseline conjunction condition the target remains the same on every trial. As such, it will most fully benefit from priming and consequently should yield the fastest search times overall. In contrast, perfor- mance should be worst under the "switch" condition since the same target *never* repeats
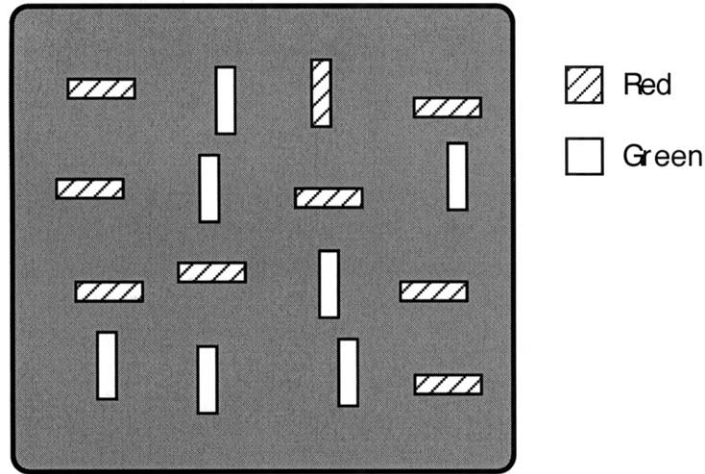
Fig. 1. A representative search display from the experiment (set size = 16). The target is present in the figure (the red vertical bar).

and there is little opportunity for priming to develop. Priming benefits are likely to be larger in the streak than switch condition, and overall search performance should then be better under the streak than the switch condition but not as good as under the conjunction condition since priming there should be maximal, because the target is *always* the same.

In the streak condition, the orientation of the target repeats for long stretches of continuous trials ("streaks"). Performance should then be better in the later part of a streak, compared to the beginning of a streak, since in the later part, the target has been the same for a number of the preceding trials. In other words, priming should build up over a streak with consequent reductions in reaction times for later positions in a streak. The target was only present on half of the trials. We made no a priori assumptions that priming occurs only for the target. It is certainly possible that priming could also take place for the orientation of the distractors, thus leading to their faster rejection as non-targets. In fact, Maljkovic and Nakayama (1994, Experiment 8) showed that their priming effects on response times were both due to target facilitation *and* distractor inhibition.

2. Methods

2.1. Observers

Ten naive observers recruited from the graduate student populations at Ohio State University and Harvard University participated in the experiment. All observers were unaware of the purpose of the experiment.

2.2. Stimuli

Stimuli were presented on a 75 Hz cathode ray tube (CRT) screen controlled by a G3

Macintosh computer. Stimuli were presented within an invisible 4 by 4 matrix on the screen subtending 13.2° by 13.2° (at a viewing distance of 57 cm), and each stimulus item was confined to a 2.2° by 2.2° square that was centered on one of nine random positions within the square which resulted in a slight irregularity in the appearance of the array. The size of the bars we used as stimuli was 1.4° by 0.35°, the same whether they were

	Condition		
Trial no.	Conjunction	Switch	Streak
n			
n+1			
n+2			
n+3			
n+4			
n+5			
n+6			
n+7			
n+8			
n+9			

Fig. 2. The identity of the target under three of the four different conditions of the experiment. Under the random condition (not shown in the figure) the target identity was determined randomly from trial to trial. The target was red on all trials in all conditions while its orientation could be vertical or horizontal in all conditions except for the conjunction search where the target was vertical on all trials. The target identity on any given trial determined the distractors, so if the target was vertical the distractors were red horizontal and green vertical, while if it was horizontal the distractors were red vertical and green horizontal. On target absent trials the distractors were red horizontal and green vertical in the conjunction search, while they could be either red horizontal and green vertical or red vertical and green horizontal in the other three conditions.

horizontal or vertical. The bars were either red (12.7 cd/m^2) or green (11.8 cd/m^2). The display items appeared on a black (0.5 cd/m^2) background.

