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Simple and Inexpensive Design for a Colour Vision Test Cabinet

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Abstract— *The intensity and colour content of daylight varies as a result of diurnal changes as well as differences in weather and seasons. Colour tests recommended to be performed under daylight conditions would have poor repeatability if conducted under such varying daylight conditions. Therefore, it is necessary for colour tests to be conducted under standard conditions in all subjects. In the present paper we have established a method for designing a colour vision test cabinet that facilitates colour testing under the constant conditions and standard requirements. In addition, we compare the Farnsworth-Munsell 100-Hue Test obtained under our conditions with the normative data in the literature.*

Keywords— *Colour vision, colour vision tests, colour vision cabinet, Farnsworth-Munsell 100-Hue Test.*

I. INTRODUCTION

Conducting colour discrimination tests is fundamental to the study of colour vision. Such tests are conducted both in medical establishments and for the purpose of various scientific studies. For the proper conduct of these tests and the generation of accurate results, both the illumination of the work surface and the colour reflectance properties of surrounding surfaces play an important role. According to the original Farnsworth instructions for conducting the Farnsworth-Munsell 100-Hue Test (FM-100 test) [1], the working surface must be illuminated with a uniform white light with a colour temperature of 6750 K and an intensity of not less than 25 foot candles, equal to 269 lux (lm/m^2). In order to ensure these conditions, it is best to perform the tests in a white surface cabinet with quality lighting installed within it.

The purpose of this paper is to describe a methodology for constructing a standardized cabinet suitable for colour vision research, adhering to Farnsworth's instructions.

II. MATERIALS AND METHODS

Fig. 1. General view of the colour test examination cabinet.

The general appearance of the colour testing cabinet is shown in Figure 1. Its dimensions are commensurate with the dimensions of the fluorescent lamps and the area required for the person to work freely with the relevant tests.

The cabinet construction consists of an aluminium frame, which provides the mechanical integrity and strength for the mounting of MDF panels. For construction of the frame, aluminium square tubing of size 30x30 mm is used. This box-section profile is lightweight, easily accessible and quickly assembled, providing very good structural strength. The profiles used are of the following sizes:

Profile 30x30mm, 4F, L = 1600mm - 4 pieces
Profile 30x30mm, 4F, L = 1300mm - 5 pieces
Profile 30x30mm, 4F, L = 600mm - 6 pieces

22 L-type inner bracket connectors are used to assemble all sections.

The overall appearance and dimensions of the frame are shown in Figure 2.

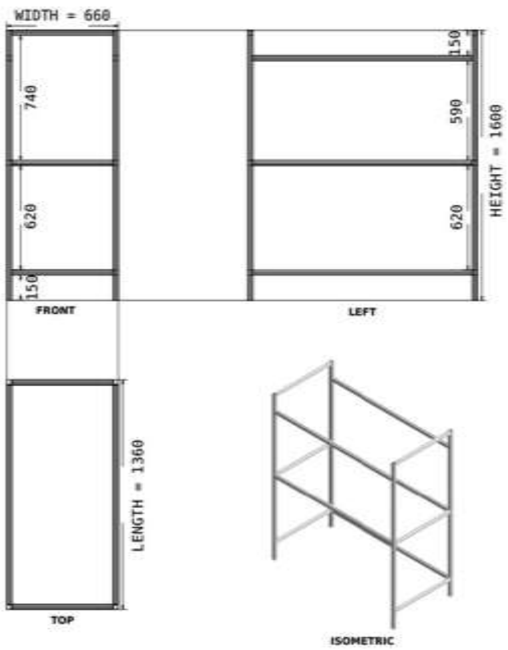

Fig. 2. Overall appearance and structural dimensions of the frame.

