

Red Affects Reaction Times and Hit Rates in a 2AFC Classification Task

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Abstract

We measured reaction times and hit rates in a 2AFC orientation discrimination task. Gabor patches at different spatial frequencies and two levels of contrast (0.15 and 0.6) were presented surrounded by red, blue, or grey isoluminant backgrounds. Results revealed lower accuracy and slower reaction times when the gabors were surrounded by red in comparison to blue or grey backgrounds. We interpret these results as evidence that i) exposure to long-wavelength light interferes with both magnocellular and parvocellular processing; but ii) long-wavelength light causes greater relative inhibition of magnocellular processing. These findings are relevant to the interpretation of studies that use red backgrounds to selectively isolate magnocellular contributions, and may have implications for the interpretation of studies of the effect of red contexts on diverse perceptual and cognitive tasks.

Keywords: reaction time; red backgrounds; magnocellular; parvocellular; Gabor patches

Introduction and Rationale

Several psychophysical studies have reported that red backgrounds affect perceptual and cognitive tasks in comparison to other colors or grey backgrounds. For instance, red backgrounds slow simple reaction times to large dots in comparison to small dots (Breitmeyer & Breier, 1994). Red backgrounds attenuate the effects of backward masking by structure (Bedwell, Brown, & Orem, 2008). Red backgrounds reduce the lower field advantage in detecting spot stimuli (Maehara, Okubo & Michimata, 2004). Red background reduce the global precedence effect in processing hierarchically organized stimuli (Michimata, Okubo, & Mugishima, 1999). Red backgrounds reduce vection effects from expanding flowfields (Seno, Sunaga, & Ito, 2010). These results are generally interpreted as suppressive effects of long-wavelength light on neurons in the magnocellular retino-geniculate-cortical pathway, which is most sensitive to low spatial frequencies and motion, and responds best to low contrasts (see Livingston & Hubel, 1984; 1988).

However, computational analysis of the effects of colored filters on cone activations and on color-opponent mechanisms (Skottun, 2004) indicates that long wavelengths may have a suppressive effect also on the parvocellular pathway, which is most sensitive to color and higher spatial frequencies and responds best to higher contrasts. Because the stimuli used in previous studies did not allow for precise control of spatial frequency, whether red backgrounds selectively interfere with magnocellular processing or generally suppress activity in both visual channels remains unclear. In two experiments, we measured

reaction times in a 2AFC orientation discrimination task. To precisely control spatial frequency, we used Gabor patches. Patches could be either horizontal or vertical, could be surrounded by red, blue, or grey isoluminant surrounds, and were set at either low (0.15) or high (0.6) contrast levels.

General Methods

Participants

Nine members of the Parma community volunteered for each of the two experiments. All had normal or corrected-to-normal eyesight. Most were unaware of the aim of the study although three of them (the authors) were not. The authors and two other participants were run in both experiments.

Stimuli, Apparatus, and Procedure

In both experiments, we used six Gabor patches (mean luminance = 136 cd/m²) with spatial frequencies equal to 0.25, 0.5, 1, 2, 4, and 8 cycles/deg, horizontal or vertical orientation, and 0.15 or 0.6 contrast. Stimuli were presented for 100ms on a carefully calibrated Elo-Entuitive LCD monitor (maximum luminance = 213 cd/m²) driven by a MacMini G4 computer running Psykinematix v1.4.2 (KyberVision Consulting 2006-2012). Theoretical isoluminance was checked, and appropriate modifications were performed, before running each participant using a Minolta luminance meter. For this reason, RGB values for the red, blue, and grey surrounds could vary slightly from participant to participant due to monitor variability over time. However, typical values were: 0, 0, 255 (blue), 75, 0, 0 (red), and 10, 11, 10 (grey). These resulted in background luminances at 11 cd/m² ± 0.5 cd/m². Participants saw one Gabor patch at a time and performed a two-alternative forced-choice (2AFC) classification of the Gabor orientation by pressing one button for horizontal and one for vertical on the computer keyboard. Surround color was blocked and the order of blocks was counterbalanced across participants. Each spatial frequency was presented 15 times at a given orientation within each block.

Analysis and Results

Before analysis, we excluded anticipatory reaction times (<200ms) and misses. This reduced the dataset by approximately 5%. Inspection of individual distributions showed positive skew. Therefore we applied a Box-Cox transformation ($\lambda = -1$) to normalize the data. This transformation is equivalent to converting times to speeds such that the averages of the transformed data are harmonic

means. Results from all participants were inspected individually before group analysis.

Both reaction times (RTs) and hit rates were analyzed by a 2 (low and high contrast) \times 3 (surround color) \times 6 (spatial frequency) repeated-measures ANOVA, with contrast as a between-participant variable and spatial frequency and surround color as within-participants variables.