2.3. Procedure

The four conditions (see Fig. 2) were the conjunction condition where the potential target was always red and vertical, the switch condition where the red target always changed its orientation between horizontal and vertical from one trial to the next, the streak condition where the red target could be vertical or horizontal but retained the same orientation for longer 'streaks' within each block of trials, and the 'random' condition, where the target's identity changed randomly from one trial to the next. The "streaks" of the streak condition were generated as follows: the probability that the target on the previous trial would be repeated on any one trial was equal to $1 - N(0.1 - (0.01N))$ where N is the present number of repeats of the orientation of the potential target. Thus, if the target was vertical on trial $n - 1$ and horizontal on trial $n - 2$ the probability of a vertical target on trial $n + 1$ was 0.91 and on trial $n + 2$ it was 0.84 and so on. The probability function was set to asymptote at the probability 0.75 so that when N was 5 the probability was 0.75 and remained so until $N = 8$ where the probability was set to 0, since the maximum length of a streak was 8. Thus, the streak length was never fixed, but a similar target to the previous one was most likely to be presented on each trial. It is important to note that the target was only present on 50% of the trials. So even though we define each trial with respect to the target in each case, the target was actually only present on half the trials.

Observers responded by pressing the appropriate key whether the target was present or absent in a search array of 4, 8, 12 or 16 display items (the set sizes were picked randomly from trial to trial). Observers were instructed to respond as quickly as possible while maintaining a high degree of accuracy. The display remained visible until the response. For the conjunction condition observers were told that the target was the red vertical bar, while for the random, streak and switch conditions observers were told to search for the oddly oriented red item. Observers were not informed of any differences between the streak, switch and random conditions. Observers performed 300 trials of the conjunction, switch and random conditions. They performed 800 trials under the streak condition, which was necessary since our intention was to study performance "within a streak" resulting in a need for a greater number of trials than for the other conditions for reliable results. Blocks of 100 trials each were run in counterbalanced order. Auditory feedback was given depending on whether the response was correct or incorrect. Data associated with mistakes were not used for the analyses of response times.

3. Results

3.1. Overall search performance

Fig. 3 plots reaction time vs. set size for the four conditions, separately for the present and absent trials. In accord with our predictions, overall search times were fastest in the conjunction search where the potential target is always the same. Search times were slower
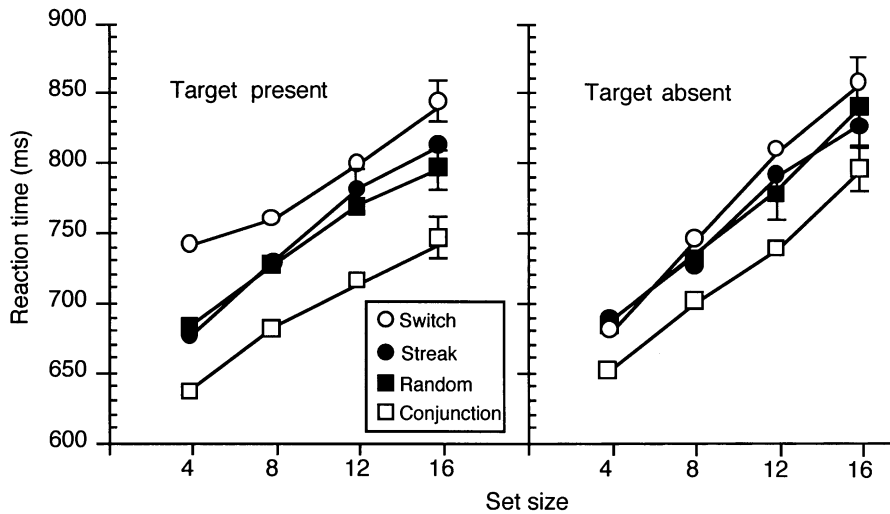
Fig. 3. Overall search rates for the four different conditions of the experiment. The error bars show the largest standard errors for each condition.

and similar under the streak and random conditions and they were slowest under the switch condition where the potential target always switches orientation from one trial to the next. A repeated measures ANOVA revealed significant main effects of condition ($F_{(3,27)} = 98.2$, $P < 0.0005$)[1] and set size ($F_{(3,27)} = 170.7$, $P < 0.0005$). The interaction between condition and set size was not reliably different from zero ($F_{(9,81)} = 1.67$, $P > 0.11$), which indicates that the effects of condition were not on the slopes of search times vs. set size (the search rates in each case) but on the overall mean reaction times. Post-hoc comparisons (see Girden, 1992) revealed statistically significant differences between all conditions (all $F_{(1,9)} = 58$ or higher, all P values <0.001)[2] except the comparison between the streak and random conditions ($F_{(1,9)} = 1.71$, $P > 0.22$). Search times for vertical vs. horizontal targets were indistinguishable (772.8 and 775.2 ms, respectively) and cannot account for the fastest search times in the 'conjunction' condition (where the target was always vertical). Note that regression statistics and error rates can be found in Table 1.

