Original Article

# Color Filling-In: A Comparison Between Opponent Channels

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## ABSTRACT

The study aimed to investigate the effect of target eccentricity on color filling-in latency. Achromatic, red-green and blue-yellow opponency systems were tested and target fading latency (TFL) results between dichromats and trichromats were compared. Trichromats presented a steeper center to periphery TFL decline in both achromatic and blue-yellow experiments compared to the red-green experiment. This was interpreted as being due to nonretinotopic cortical area influence on color filling-in. Dichromats presented no significant center to periphery TFL difference in the blue-yellow experiment. This result indicated that the dichromat single olor opponent system is more evenly distributed across the visual field than the trichromat system.


**Key words**: color filling-in; visual eccentricity; opponent channels; dichromats; trichromats.

## INTRODUCTION

When a small visual stimulus is presented to the periphery of the visual field it fades into the background during steady fixation. This phenomenon is known as Troxler's effect and is used to investigate perceptual filling-in. Ramachandran and Gregory (1991) created an experimental model in which a small peripheral target is presented on a display with a uniform background. After a few seconds of central fixation, the target disappears. The filling-in latency varies according to the visual parameters used to construct the image and is usually faster for smaller and more eccentric targets (De Weerd et al. 1998). Differences in visual processing of stimuli from different eccentricities of the human visual field are quite relevant to Neuroscience, as they can elucidate certain aspects of the functional organization of the visual brain.

In trichromats, a steep decline in red-green opponency occurs from the center to periphery, and a more gradual loss is observed for blue-yellow opponency (Mullen & Kingdom 2002), (Sakurai et al. 2003). In contrast, dichromats only present blue-yellow opponency, but to date, no color field maps are available for this group.

The purpose of this work was to compare color filling-in latency between dichromats and trichromats at two different visual field eccentricities. Achromatic, red-green and blue-yellow opponency systems were tested. The study investigated whether the differential distribution of cone opponency across the visual field influenced color filling-in latency.

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# METHODS

## Subjects:

Twelve trichromats were selected, four males and eight females, including the author M.C., presenting normal corrected near visual acuity, with a sample age range of 18 to 50 years-old. Nine dichromats were selected, all male, four protans and five deutans, presenting normal corrected near visual acuity, with a sample age range of 20 to 48 years-old. All the subjects gave their free informed consent. The Brasília University's Human Research Ethics Committee approved this protocol, which adheres to the tenets of the Helsinki Declaration. All subjects, except the author, were naive to the purpose of the experiment.

## Apparatus and stimuli:

The stimuli were generated by an IBM compatible personal computer, equipped with Matlab software and presented on a 17-inch color monitor (Samsung Sync Master 753 DFX).

The target was a circular patch 0.4° in diameter, presented at 4.5° and 10.5° eccentricities from a central fixation point, alternating between 90° and 270° field positions. A black cross in the center of the screen was used for fixation. Each position was tested 36 times. The latency for target disappearance was computed.

The red-green opponent system was tested with a red (CIE x=0.60, y=0.32) target and green (CIE x=0.26, y=0.45) surroundings. The blue-yellow system was tested with a yellow (CIE x=0.38, y=0.53) target and blue (CIE x=0.15, y=0.06) surroundings. All tests were performed with random target brightness variation.

## Procedure:

The subjects were maintained under scotopic conditions for 5 minutes prior to testing to produce uniform adaptation status at the onset of the experiment. They were positioned at 57 cm from the screen using a chin rest; the experiment was run in a dark room.

The subjects were asked to maintain voluntary steady fixation at the central cross and were instructed to press "enter" on the computer keyboard as soon as they realized the target had faded. They were allowed to blink normally. The time between stimulus onset and the subject's response was recorded as the target filling-in latency (TFL).

Each trial was preceded by a 2 second duration screen without the target, in order to eliminate afterimage of the previous stimulus. All experiments were performed binocularly.

# RESULTS

Data from both groups are expressed as the filling-in latency mean $\pm$SEM and were statistically analyzed by one-way ANOVA. The significance level was set at 1%; the null hypothesis was that no effect exists concerning target position in the TFL results.

Faster periphery TFLs were observed in all experiments. The difference between TFLs from the center to the periphery was significant ($p<0.01$) for: (i) both trichromats and dichromats in the achromatic and red-green experiments; (ii) trichromats in the blue-yellow experiment. No significant difference occurred in from center to periphery TFL for dichromats in the blue-yellow experiment ($p>0.01$) (Figure 1). Furthermore, trichromats presented a steeper center to periphery decline in both achromatic and blue-yellow experiments compared to the red-green experiment (Figure 1).

