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COMPARISON OF CHROMATIC CONTRAST SENSITIVITY OF COLOUR VISION DEFICIENT PEOPLE AND NORMAL COLOUR OBSERVERS

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Abstract

In Europe 8% of the male population lives with colour vision deficiency (Gegenfurtner, Sharpe, 1999; Mollon, Pokorny, Knoblauch, 2003). However from ophthalmological point of view their vision is just like the vision of normal colour observers, they perceive colours in a different way, generally they can discriminate less colours. (Samu, Wenzel, K., Ladunga, 2001). This difference puts them at a disadvantage in many different situations.

The human body is excellent in adaptational mechanisms as it can be understood from blind people's example. The sensitivity of their unimpaired sensory organs increases in order to be able to collect more information and so to compensate the lack of their vision.

In virtue of this example a couple of questions might occour: do people with colour vision deficiency, who can discriminate specific colours harder than normal colour observers, have worse performance in visual acquity also? Are the functions of our image processing able to compensate the deficiency of colour vision?

In order to answer these questions we designed a complex series of measurements. We applied two series of examining images. One of them contained achromatic (dark pattern on light background) while the other contained coloured (red pattern on green background) pseudoisochromatic images. The achromatic and the chromatic contrast between the pattern and the background was large in the first images and small in the last ones, hence the images were ordered from the easiest to the most difficult one. The variable that represented the result of the measurements was the number of the first image of which the participant could not tell the orientation of the Landolt-C (Samu, Wenzel, Ladunga 2001). This number gives representative information about the actual participant's contrast sensitivity (Barten. 1999).

The results of the survival analysis show that normal colour observers find the orientation of the coloured figures with higher rate however participants with colour vision deficiency were more successful in the achromatic series.

Keywords: Colour vision deficiency, contrast-sensitivity, chromatic contrast-sensitivity, pseudoisochromatic plates

1 Introduction

The eye plays an important role in our life, not only for seeing objects in the surrounding world, but also for reading books, watching films, or recognise different objects and different members. The contrast sensitivity of the eye is generally regarded as the most important factor for the ability of the eye for seeing objects. Objects can generally be better distinguished from each other or from their background, if the contrast sensitivity of the eye is large (Barten, 1999; Kim, KyoungHo Lee, 2013). Contrast is the difference in luminance or color and contrast sensitivity is the capacity of the eye to distinguish these differences (Eli Peli, 1990).

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Not only contrast sensitivity helps our vision in orientation and navigation. The image processing functions of our brain play important role in recognising particular details of our environment. (Gregory, 1997, Hoffman, 1998, Livingstone, 2002). Therefore we completed our experiments with measurements done with an eye-tracker.

An eye-tracker is a device for measuring eye positions and eye movements. Eye-trackers are used in research on the visual system, in psychology, in psycholinguistics, marketing, as an input device for human-computer interaction, and in product design (Gegenfurtner, Lehtinen, Säljö, 2011). The complete eye-tracker system contains a display connected to a computer, a camera positioned over against the participant watching the display and the lighting devices. The camera detects the eye movements provoked by the effect of the displayed images with high frequency. The eye movements are evaluated by computer.

Henceforth we introduce the conclusions based on the results of the chromatic and achromatic tests. The evaluation of the huge amount of data gained from the eye-tracker measurements are still in process.

2 Participants

90 participants aged between 18 and 35 participated in the study (42 male, 48 female). 9 of the participants reported color vision deficiency which was confirmed with an anomaloscopic measurement (Fletcher, Voke, 1985) and with Ishihara plates (Ishihara, 1994). They were recruited at the Szent István University in Budapest, Hungary. The study was performed in accordance with the ethical guidelines for scientific research of the Szent István University (Wuerger, Watson, Ahumada, 2002).

3 Test images

For the eye-tracker measurements we prepared and applied two series of examining images. One of them contained achromatic (dark grey pattern on light grey background) while the other contained coloured (red pattern on green background) pseudoisochromatic images (Wenzel, Samu, 2012).