4. Further analysis and discussion

The observed search times are consistent with our predictions assuming priming effects, suggesting that the repetition of the same target and distractors from one trial to the next has a large effect on search times. Search is fastest where the target identity is always the same (in the conjunction condition) and slowest when the target is never the same from

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[1] All P values are corrected for variations from sphericity (see Girden, 1992).

[2] The P values are Bonferroni corrected for multiple comparisons.

Table 1
Regression statistics and error rates for four different conditions of the experiment

Condition		Intercept (ms)	Slope (ms/item)	Error rates (%)
Conjunction	Target present	607.2	8.7	3.2
	Target absent	604.0	11.8	4.9
Random	Target present	650.4	9.5	5.3
	Target absent	658.2	10.9	6.1
Streak	Target present	635.5	11.5	5.9
	Target absent	640.8	12.1	6.4
Switch	Target present	701.0	8.4	7.2
	Target absent	621.6	15.1	7.9

one trial to the next (the switch condition). Can priming due to the consistency of the target and distractors explain this difference? (Recall that if the target stays the same from one trial to the next, so do the distractors.) The streak condition was specifically designed to answer this question.

4.1. Search times within a streak

In the streak condition the potential target, and the distractors, were the same for long stretches of adjacent trials. If priming has an effect on response times in this paradigm, we expect to see response times decrease as the number of repetitions increases. The data in Fig. 4 confirm this prediction, presenting response times as a function of the position of a trial within a streak. The negative slopes between number in streak and response times indicate that the benefit of repeating the target and distractors speeds the search by about 9–15 ms for each repetition.

The priming we observe is similar both for present and absent trials. The differences between the slopes of position in streak and reaction times for present vs. absent responses were not significant ($t_3 = 0.64$, $P > 0.25$). This indicates that target orientation is not the only thing that is primed from trial to trial; the orientation of the distractors also primes from one trial to the next.

4.2. Analysis of adjacent 'present', and adjacent 'absent' trials

Although the comparison between target absent and target present trials (as depicted in Fig. 4) is informative, there are some ambiguities. In both the target present and target absent case, preceding trials can be of either variety. For example, a target absent trial can be preceded by a target present or absent trial. Thus, one cannot assess the relative contribution of repeated targets and repeated distractors. What is needed is a more clear cut method to assess the priming of each alone. Because the distractors always repeat along with the target, our best strategy is to focus on the "target absent" repeats by themselves. If the distractors mediate much of the priming effects seen here, then we should expect that a trial-by-trial assessment of priming of target absent trials should be similar to that seen for the target present trials.

