The Effect of Element Colour on Reaction Time in Visual Search Tasks

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Abstract

The magnocellular (M) pathway has been shown to be important in focusing attention in serial visual searches, with longer (red) light wavelengths being shown to inhibit M-pathway functioning. Given this inhibition of the M-pathway, this experiment investigated the effect of element colour in visual search. It was hypothesised that reaction times for red/orange stimuli would be significantly longer than for green/blue stimuli. Thirty-nine participants undertook a visual search task, combining two colour conditions (red/orange, green/blue), two search types (similar: O,Q, dissimilar: O,X) and three distracter set sizes (3, 6, 9). The results of the experiment generally supported the hypothesis, with reaction times for red/orange elements significantly greater than for green/blue elements. These results provide evidence that longer wavelength input does have an inhibitory effect in visual search, and provides some evidence of M-pathway involvement in the focussing in the visual search process.

Introduction

Feature Integration Theory (FIT; Treisman & Gelade, 1980) is a theory of the serial and parallel operations that occur in visual search. FIT proposes that feature searches, where targets differ from non-targets on one perceptual dimension (e.g., horizontal line amongst vertical lines), are resolved through pre-attentive processes working in parallel. Such searches are unaffected by the number of elements. Conjunction searches, where targets differ from non-targets on more than one dimension (e.g., red square among red triangles and green squares), are proposed to involve serial search, due to a requirement for focal attention. Such searches are therefore sensitive to element numbers: the more elements the more time to resolve the search.

Steinman, Steinman, and Lehmkuhle (1997) found the magnocellular (M) pathway was important in focusing attention in serial searches, with attention captured by cues preferentially exciting M-pathways. Further evidence of the role of the M-pathway in serial visual search comes from studies of dyslexics, who are believed to have disordered M-pathway functioning. Lovegrove, Martin and Slaghuis (1986) found that dyslexic children's temporal contrast sensitivity was significantly lower than normal readers at low spatial frequencies, where M-pathways are believed to operate. Vidyasagar and Pammer (1999) found dyslexics were significantly slower than normal controls in serial type conjunction searches. Given dyslexics possible M-pathway deficit, this provides further evidence for the role of the M-pathway in visual searches.

Despite the M-pathways' achromaticity, certain light wavelengths, specifically the longer (red) wavelengths, appear to have inhibitory effects on the pathway. In a series of experiments, Chase, Ashourzadeh, Kelly, Monfette, and Kinsey (2003) reported that red light can impair functioning on tasks that are M-pathway dominant, such as text perception. Reid and Shapley (1992) investigated cone inputs to lateral geniculate nuclei receptive fields in macaque monkeys, a species whose colour vision is similar to humans. They reported that a considerable proportion of centre-surround M neurons have inhibitory surround input from L-type cones, which are maximally sensitive to red wavelengths.

Given that red wavelength input may inhibit M-pathway functioning in serial searches, this experiment investigated the effect of element colour in visual search. Based on the research by Triesman and Gelade (1980), it was hypothesized that increased distracter set size would increase reaction time in serial searches. It was also hypothesised that reaction times for red/orange elements in serial (conjunction) searches would be significantly greater than reaction times to green/blue elements. An interaction between colour and search type was also hypothesised, in that the use of red/orange elements would increase reaction time compared to blue/green elements, but only in serial (conjunction) searches.

Method

Participants

Thirty-nine participants, both male and female, of varying age, with normal or corrected-to-normal vision completed the experiment. Participants were students of the University of Tasmania, and friends, relatives, and classmates of the experimenters.

Materials

Stimuli were presented at a distance of 0.6m, in the centre of a 20-inch Sony visual display unit interfaced with a PC. The letter square size was 15 pixels, and the size of space was five pixels. Targets were present in half the trials and absent in half. There were four stimulus conditions. In the dissimilar condition, the target was a red letter O among orange Os and red Xs (red/orange condition), or a green letter O among blue Os and green Xs (green/blue condition). In the similar condition, the stimuli setup was the same, except that Qs were used instead of Xs. The distracter set size was three, nine or 15. In all cases the display background was black. Displays remained visible until the participant responded.

Procedure

Participants completed the experiment in a darkened room in the School of Psychology. Participants were instructed to rest their chin on a chin rest and look at a fixation point in the middle of the screen. When a stimulus appeared participants pressed a button with their left hand when the target was present or with their right hand if it was absent. Participants completed a 20-trial practice task, looking for a triangle amongst circles and then proceeded to the experimental tasks. Participants completed 144 trials at each of the four experimental conditions, with the presentation order of each condition counterbalanced. Reaction times were measured from stimulus onset.

