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# Effects of Habitual Scanning on the Pattern of the Lateralisation of Colour Categorical Perception

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## Abstract

Lateralisation of colour categorical perception has been investigated in a variety of studies, and the pattern of how the colour categorical perception lateralised is still being debated. It is possible that habitual scanning can help with this debate. The purpose of this study was to look into the effect of reading direction on the pattern of colour categorical perception. The study included sixteen right-to-left readers, all native Arabic speakers, 6 females and 10 males, ranging in age from 20 to 34 years old, with a mean age of 28.19 years (SD = 3.97). Lateralisation of colour categorical perception was tested using a target detection task with an eye-movement measure to a fixation point. Each participant's eye movement timing from target onset to a fixation point was calculated in each hemisphere (left-right) and category (within-between). Anova 2 ways repeated measure was applied. This study did not replicate the pattern of lateralisation colour categorical perception demonstrated by left to right readers. Right to left readers did not support the left hemisphere lateralisation for colour categorical perception. This result raises the question of whether reading direction plays a role in the lateralisation of colour categorical perception.

## Keywords

Habitual Scanning, Categorical Colour Perception, Reading Direction, Lateralisation, Hemisphere

## 1. Introduction

The colour spectrum is a physical continuum of a wavelength of light that is perceived discontinuously, as discrete categories or segments of hues (Harnad, 1987). This perceptual segmentation is a component of a phenomenon known as

Categorical Perception (CP) (Goldstone & Hendrickson, 2010). When a continuum is segmented into categories and those categories affect discrimination, CP is displayed. CP can be defined experimentally as faster/more accurate discrimination of a pair of colours drawn from a different category boundary than two pairs from the same category. This occurs even when the differences in stimulus between the pairs of stimuli are equal (Gilbert et al., 2007; Roberson et al., 2008). For example, CP has been demonstrated in a variety of perception phenomena, including auditory perception of speech (Joanisse et al., 2007), non-speech sound (Pastore et al., 1990), phonemes (Minagawa-Kawai, et al., 2005), line length (Tajfel & Wilkes, 1963), and various dimensions of face perception such as facial expressions (Levin & Angelone, 2002). CP has also been demonstrated using a variety of different colour perception tasks. For example, same-different (Boynton et al., 1989), similarity judgements (Roberson et al., 1999), visual search and target detection tasks (Daoutis et al., 2006; Al-Rasheed et al., 2014), and X-AB tasks (Pilling et al., 2003).

Despite numerous studies indicating that categorical perception is a genuine phenomenon, the origin and nature of this phenomenon are still being debated. To clarify the origin and nature of the CP, Gilbert et al. (2006) recently argued that if the CP of colour is related to language, it should be exhibited/stronger in the left hemisphere (LH), but not in the right hemisphere (RH), because the LH is dominant for language. Gilbert et al. (2006) used a visual search task with 12 coloured squares arranged in a clock shape to test this. Half of the sets were positioned on the right side of the monitor, while the other half were positioned on the left. Eleven of the squares belonged to the same colour category, while the twelfth square belonged to a different colour category. Targets were lateralised to the left or right of the visual field. Participants had to decide whether the target was to the left or the right of the fixation point. Gilbert et al. (2006) found a significant category effect when target and distractors from different categories were presented in the right visual field but not the left. They argued that this pattern of lateralisation was consistent with CP due to the implicit use of language.

Several studies had replicated the works of Gilbert et al. (2006) who were the first to do so by re-analysing their previous work in a way that considered the lateralisation of the CP, which included visual field as a factor. Their reanalysis revealed a significant categorical effect for targets on a different coloured background appearing in the RH than LH. In a simplified version of their search task, Drivonikou et al. (2007a) tested the lateralisation of CP. The task entailed searching for a target object of one colour against a uniform background of a different colour, with the target appearing in 12 positions in a clock shape (Franklin et al., 2005). The participants' task was to click the mouse as soon as they detected the target. The category effect was found in both visual fields, but it was significantly larger in the right visual field than the left. This study tested two category boundaries (blue-green) and (blue-purple), and the results were the same in both. Drivonikou et al. (2007b) conducted additional research on the lateralisation of colour CP in three different samples: Greeks, English, and "Africans". Their findings revealed that the left hemisphere lateralisation of CP can only be found if the category boundary is marked in the language.