Our approach was to cull from the whole data set, for all observers and for all set sizes, all pairs of trials where a present trial followed a present trial, and an absent trial followed
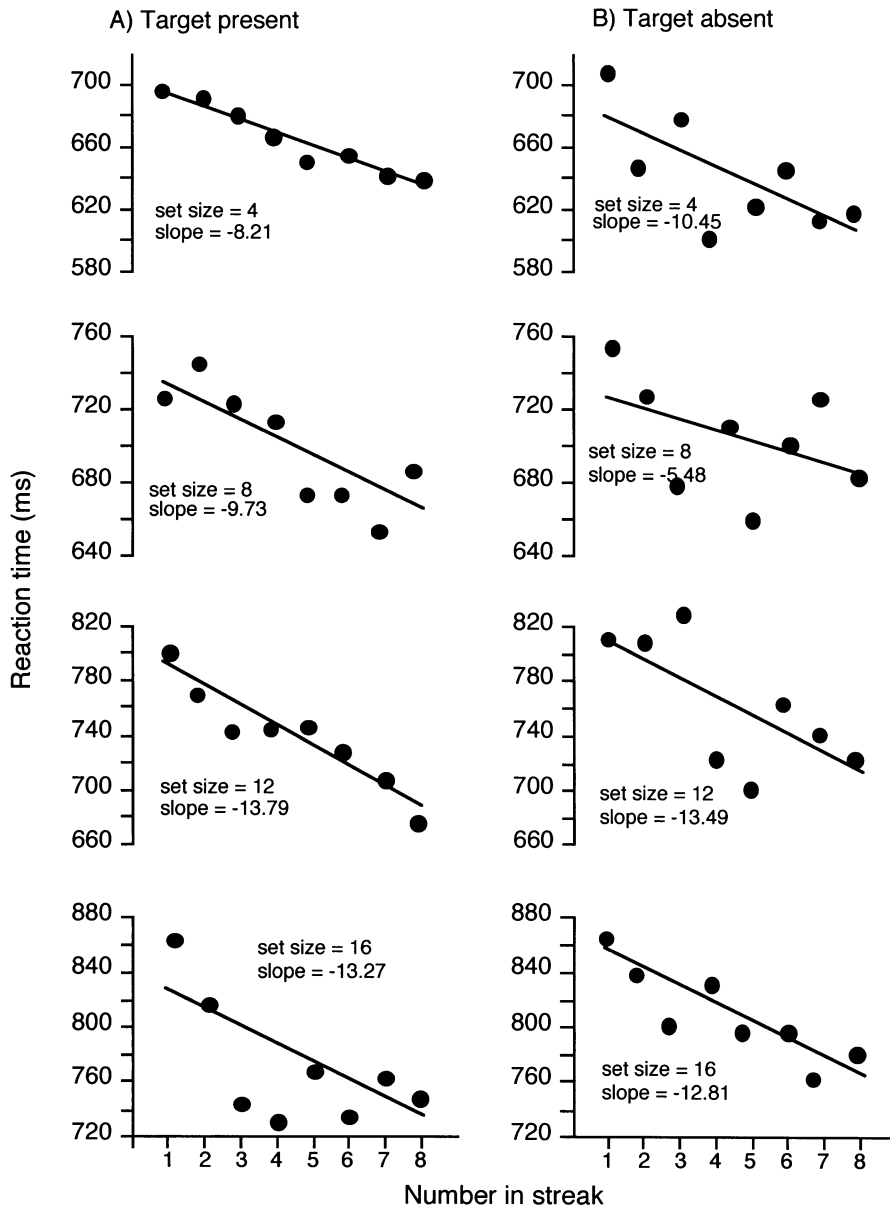
Fig. 4. Search performance in the streak condition as a function of where in a streak a particular trial was; drawn separately for each set size and whether the target was present or absent. For example, if number in streak is 6, it means that on the five previous trials the target to be found was the same as the present one. Streak length is independent of whether the target actually was present or not (recall that the identity of the target on any given trial defines what the distractors will be on that trial). The slopes indicate how much search times decreased with each repetition of the same search. The superimposed lines are the best linear fits to the data (all R^2 ranging from 0.62 to 0.92).

another absent trial. This has the advantage that the correct responses within the pair are always the same and thus are not subject to artifacts due to response competition (see Luce, 1986). The results of this analysis are detailed in Fig. 5, comparing each condition in relation to the grand mean of all reaction times. For example, in the target present case (Fig. 5A), we show that if the distractor repeats from trial to trial, there will be a benefit of 7.91 and 9.63 ms for horizontal and vertical red distractors, respectively. Conversely, if the distractors do not repeat, there should be an increase in reaction time of 10.92 and 12.43 ms. Most interesting is the fact that this exact pattern is also seen in the target absent case. Furthermore, the overall effect of repeated vs. non-repeating distractors in the target present and target absent case is statistically identical ($F_{(1,9)} = 1.13$, $P > 0.25$).

At a more mechanistic level we might conclude that repeated trials having the same oriented red bar will facilitate subsequent trials. This would suggest something similar to the priming seen in Maljkovic and Nakayama (1994, 1996), that repeated presentations of the same target render that target more salient and thus reduce reaction times. Yet, this cannot be the full explanation. First, we need to consider the target absent case. If priming was solely tied to target repetition, no decrease in reaction time should be evident for the absent trials since there is no target to be primed. Yet, the data presented in Fig. 4 show that there is an equally large drop in reaction time for target absent trials as the streak position increases. As such, we can reject the view that "what is primed" is simply that of the target. Perhaps "what is primed" must also lie with the distractors as this is common in both the target present and absent cases.