Design and Data Analysis

The design was a 2 (Colour: red/orange, blue/green) x 2 (Similarity: similar, dissimilar) x 3 (Distracter Set Size: 3, 9, 15) within-subjects design. The dependent variable was mean reaction time to correct target present responses. Data was analysed using SPSS. Means were analysed using Repeated Measures Analysis of Variance (ANOVA), with Greenhouse-Geisser adjustments. Significant main effects and interactions were further analysed with breakdown ANOVAs and Bonferroni adjusted pairwise comparisons. Results were considered significant where $p < .05$.

Results

Means were computed for all conditions and are shown in Figure 1. As can be seen in Figure 1, mean reaction times for all red/orange stimuli, were longer than for green/blue stimuli, and reactions times increased with increasing distracter set size.

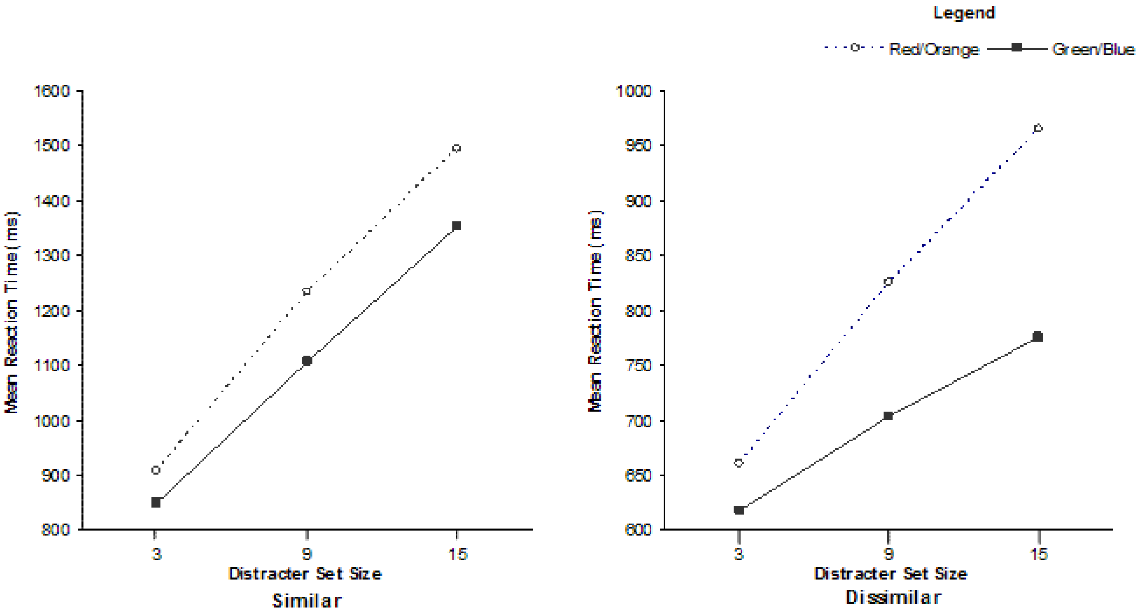

Figure 1. *Mean reaction time for both stimulus colours at each distracter set size for both the similar and dissimilar conditions.*

The three-way ANOVA conducted on the data showed a significant main effect for colour, $F(1, 38) = 56.81$, $p < .001$, with targets identified significantly faster in the green/blue (mean = 901.5ms) than the red/orange (mean = 1014.82ms) condition. The main effects of similarity, $F(1, 38) = 526.95$, $p < .001$, and of distracter set size, $F(1.63, 61.89) = 566.08$, $p < .001$ were also significant.

Targets were identified significantly faster in the dissimilar condition (O,X; mean = 758.41 ms) than the similar condition (O,Q; mean = 1157.91ms) and Bonferroni adjusted pairwise comparisons revealed significant differences between times for all distracter set sizes ($ps < .001$), with reaction time increasing with increased distracter set size.

These main effects were qualified by a significant colour by distracter set size interaction, $F(1.57, 59.68) = 23.22$, $p < .001$ (see Figure 2) and a significant similarity by distracter set size interaction, $F(1.93, 73.25) = 124.05$, $p < .001$ (see Figure 3) following Greenhouse-Geisser adjustment.