Further research has been conducted into the lateralisation of CP in category boundaries marked in one language but not another. Roberson et al. (2008) compared Korean and English speakers using Gilbert et al.'s (2006) visual search task, across two Korean basic colour categories, yeondu (yellow-green) and chorok (green) that were not marked in English. The Korean sample demonstrated a significant category effect, whereas the English sample did not, and the category effect was found to be significant in the left hemisphere but not in the right for fast responders.

The findings of Gilbert et al. (2006) were investigated further using novel techniques such as "event-related potential (ERP) and functional magnetic resonance imaging (fMRI)". Siok et al. (2009) used a Chinese sample to test left hemisphere lateralisation of colour categorical perception. During a rapid MRI study, participants' brain activity was measured while performing a visual search task. Cross category boundary activity was faster and stronger in the language areas of the left hemisphere of the brain: the inferior prefrontal cortex, the middle temporal gyrus, and the posterior temporoparietal. Along with these areas, the visual cortex has shown stronger activation for pairs of stimuli from different category boundaries than for stimuli from the same category boundary. Liu et al. (2009), discovered the same result when they investigated the left hemisphere lateralised for colour CP using Gilbert et al. (2006) task with a Chinese sample. $N_2$-posterior-contralateral was used to indicate the attentional demands of target and distractor relationships within and cross categories. The results showed that between-category conditions had higher Left hemisphere $N_2$pc components than the same-category conditions.

The findings support the notion that left hemisphere lateralisation of category perception has progressed beyond the colour framework. Gilbert et al. (2007) used dog and cat shapes to investigate the lateralised colour CP. Following this task procedure, the comparison was the target-distractor relationship; within-category (e.g., cat1-cat2) or between-category (e.g., cat1-dog1). According to the results, targets in the between-category condition were detected faster than targets in the same-category condition. This was discovered in both visual fields, but was significantly stronger in the RVF. Kosslyn et al. (1989) presented further evidence of LH lateralisation of colour CP. In a set of experiments, they put both hemispheres to the test in terms of computing categorical and metric spatial judgments. They discovered that the LVF quickly detects metric spatial judgments such as the assessment of exact distance (2 mm, 3 mm, and 2.54 cm). The RVF, on the other hand, quickly detects categorical judgments such as on/off, left/right, and above/below.

Although converging evidence supports the bias of the left hemisphere in colour categorical perception, it is possible that other factors may contribute to this effect in adults. Eviatar (1995, 1997) compared samples that differed in their reading direction; right-to-left readers and left-to-right readers. Using a target detection task, participants were asked to identify a target among distractors. Target and distracters appeared in opposing visual fields at the same time. Distractors in the LVF dispensed left-to-right readers, whereas distractors in the RVF dispensed right-to-left readers. In the right-to-left readers, the RVF distractors disrupted the reader but not the LVF distractors, resulting in contradictory results. The findings indicated that habitual scanning gave attentional priority to stimuli appearing in the LVF for Left-to-Right readers and RVF for right-to-left readers. It was discovered that the attentional priority was impulsive. Eviatar's discovery raises the possibility that a change in habitual scanning leads to a change in the pattern of colour categorical perception. In another study by Simola et al. (2009) in which the effect of habitual scanning on target detection task was investigated, an effect of parafoveal preview on target detection was discovered; participants having right-to-left script readers benefited from parafovea information to the right of fixation, whereas this was not the case for the left-to-right script readers who benefited from parafovea information to the left of fixation. These findings suggested that detecting a target on display should be better in one visual field than the other, and that this should be dependent on habitual reading direction. Several other studies that looked at the effect of habitual caning on different aspects of perceptions came up with nearly identical results (Ibrahim & Eviatar, 2009; Smith et al., 2015; Afsari et al., 2016; Chung et al., 2017; Kermani et al., 2018).

Despite reviews of previous studies investigating the lateralisation of colour categorical perception, the pattern of lateralisation of the CP has been inconsistent. It is unclear whether the bias effect can be explained by the reading direction. The motivation behind this paper is to test the pattern of the generality of laterality effects across speakers of different habitual scanning.

## 2. Aim of the Study

This study investigated the possible effect of habitual scanning on the pattern of colour categorical perception, by comparing the results from right-to-left script readers to the pattern shown from left-to-right readers in English (Gilbert et al., 2006; Daoutis et al., 2006; Drivonikou et al., 2007a). The findings of this study will have implications for our understanding of the origin and nature of categorical colour perception.