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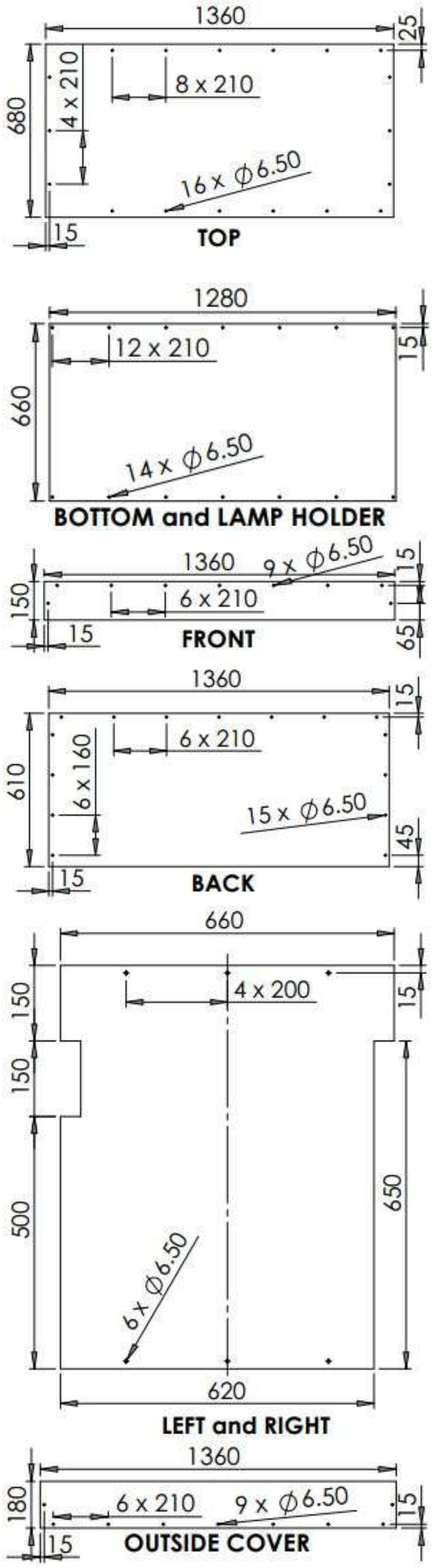

Fig. 3. General appearance and dimensions of panels. Bottom and Lamp Holder, Outside Cover, Left and Right are 2 each, Top, Front and Back are 1 each.

10mm-thick MDF panels are installed on the frame. These panels are relatively lightweight, while providing strength and rigidity to the structure. The material of the panels provides good adhesion with the paint, while being a good electrical insulator. The panels are mounted on the inside of the frame resulting in complete enclosure without seeing the structural profiles. We used DIN7991/ISO 10642 bolts, M5x14 in size, in combination with 30TN-M5 nuts to secure the panels to the structural profiles. The drawings of the panels used are shown in Figure 3.

All panels are mounted by clamping with the respective mounting bolts. The back panel is mounted first, followed by the front panel and then the two side panels, so that a solid connection with the back and front panels is obtained. Next is the installation of the bottom panel. On the middle panel (lamp holder) the fluorescent lamp holders are mounted at the appropriate distance. The installation diagram is shown in Figure 4.

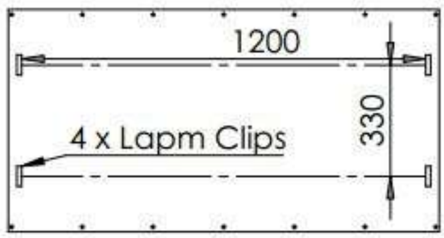

Fig. 4. Installation of fluorescent lamps.

The middle panel is mounted with the holders down. An electronic ballast for mounting fluorescent lamps is mounted on the top of the panel. The ballasts are connected to the lamps according to the diagram shown in Figure 5.

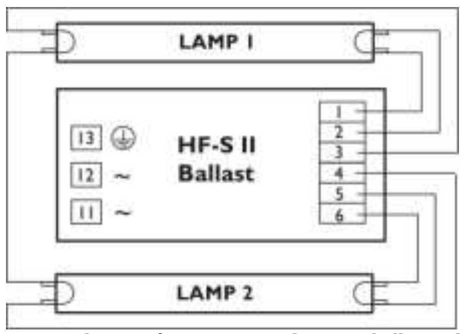

Fig. 5. Wiring diagram for connecting electronic ballast to lamps.