In both series the pattern traced out Landolt-C figures and the task was to find the orientation of the figure. In the images of the achromatic series the Landolt-C figures are dark grey while the background is light grey. The size and brightness of the dots are sightly different in a random layout like in the figures of the Ishihara test. In the images of the series the luminance contrast progressively decreases as the Landolt-C figures are getting lighter. The magnitude of the change of the contrast was designed and audited based on measurements (Oleari, 2015). The series contains 10 images. The first image of the series can be seen on the left part of Figure 1.

The dots of coloured images are red (Landolt-C figure) and green (background). This series contains 16 images. The chromatic contrast between the Landolt-C figure and the background is the higher in the first image and decreases solidly as we mix more and more green to he colour of the Landolt-C. The first image of the series can be seen on the right part of Figure 1.

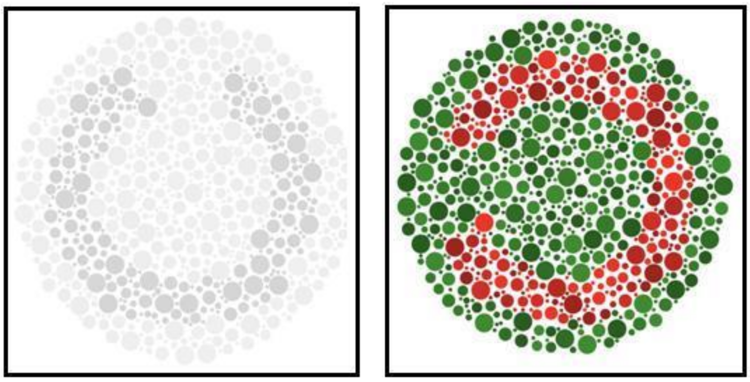

Figure 1 – Test images (left: achromatic image, right: coloured image)

4 Eye-tracking procedure

A Tobii X2-60 eye-tracker and Tobii Studio software (version 3.0.5, Tobii Technology AB, Sweden) were used for recording and analysing the gazing behavior of the 90 participants (Machin, Cheung, Parmar, 2006). The experiment took place under controlled environment (lighting, temperature etc.) in the sensory laboratory of the Department of Postharvest and Sensory Evaluations of Szent István University, Budapest, Hungary.

Participants took a seat in front of the eye-tracker screen in a relaxed way with their eyes at a distance of approximately 70 cm holding the mouse in their dominant hand. They were instructed not to change their position during the test. After successful calibration, an instruction screen explained the details of the method. A black fixation cross was presented for 3 seconds in the middle of the screen to standardize the starting point of the subjects. Without time limit, participants had to find the gap in the Landolt-C figure. Participants needed to click the left mouse button once as soon as they found the gap, then the mouse pointer appeared on the screen and they should click on the gap. Two warm up tasks were used to familiarize participants with the procedure and these were left out from the data analysis.

5 Rates of matches

The result of the evaluation of the measurements with the achromatic and coloured test series are summarized in Table 1.

Table 1 – Count and percentage of hits

Images				Hit		Total
				no	yes	
Achromatic	Participant	Normal colour observer	Count	72	252	324
			% within participant	22,2%	77,8%	100,0%
		Colour vision deficient observer	Count	5	33	38
			% within participant	13,2%	86,8%	100,0%
	Total		Count	77	285	362
			% within participant	21,3%	78,7%	100,0%
Coloured	Participant	Normal colour observer	Count	173	460	633
			% within participant	27,3%	72,7%	100,0%
		Colour vision deficient observer	Count	45	38	83
			% within participant	54,2%	45,8%	100,0%
	Total		Count	218	498	716
			% within participant	30,4%	69,6%	100,0%

6 Conclusion

As Table 1. shows while normal colour observers recognised the orientation of the Landolt-C figure in 77,8% of the achromatic images, participants with colour vision deficiency recognised 86,8% of them. However while normal colour observers recognised 72,7% of the coloured images, participants with colour vision deficiency recognised only 45,8%. Hence it can be concluded that normal colour observers were more successful in the coloured series while participants with colour vision deficiency were better in recognising achromatic images. This conclusion was proven with analisys of variance based on the collected data ($\alpha<0.05$) (Dytham, 2011).

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