## 3. Methods of the Study

### 3.1. Participants

Sixteen right-to-left readers participated in this study; all were native Arabic speakers from the undergraduate and postgraduate population of Surrey University. They were all right handed and had not been in the United Kingdom for more than two years comprising 6 females and 10 males, with age ranging from 20 to 34 years old, and with a mean age of 28.19 years (SD = 3.97). All participants had normal colour vision as assessed by the University Colour Vision Test (Fletcher, 1980).

### 3.2. Apparatus and Experimental Set up

A 17-inch cathode-ray tube (CRT) monitor was used for testing the sample, and a Cambridge Research Instrument Colour CAL was used to obtain the CIE co-coordinates. An Applied Science Laboratories model 504 pan/tilt eye tracker and gaze tracker was used to measure the participant's pupil diameter and point of gaze on stationary (fixed) points. The tracker camera was placed directly under the monitor, against the participants faces and it was sensitive to near-infrared light, enabling a participant's eye movements to be recorded in the dark. The eye-movement output was digitised using Canopus ADVALUE and CHROMA-300 analogue digital video converter, while the digital video was analysed using Apple's iMovie digital video editing system.

### 3.3. Stimuli

The Arabic location of the *azrock* "blue" and *akhdar* "green" boundary has previously been calculated to be approximately 7.5 blue-green (Al-Rasheed, 2015). The stimuli consisted of three chromatic colours and were only varied in Munsell Hue, with Value and Chroma constant at 6/8. The distance between adjacent stimuli was measured in Munsell hue steps (E 9). The first two stimuli were green, while the third was blue. The Munsell codes and the CIE (1931) Y, x, y/L* u* v* chromaticity coordinates of the colours and of the grey and white point of the monitor were: (3.75 BG - 19.47, 0.228, 0.342/); (6.25 BG - 19.47, 0.220, 0.322/); (8.75 BG - 19.47, 0.214, 0.304/); (19.47, 0.336, 0.344) and (64.80, 0.326, 0.335). Figure 1 shows the three chromaticity co-ordinates of the stimuli and the grey and white point of the screen.

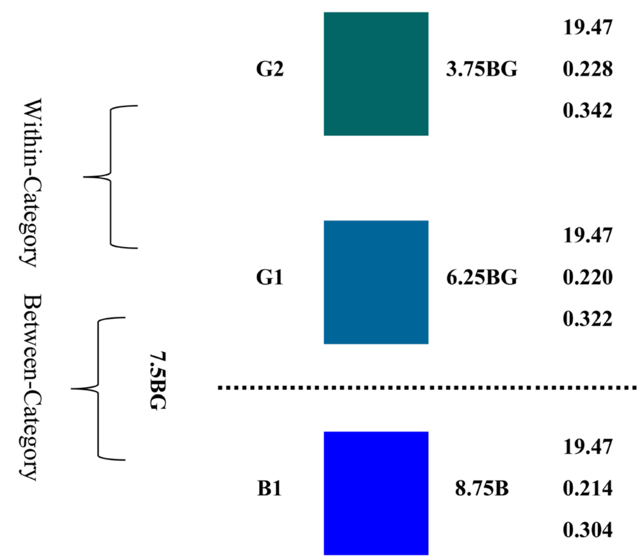



Figure 1. A representation of the three stimuli with Munsell codes and CIE (1931) Y, x, y/L* u* v* chromaticity coordinates. G2 and G1 stimuli are from the same category, while G1 and B1 stimuli belong to a different category. 2.5 hue steps were equally separated between adjacent pairs. The dashed line between G2 and G1 represent the Arabic blue-green linguistic category boundary.

### 3.4. Procedure

First, the participant's eye movements were calibrated. Participants were instructed to focus on nine spots pictured on the computer screen consecutively, and signals of the pupil and corneal reflections were recorded. The calibration procedure was completed when the participants' corneal reflection and pupil signal cross hair successfully hit all nine points. When the crosshair failed to hit any of the nine points, the calibration procedure became inaccurate and iterative. See Franklin et al., 2005 for more calibration procedure information.