This seems indeed to be the most parsimonious account for the results since there
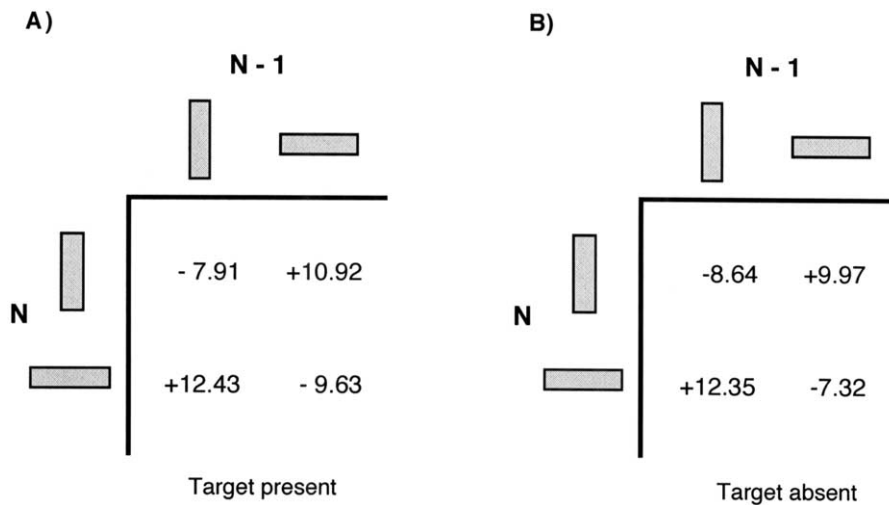
Fig. 5. The effects of the preceding trial ($N - 1$) on the following one (N), depending on whether the target on the previous trial was horizontal or vertical. As an example, the number in the top left cell in (A) shows that search for a vertical target was 7.91 ms faster than the overall mean, when the target on the preceding trial was also vertical. (A) Results of this analysis for the target present trials. (B) Similar results for the target absent trials. Note that the data represent only trials that were preceded for (A) by a trial where on the previous trial the target was present, and for (B) by a trial where on the previous trial the target was absent.

appears to be no more priming on the target trials than the absent ones, and the distractors are present on all trials, but the target is only present on half the trials. It is, however, also possible that there is considerable priming from the target that nulls the priming effects of the distractors. Given the considerable evidence for priming for task-relevant stimuli in the absence of any distracting stimuli (e.g. Biederman & Cooper, 1991) this must be considered a possibility. This would, nevertheless, only account for the priming on the target present trials. Further research is needed to resolve the issue. Nevertheless, the fact that absent trials result in a considerable priming effect upon the following trial is perhaps surprising given the emphasis laid on target processing in visual search theories (Treisman & Gelade, 1980; Wolfe, Cave, & Franzel, 1989).

The above finer grain analysis of the streak condition provides direct evidence for priming in visual search tasks. Furthermore, since the streaks are the longest in the conjunction case and don't exist in the switch condition, the decrease in reaction time for positions in the streak nicely explains why performance is fastest in the conjunction and slowest in the switch condition. The streak condition results also fit with the finding that the reaction times for the streak and random case lie intermediate between these two extremes.

One possibility that should be mentioned is that observers may have adopted a more liberal quitting strategy for 'absent' responses as their 'present' responses became faster, as the streak length increased thus accounting for the speeded absent trials within a streak. While this is possible it would seem to also require that the error rates on absent trials would increase since if observers adopt a more liberal quitting rule, error rates should go up (cf. Gescheider, 1997). This was not the case, however (the slope of error rates vs. streak length was not significantly different from zero).

These results indicate that there is as much priming between pairs of target absent trials as there is between pairs of present trials. This is indeed consistent with the view that a large part of the priming is bound to the distractors.

4.3. Conjunction search in the context of priming

Theories of efficient visual search (Duncan & Humphreys, 1989; Treisman & Gormican, 1988; Wolfe, 1994) postulate a top-down process, which aids in the selection of a target in conjunctive search. Our results, on the other hand, suggest that an explanation for relatively efficient conjunction search does not require the concept of top-down processing. Our hypothesis is that priming alone can account for the advantages seen for conjunctive visual search. We provide arguments and further analysis to support this view below.