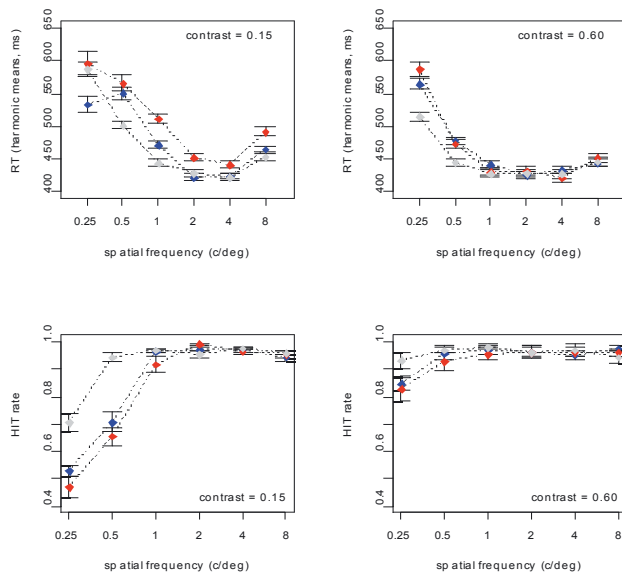


Figure 1: Average RT (upper graphs) and hit rate (lower graphs) in experiments 1 (on the left: low contrast, 15%) and experiment 2 (on the right: high contrast, 60%). Each data point represents the mean (\pm standard error) of all participants ($n = 9$) in each experiment. Colors correspond to surrounds.

Reaction Times (RTs): Surround color modulated reaction times, $F_{2,31} = 3.9$, $p < 0.05$, with overall slower RTs for red, compared to blue or grey surrounds. RTs were also modulated by spatial frequency, with higher times for gabors at low, compared to medium and high, spatial frequencies $F_{5,80} = 156$, $p < .0001$. This effect however was further modulated by contrast $F_{5,80} = 111$, $p < 0.0001$, and red surround color $F_{10,160} = 3.2$, $p < 0.05$. A significant 3 way interaction, $F_{10,160} = 4$, $p < 0.005$ suggested that the effect of red color on response times was most evident when gabors were presented at a low contrast (15%) and low spatial frequencies.

Hit rates: A main effect of surround color, $F_{2,32} = 30$, $p < 0.0001$, revealed lower accuracy for red, compared to grey ($p < 0.0001$), and blue ($p < 0.05$). In addition, the blue surround was associated with lower performance compared to grey ($p < 0.0001$). As expected, both spatial frequency and contrast modulated response accuracy, $F_{5,80} = 177$, $p < 0.0001$ and $F_{1,16} = 18$, $p < 0.005$, respectively. However, both factors significantly interacted with color surround spatial frequency, $F_{10,160} = 16.5$, $p < 0.0001$; contrast, $F_{2,32} = 10$, $p < 0.005$. Finally, a 3 way interaction, $F_{10,160} = 7$, $p <$

0.0001 indicated a pattern of response accuracy similar to what observed in reaction time findings.

Discussion and Conclusion

We observed an effect of red backgrounds on both reaction times and hit rates for a 2AFC orientation discrimination task. Participants were generally slower and less accurate with red in comparison to blue and grey backgrounds. However, this effect was most prominent with low-contrast Gabor patches and at lower spatial frequencies as supported by the pattern of two- and three-way interactions. This pattern of results can be interpreted as evidence that there is some interference by long-wavelength light even in conditions that favor parvocellular over magnocellular processing (high contrast stimuli or higher spatial frequencies, or both). However, the most evident effect of red appears to take place in the conditions that favor magnocellular processing (lower contrast stimuli or lower spatial frequencies, or both).

These findings are relevant to the interpretation of studies that use red backgrounds to selectively isolate magnocellular contributions, for instance, in schizophrenia (Bedwell, Brown, & Miller, 2003) or dyslexia (Edwards, Hogben, Clark, & Pratt, 1996).

In addition, our findings may have implications for the interpretation of studies of the effect of red contexts on diverse perceptual and cognitive tasks. For instance, recent studies have reported that red contextual colors elicit less positive retail outcomes in simulated purchasing experiments (Bellizzi & Hite, 1992); that red backgrounds elicit higher bids in online auctions and negotiations (Bagchi & Cheema, 2012); and that red reduces the consumption of food (Bruno, Martani, Corsini, & Oleari, 2013; Genshow, Reutner, & Wänke, 2012) or moisturizing cream (Bruno, Martani, Corsini, & Oleari, 2013) when these are presented on red plates. Although these findings are often interpreted as due to symbolic associations of red with danger and arousal, we speculate that they might in part depend on selective suppression of the processing of visual sensory information by long-wavelength light, possibly reducing the allocation of attention or other cognitive resources to stimuli surrounded by red.

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