The front exterior panel is mounted with a pre-installed electric key. The back exterior panel is mounted with a power cable inserted through it. The cable connects to the key on the front exterior panel. Finally, the top panel is fitted, which closes in the wiring harness.

To create a white matt surface in the cabinet we used the method described by Nick Knighton and Bruce Bugbee [2]. We used a ratio of 50% paint and 50% barium sulphate. We applied the mixture in 4 layers with the help of a long fringe roller. This provided a matt, non-reflective surface. In order not to contaminate the white surface during the mounting of the panels, painting was carried out after the complete

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assembly of the cabinet. Figure 6 shows a picture of the actual cabinet during the experiment.

Fig. 6. Real photo of the white surface of the cabinet.

For lighting in the cabinet, we used two Philips MASTER TL-D Super 90 Graphica 36W 965 fluorescent lamps with the following characteristics:

Colour temperature: 6500K / Cool Daylight / Daylight.
Colour rendering index Ra8: 98%
Luminous flux: 2100 lm (58.3lm / W at 25 degrees C)
Chromaticity Coordinate X 310
Chromaticity Coordinate Y 323
Luminance Average EM 0.8 cd/cm^2
The emission spectrum of the lamp is shown in Figure 7.

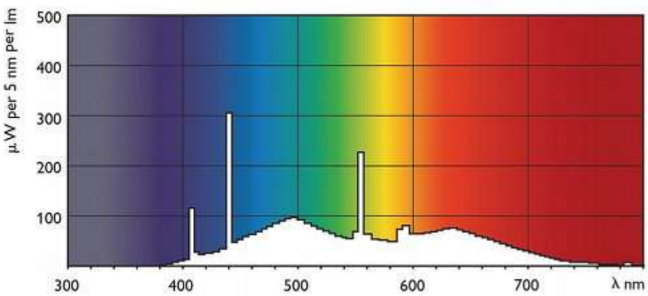

Fig. 7. Radiation spectrum of Philips MASTER TL-D Super 90 Graphica 36W 965, according to official Philips website.

We used a Philips HF-Selectalume 2x36 TL-D II electronic ballast to turn on the fluorescent lamps, which was connected according to the manufacturer's recommended circuit.

In order to improve the uniformity of illumination, we fitted reflectors for each lamp aimed at the near top corner of the cabinet. In this way we achieved multiple reflections of light and a correspondingly uniform illumination on the work surface.

The illumination on the work surface created by the lamps is quite high. The illumination of only one of the lamps results in uneven illumination of the work surface. To reduce the brightness of the work surface, we used two coats of Rosco E-Colour # 209 Neutral Density Filter: .3 Neutral Density.

III. Results and Discussion

Illumination, colour temperature, and colour coordinates were measured at 21 points across the entire lower surface of the cabinet using MINOLTA chroma meter XY-DC XY-1. The colour temperature value at all points was 6350 K. The colour coordinates at each point were x = 0.32, y = 0.33. The measured values for illumination are shown in Figure 8. At the test site, the illumination is between 285 and 295 lx, which corresponds to that recommended for Farnsworth [1] illumination of over 269 lux.

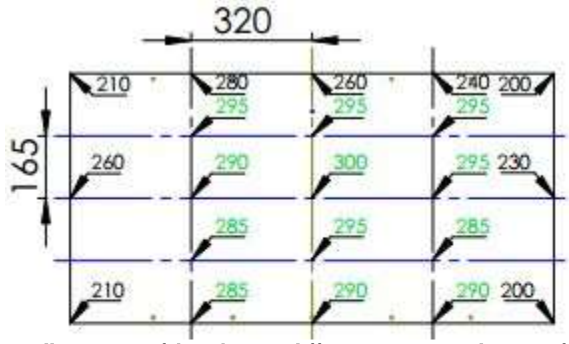

Fig. 8. Illumination of the cabinet at different points on its lower surface.