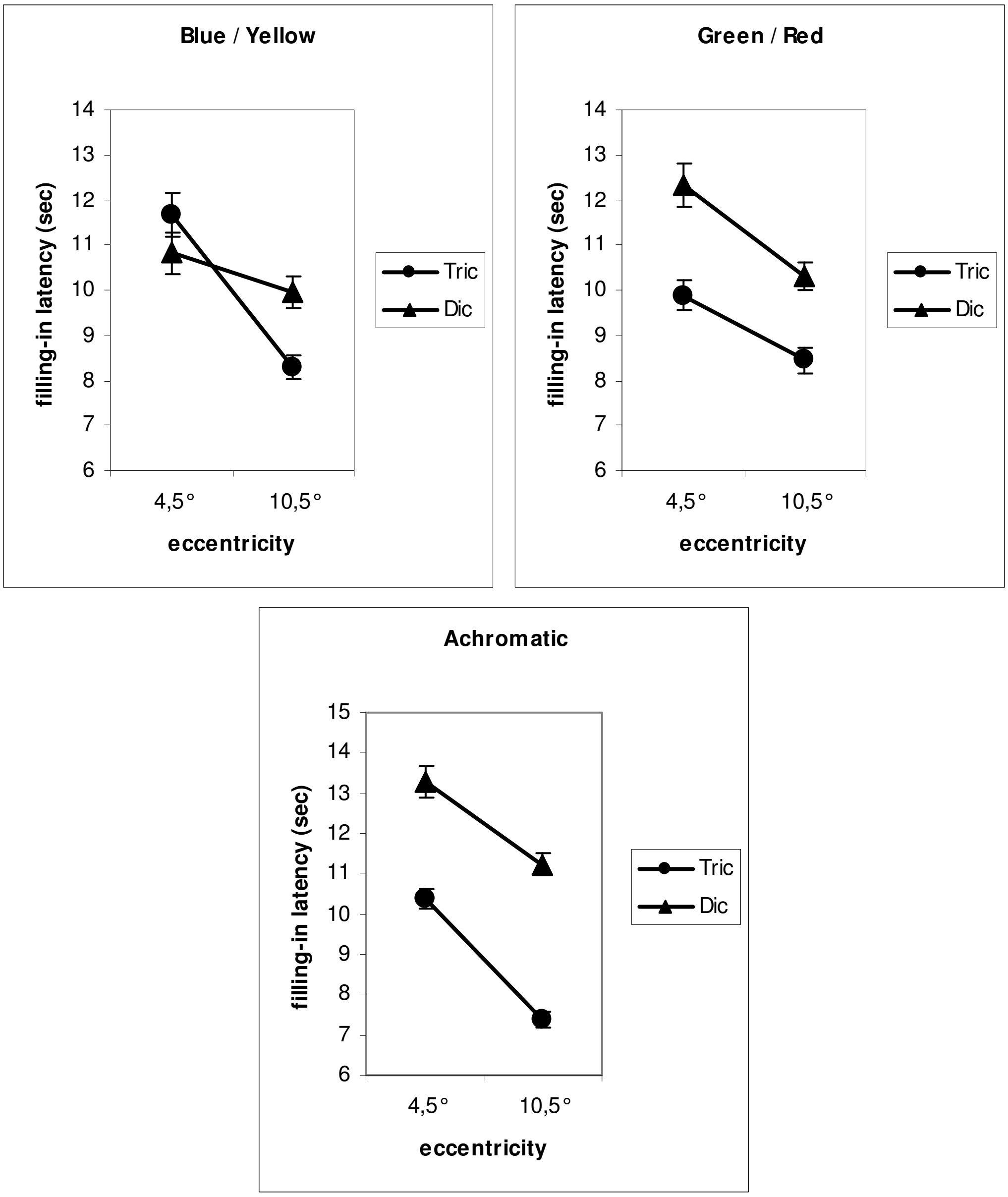


Figure 1: Mean TFL (sec) ± SEM for trichromats and dichromats at the two eccentricities tested. Significant center to periphery TFL difference ($p<0.01$) for: (i) both trichromats and dichromats in the achromatic and red-green experiments; (ii) for trichromats in the blue/yellow experiment. No significant TFL difference occurred from center to periphery for dichromats in the blue/yellow experiment ($p>0.01$).

## DISCUSSION

The results of the present experiment clearly show the decline in perceptual fading latency from a central to a peripheral target, consistent with a known decline in color vision towards the peripheral visual field (Seiple et al. 2004), (Anderson et al. 1991). Center to periphery color vision decline is attributed to retina cytoarchitecture (Mullen & Kingdom 2002). Trichromatic primate color vision is mediated by two cone-opponent processes. The first is the red-green opponent system, which differentiates the L from the M cone outputs and is connected to the parvocellular system. The other is the blue-yellow opponent system, which differentiates the S cones from a combination of L and M cones connected to the koniocellular system. The high L and M cone density at the fovea confers a red-green opponency specialization to this area and a steep decline away from the same. S cones are not present at the central 0.35° retina, consequently, center to periphery loss in blue-yellow opponency is more gradual (Mullen & Kingdom 2002), (Curcio et al. 1990). Dichromats lack L or M cones and only present blue-yellow color opponency (Gegenfurtner & Sharpe1999).

The exact cortical location of color filling-in is still controversial. Recent findings involving functional magnetic resonance imaging (fMRI) have shown that surface color filling-in occurs only in the primary visual cortex V1 (Sasaki & Watanabe 2004). However, a previous study recorded cell activity in the monkey V1 visual cortex, while performing color filling-in, and failed to show a corresponding change in surface activity (Pessoa & De Weerd 2003).

Retinotopic cortical visual areas present a topographical correspondence with the visual field. Color filling-in strictly at retinotopic cortical areas would render a steep red-green and a more gradual blue-yellow center to periphery TFL decline. However, the opposite was observed for trichromats, suggesting the influence of nonretinotopic areas on the color filling-in process.

Dichromat S cone distribution is similar to that found in trichromats and the number of L or M cones equals the sum of trichromat L and M cones (Gegenfurtner & Sharpe1999). Consequently a similar blue-yellow center to periphery TFL decline was expected in both groups. The result suggests that the dichromats only color opponency channel is more evenly distributed throughout the visual field.

## CONCLUSIONS

1- Faster TFLs for peripheral targets found in the current tests support the decline of color opponency from the center to the periphery.

2- Trichromats presented steeper center to periphery TFL decline regarding blue-yellow opponency compared to red-green opponency, which suggests that color filling-in might be processed by higher nonretinotopic brain regions.

3- Similar center and periphery TFLs found for dichromats in the blue-yellow experiment lead to the conclusion that their only color opponency system is more evenly distributed across the visual field than that of trichromats.

4- Differences between red-green and blue-yellow experiment results corroborate recent evidence concerning the functionally of distinct opponent color systems in human vision.

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