Recall that we started with the hypothesis that search times in the "conjunction" condition should be faster than all other conditions. This is evident from our main results (shown in Fig. 3). In arguing against the necessity of top-down processing we hypothesize that conjunctive search is simply one end of a continuum of priming where priming is at its maximum asymptotic value. To test this idea, we compare conjunctive search, where the target is the same on all trials, with the streak condition, where target identity can change over a block. Rather than contrast the overall performance of the streak vs. conjunctive conditions, however, we test our hypothesis by selecting trials where there should be little
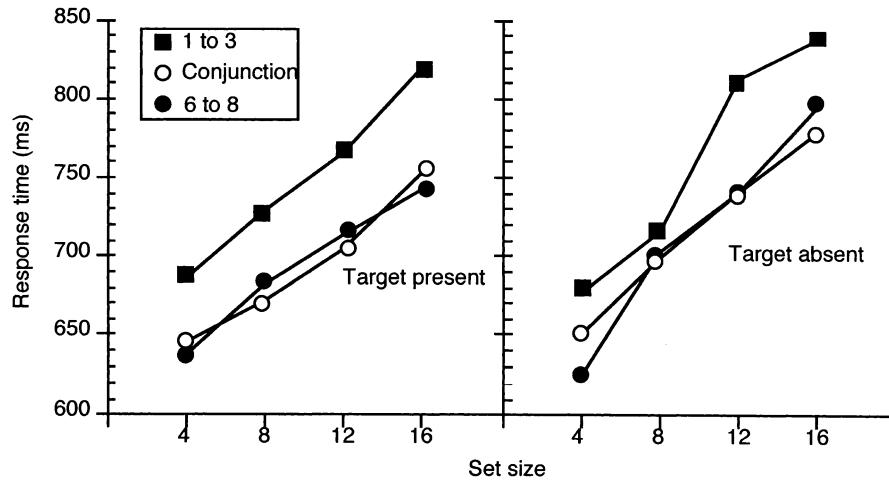
Fig. 6. A comparison of the results from the conjunction search (open circles) and two phases from the streak condition: a weighted average of the first three trials (squares), and the last three trials (filled circles) within a streak.

or no priming benefits (trials 1–3 in the streak) vs. trials where priming should be very high (trials 6–8 within a streak).

The role of priming in conjunction search can be demonstrated by plotting the reaction time vs. set size relation for low and high primed states (see Fig. 6). The filled squares in Fig. 6 represent average reaction times for trials 1–3 within a streak while the filled circles show reaction times for trials 6–8. The data from the conjunction task (open circles) are presented for comparison. Note that for the high priming condition (trials 6–8) there is an approximately 100 ms advantage in comparison to the earlier trials (1–3). Most significant is the fact that for trials 6–8 in a streak, the data are indistinguishable from the conjunction condition.

This result suggests two important conclusions. First, priming alone is sufficient to achieve a level of performance attained in the conjunction case where certain knowledge of target and distractor identity is available. Second, priming can build up rapidly, such that by six to eight repetitions, it is equivalent to the conjunction case. Thus, there do not seem to be any differences in search performance when the identity of the target is known completely (the red vertical item in the conjunction condition), and when only its color is known (the oddly oriented red item) when priming effects are controlled for. In other words, there is no benefit to top-down guidance that cannot be accounted for by priming.

4.4. Slopes vs. intercepts

While our results show that search becomes increasingly difficult with each added item to the set size under all conditions, the priming effects do not seem to change the effect of each added item to the display. The regression statistics in Table 1 show that the slopes of set size vs. reaction times are comparable between the three conditions, whereas the intercept differences are considerable. This is also evident in the comparison between early and

later trials in a streak (Fig. 6). This means that search rates are constant under all conditions. The priming benefits are independent of the set size on a particular trial. Consistent with this, Wolfe, Butcher, Lee, and Hyle (2001) found large intercept decreases for top-down guidance in simple feature search (where search times are independent of set size).

The lack of any change in search rate is unexpected in the context of an expected increase in target identifiability. For example, theories of visual search (e.g. Duncan & Humphreys, 1989; Grossberg et al., 1994; Treisman & Gormican, 1988; Wolfe, 1994) invoke top-down guidance to account for differences in slopes of set size vs. search time, i.e. the search *rates* in each case. Our results indicate, nevertheless, that the effect of top-down guidance is constant; it affects overall search times but not the search rates. This is a clear conclusion, since the only difference between the different conditions was the amount of top-down guidance available to observers.