Figure 9 shows the data measured under our conditions for 47 subjects (18-55 years old) with normal colour vision (Ishihara Test for Color Deficiency, 38 Plates Edition and The City University Color Vision Test, Third Edition, 1998) using the new cabinet. The figure represents square root of the total error score as a function of age. Black dots indicate our individual data. Purple squares and line depict the averaged data for ages 18-29, 30-39, 40-49 and 50-55 years, obtained in our experiment. Red dots and line show normative data for each year of age 18-22 and for decades 30-60 taken from Kinnear & Sahraie [3]. The blue triangles and blue line represent the normative data of Verriest et al. [4] for 18-19 years and each age decade 20-60 respectively.

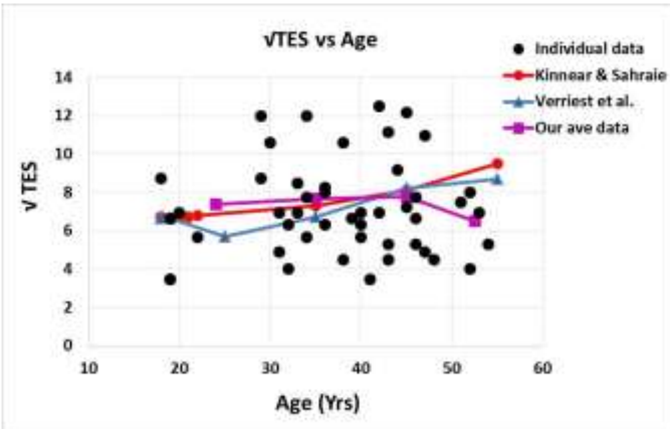

Fig. 9. Square root of the total error score as a function of age. Black circles indicate individual data obtained from us; purple squares and purple lines indicate group means; red circles and red line indicate normative data obtained from Kinnear & Sahraie (2002) and blue triangles and blue line indicate normative data taken from Verriest et al. (1982).

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The deviation of the 50-55 group age in our data is most likely due to the small number of subjects in that group (only 5). In the other age groups, the average data obtained in our study were closed to the normative data obtained from Kinnear & Sahraie [3] and Verriest et al. [4], despite the smaller number of subjects tested by us. The normative data from Kinnear & Sahraie are taken from 395 tested subjects. Unfortunately, the conditions under which the data were collected are not well controlled. Authors used different daylight illumination - either natural or artificial in a number of schools and laboratories. They do not include other specific data about illumination, colour temperature and light spectrum in their research. The other normative data received from Verriest et al. were carried out with controlled illumination - C-luminant at an illuminance of 200 lux, but they also don't give information about colour temperature and light spectrum. 232 subjects participated in their study.

The other controlled study was that of Smith et al [5]. In 1984 they tested binocularly 37 observers (26-68 years). The tests were conducted under l500 lux illumination from two desk lamps Verilux (F15T8VLX) 15-W fluorescent lamps with a color temperature of 6200 K. The authors compared the data they received with the Verriest normative data [4] and found no statistically significant differences. (Their fig. 1, bottom data). Note, that the Colour Rendering Index of the Verilux lamp is only 94%, while the lamp used in our experiment has a Color Rendering Index of 98%.

Knoblauch et al. [6] tested age and illuminance effects on the FM-100 test for 75 subjects with normal colour vision (20-79 years of age) using controlled parameters. Their test was illuminated by a MacBeth Executive Daylight source. The test was carried out at several illuminance levels - 5.7, 18, 57, 180 and 1800 lux, the color temperature was 6600K. Using the data from their 180 lux condition, the authors compared their results with Smith et al. [5] and found that the two measures were significantly correlated.

IV. CONCLUSION

The cabinet created in our laboratory is a quick and inexpensive way to design a device that is suitable for colour vision tests. This avoids the inconvenience of daylight changes and operates under standardized conditions for all test participants. Colour temperature, colour coordinates and illumination of the cabinet are in accordance with Farnsworth's original instructions for conducting the FM-100 test. Our data under these conditions are very close to the normative data in the literature [3,4]. We assume that the cabinet has standardized parameters that are suitable for conducting a FM-100 test as well as other colour tests. Conducting colour discrimination tests under constant and standardized conditions make it possible to compare the results obtained with different subjects. This allows us to claim that the differences in the error scores are not due to the different test conditions.

ACKNOWLEDGMENT

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

FUNDING SOURCES

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