As can be seen in Figure 2 and confirmed by breakdown ANOVAs blue targets were identified significantly faster than red targets at all distracter set sizes: 3, $F(1, 38) = 14.44$, $p < .01$; 9, $F(1, 38) = 58.97$, $p < .001$; and 15, $F(1,38) = 50.75$, $p < .001$, although the RT difference increased with increasing distracter set size. Breakdown ANOVAs with Greenhouse-Geisser adjustments showed significant effects of distracter set size for both colours: Red/Orange, $F(1.69, 64.22) = 391.44$, $p < .001$; and Green/Blue, $F(1.65, 62.76) = 340.83$, $p < .001$. Bonferroni adjusted pairwise comparisons showed RT increased significantly with increased distracter set size ($ps < .001$) for both colours, with these RT increases larger in the red/orange condition.

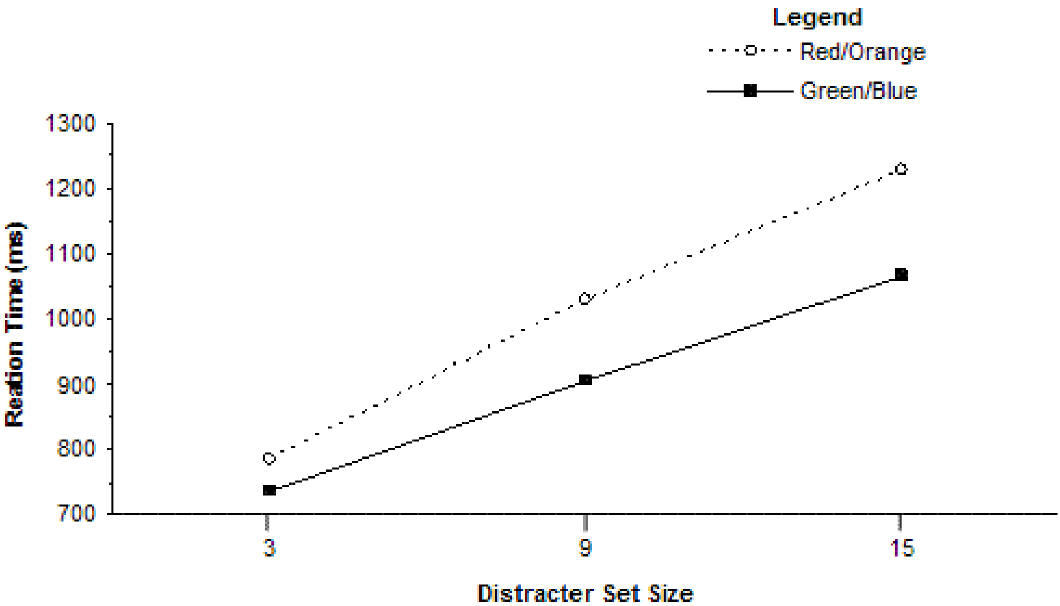

Figure 2. *Mean reaction time (ms) for both the red/orange and blue/green conditions at each distracter set size.*

As can be seen in Figure 3, and confirmed by breakdown ANOVAs, dissimilar targets were identified significantly faster than similar targets at all distracter set sizes: 3, $F(1, 38) = 313.77$, $p < .001$; 9, $F(1, 38) = 405.23$, $p < .001$; and 15, $F(1, 38) = 427.60$, $p < .001$, although the RT difference between both conditions increased with increased distracter set size.