The main data collection phase began after the eye movements were calibrated; the experiment was divided into two phases, each with 16 trials. Each trial began with a black and white bulls-eye flashing on a grey background. Following fixation, a blank grey background of the same luminance as the target appeared for 250 ms, followed by a 4-second presentation of the target and background. The target location was displayed at random in twelve different positions, arranged radially around a central fixation marker, with the constraint that the trails appeared equally to the right and left. On a coloured background 40 × 30 cm, the target appeared in a circular shape with a diameter of 3 cm and a visual angle of 3.22˚. Two different categories of stimuli were paired to create one across-category pair (G1-B1) and another within-category pair (G1-G2). In each trial of each pair, one stimulus appeared as the target while the other stimulus as the background. However, across trials, each stimulus within a pair was used as the target half of the time and half of the time as the background (See **Figure 2**).

## 4. Results

The fixation times, which are the times from the onset of the target until the eye hits the target and essentially stops scanning around the target, were calculated and used to analyse eye movement. A point of gaze coordinates and the videotaped output were used to create those fixation times. Trials were excluded from the analysis for two reasons: first, if the eye-movement signals were lost or not fixated at all (mean = 1.50, SD 2.88), and second, if multiple eye-movements around the monitor occurred before the eye movement to the target (mean = 0.56, SD 0.96). In total, 992 trails were examined for all participants, with the average number of trails examined per participant being 62, with a standard deviation of 3.22. All participants were subjected to at least 13 trials per condition (See **Figure 3**).

Average of incorrect trails for each participant, for each companion of category (within/cross) and visual field (left/right) was calculated. Error score data were analysed using ANOVA two-way repeated measure. There was no significant effect of category, (mean, (S.D.) within-category = 0.66 (1.12), cross-category = 0.41 (0.87), $F(1, 15) = 2.500$, MSE = 0.250, p 0.135, indicating smaller error rate for cross-category compared to within-category by about 0.25. The effect of visual fields of the average of incorrect trails was significant. Right visual field =

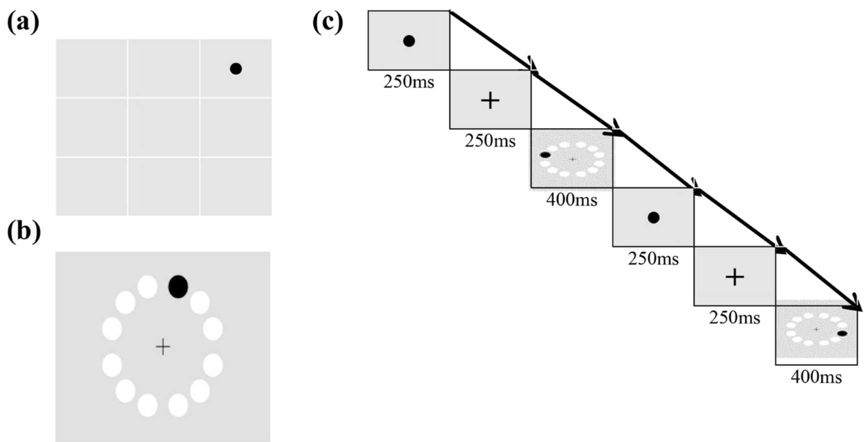
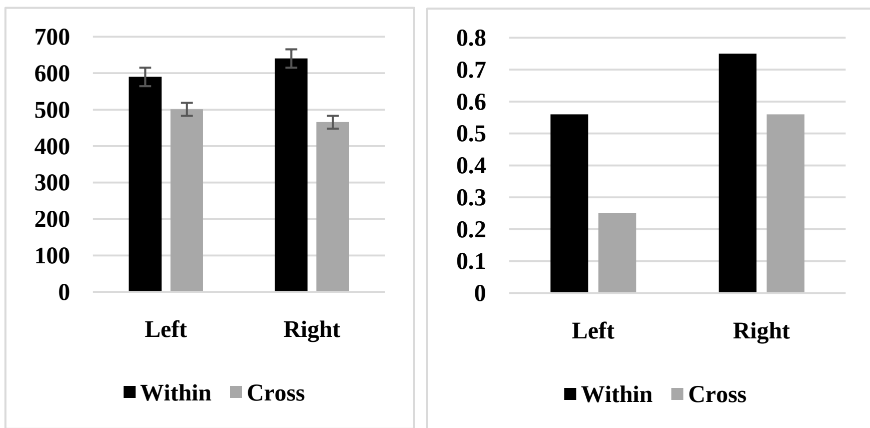



Figure 2. An example of the designs of (a) the eye's movement celebration task and (b) the target detection task. (c) The sequences of trials events of the experiment.