5. General discussion

Our results in this paper show that visual search is more efficient on trials where the relevant features are the same as those searched for in the immediate past. Theories of attentive visual search should include a role for such priming effects, but in general they do not (Duncan & Humphreys, 1989; Grossberg et al., 1994; Palmer, 1995; Treisman & Gormican, 1988; Wolfe, 1994). Conclusions have even been reached about the workings of the visual system based on differences between performance on tasks where the same search is repeated over and over again and tasks where the target and/or distractors change their identity between trials, without taking care to control for the effects of target repetition. In this paper we show that when priming effects are taken into account, there are little differences between search when the target's identity is known exactly (conjunction condition) and when only its color is known (the streak condition, when priming benefits are maximal). This suggests a counterintuitive conclusion: knowing what the target is on a given trial does not seem to facilitate search. It does appear reasonable that search should be faster for a known target rather than for an unknown one. Nevertheless, our results suggest that there are little or no benefits to top-down guidance over and above the effects of priming, at least in tasks like the one used in this experiment.

5.1. Theoretical implications

The results of the experiment have a number of implications for research and theory on visual search. Not only do they indicate that priming should play a larger role in theories of visual search but they also suggest what that role might be. Since the differences in performance between the condition where the target identity is known completely and where only its color is known can be accounted for by the differences in priming, postulated benefits of top-down guidance in conjunction search may simply reflect the benefits of priming. Thus, our results imply that a rethinking of the role of top-down guidance in visual search may be required with a major role for priming (see also Wolfe, 1998). Top-down activation may thus be better thought of as an elevated activation state for a given feature, determined by the display items on the preceding few trials. However, we do not

want to exclude the possibility that explicit top-down effects are at work in visual search along with the priming effects we have observed.

The present results should also be taken into account when differences between "subset" search, where only one of the features of the target is known (e.g. search for the *oddly oriented* red item), and conjunction search are discussed (Egeth, Virzi, & Garbart, 1984; Friedman-Hill & Wolfe, 1995; Kaptein, Theeuwes, & van der Heijden, 1995). Those differences might be accounted for by different amounts of priming due to differences in target consistency between trials.

The priming we observed was substantial both on target present and target absent trials, suggesting that priming is based on the whole search array, not only the target in each case. Thus, the global search context seems to have a large influence on response times, consistent with previous reports of global effects on search times (Bravo & Nakayama, 1992; Chun & Jiang, 1998; Enns & Rensink, 1990; Ramachandran, 1988; Wang, Cavanagh, & Green, 1994) and priming to global aspects of search arrays (Karni & Sagi, 1993). This raises the question of what is primed from trial to trial. The simple explanation of the priming of the target is clearly inadequate since it would not predict any priming benefits for the target absent trials. It seems that the priming is more global and distributed over the search array. The findings show some similarities to other reports where background groupings have been learned or primed. Karni and Sagi (1993) examined performance on a perceptual learning task where a small textured pattern of oblique lines was to be discriminated against a background of either horizontal or vertical lines. Their observers showed great improvements in performance with practice, and further experiments revealed that what was learned was the background array of oriented lines, so that when the orientation of the background lines was changed, performance deteriorated. McCarley and He (2001) found that separate elements in a stereoscopic depth plane could be temporarily primed, that repeated implicit surfaces that had the same depth relationship to other elements led to greater perceptual fluency. Taken together, these studies demonstrate both a long- and short-term alteration in perceptual grouping. Applying this to the present results, we suggest that the presentation of the same orientation distractors over a series of trials can lead to more rapid perceptual grouping. This in turn leads to more rapid target detection against this background as well as to faster decisions that the target is absent by a quicker perception of background homogeneity (see also Wang, Kristjánsson, & Nakayama, 2001).

5.2. Conclusions

The results of the experiments reported here reveal that priming has a major influence on response times in conjunction search. A large component of response times in conjunction search, commonly attributed to top-down influences, may instead reflect between-trial priming of the target and distractors. The results also suggest that priming is not only bound to a particular target but is based on the whole search array in each case.

Acknowledgements

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