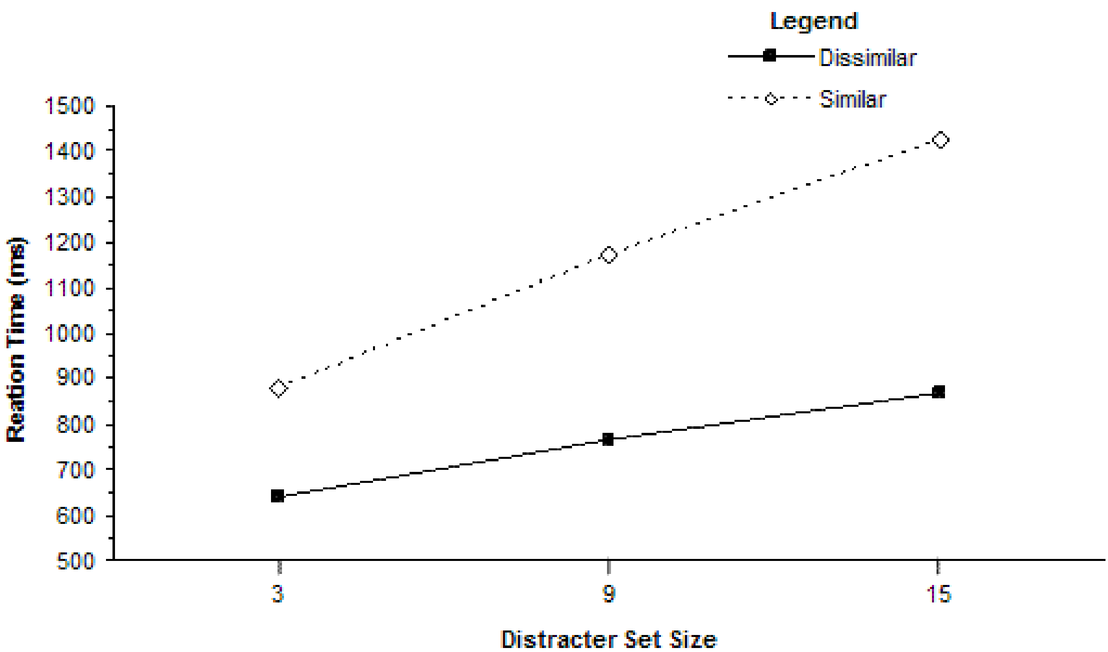

Figure 3. *Mean reaction time (ms) for both the similar and dissimilar conditions at each distracter set size.*

Breakdown ANOVAs with Greenhouse-Geisser adjustments showed significant effects of distracter set size at both levels of similarity: Dissimilar, $F(1.86, 70.72) = 200.96$, $p < .001$; and Similar, $F(1.73, 65.64) = 448.07$, $p < .001$. Bonferroni adjusted pairwise comparisons showed that for both similar and dissimilar targets, RT increased significantly with increased distracter set size ($ps < .001$). However these RT increases were larger in the similar condition.

Neither the colour by similarity interaction, $F(1, 38) = 0.15$, $p = 0.7$ nor the three-way interaction after Greenhouse-Geisser adjustment, $F(1.70, 64.48) = 2.11$, $p = 0.14$ were significant.

Discussion

The main focus of this study was on the effect of element colour in visual search, with evidence suggesting that red wavelength input may increase reaction time. It was hypothesised that reaction times for red/orange elements would be significantly greater than for green/blue elements. The significant colour effect and colour by distracter set size interaction provide support for this hypothesis. However, given that the M-pathway is important in focusing attention in serial searches (Steinman, Steinman, & Lehmkuhle, 1997), any inhibitory effect should only show in serial searches, and not in feature searches which FIT argues rely on parallel processing (Triesman & Gelade, 1980). Therefore if the dissimilar conditions were considered to be feature searches, then a significant colour by similarity interaction should have been found for the hypothesis to be fully supported. Such an interaction was not found. However the gradient of the slopes observed in the similarity by distracter set size interaction (see Figure 3) provide an explanation for the lack of a colour by similarity interaction.

Chelazzi (1999) reports that conjunction searches yield non-flat search slopes (i.e., with increased distracter set size, RT increases) and these results show that both the similar (O,Q) and the dissimilar (O,X) searches yielded significant non-flat search slopes (see Figure 3). On the surface this may appear unusual considering that similar search patterns have been used by Triesman and Gelade (1980) as feature (O,X) and conjunction (O,Q) searches. However the use of different colours means the dissimilar searches fit the criterion of a conjunction search; a target differing from non-targets on more than one dimension (Chelazzi, 1999). In this design the target and non-target differed in colour and form. Thus it could be argued that both searches were conjunction-type and hence there was no colour by similarity interaction because there was no feature-type search.

Why then, given both searches are conjunction-type, was the search-slope shown in Figure 3, steeper for the similar condition than the dissimilar condition? Chelazzi (1999) notes that different conjunction searches yield different slope functions, and here, the dissimilar search (O,X) is easier to resolve than the similar search (O,Q), because the O is quite different in form from the X, whereas the O and Q stimuli are quite similar. This increased similarity between the O and Q stimuli leads to the steeper search slope in this (similar) condition.
As a consequence, caution must be used in drawing conclusions about the attentional processing role of the M-pathway in focussed attention in visual searches. Future research could focus on the effect of colour on different types of feature and conjunction searches to ascertain the precise nature of colour inhibition. Comparisons between different stimuli types, such as shapes (e.g., triangles and squares), or line orientations would perhaps, more fully elucidate this attentional processing role.

However, the results clearly show that red input causes a significant impairment to visual search processes in conjunction type searches. The results clearly provide support for the hypothesis that longer (red) wavelength input significant inhibits M-pathway functioning. Such conclusions are supported by Reid and Shapley's (1992) previous neurobiological findings, and such findings clearly support previous research showing longer (red) light wavelengths impair functioning of the M-pathway in tasks requiring dominant use of this pathway.

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