(a) (b)

Figure 3. (a) Median target fixation time +1 MS *SE*, for correct trials for the four conditions of category (within/across) and visual fields (LVF/RVF). (b) Average of incorrect trails, for the four conditions of category (within/across) and visual fields (LVF/RVF).

0.66 (1.15), Left visual field = 0.41 (0.84), $F(1, 15) = 0.938$, MSE = 0.250, p = 0.05, with approximately 0.25 more errors for the left visual field. There was also a significant effect for the category by visual field interaction, $F(1, 15) = 0.135$, MSE = 0.016, p 0.05. The interaction effect appears to be the result of a large category effect in correct trials in the left visual field (0.31) compared to the right visual field (0.19).

Then, the fixation median RTs (ms) for correct trials for each participant, for within-and cross-category conditions for LVF and RVF targets were evaluated using a two-way repeated measure ANOVA used to test the main hypothesis, comparisons of performance targets at within and between category, and the performance at detecting the targets at the two visual fields left/right. Cross-category fixation time (mean = 483.6 ms, SD, 107.2) was significantly faster by about 131 ms than within-category fixation time (mean = 615.3 ms, SD, 124.4) [$F(1, 15) = 41.82$, mean square error (MSE) = 277,597.27, $P < 0.001$]. Although, the fixation median RTs size of the category effect was (86 ms) larger in the RVF than in the LVF, the visual field was clearly not significant [$F(1, 15) = 0.09$, mean square error (MSE) = 937.89, $P = 0.77$]. The category by hemisphere interaction was also significant [$F(1, 15) = 7.07$, mean square error (MSE) = 937.89, $P = 0.05$]. The interaction can be explained by two factors; first, the category effect size is larger in the right visual field (174.69 ms) than in the left visual field (88.75 ms), and second, the within-category fixation time is faster in the left visual field than in the right visual field by about 50.36 ms.

## 5. Discussion

Reading direction affects people's perceptions, according to studies based on variations in habitual scanning. As a result, these variations raise the question of whether and how these variations in habitual scanning correspond to different colour categorical perceptions. Arabic participants were primed to be tested for hemispheric asymmetries in colour CP for the blue-green boundary (**Figure 1**), and by observing their performances on a target detection task, using an eye movement measure. The present study found that in both visual fields, the time taken to fixate the target was faster for cross-category target-background pairs (blue-green) than for within-category pairs (different shades of blue) in both visual fields. Despite the fact that this significant category effect appeared in both visual fields and was larger in the right than in the left, the visual field was not significant. Indeed, in the present study, the right visual field, left hemisphere bias in categorical perception for adults was not supported. This study replicates the findings of al-Rasheed et al. (2014), who used the same task but with a different measuring technique, an eye-movement initiation time as a measure rather than fixation time.

The pattern of hemispheric asymmetry in categorical perception varied cross studies. For instant, Gilbert et al. (2006) and Daoutis et al. (2006), who investigated the lateralisation of colour categorical perception, found that the category effect appeared only in the right visual field, but not in the left. They reasoned that this was due to the left hemisphere being dominant for most language functions. Other studies that looked into the same hypothesis (Drivonikou et al., 2007a, 2007b; Roberson et al., 2008; Gilbert, 2007) discovered that the category effect appeared in both visual fields, with a significantly stronger categorical effect in the right than in the left. The category effect which appeared in both visual fields was thought to be the cause of trans callosal transfer (Gilbert et al., 2006; Drivonikou et al., 2007a). Recent studies, on the other hand, have failed to support the left-lateralized colour CP (Brown et al., 2011; Witzel & Gegenfurtner, 2011; Holmes & Wolff, 2012).

Despite the large number of studies on the lateralisation of colour categorical perception, the pattern of lateralisation of CP remains unstable. Several factors could potentially contribute to variations lateralisation of CP in adults. The non-significant CP lateralized to the left hemisphere shown in the current study and in Al-Rasheed (2015), may indicate an influence of habitual scanning at the lateralisation of colour CP, and there may be overall differences in visual field biases related to habitual reading direction. It is not entirely clear how the effect of habitual reading direction on the target detection task can be predicated in the two eye-movement measures. This necessitates additional research to investigate the possibility of the impact of habitual scanning on lateralisation in general, and lateralisation of colour categorical perception in particular.

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## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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