Perceived Brightness vs. Required Sunlight Luminance of RGB Lighting on Automotive Dashboards

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Color light guides at the bottom of the windshield will show safety relevant information such as autonomous mode. Therefore, it is essential to know the required RGB LED luminance values from night to blinding sunlight. We built a mock-up and made an evaluation with 18 subjects: A luminance for white of 3,300 cd/m² and a RGB ratio of 35 : 50 : 15 is recommended for safe recognition.

1 Introduction

"Light is the new chrome" – a phrase, which spreads quickly in the automotive industry during recent years. A first example for a light guide next to the line of sight of a driver is a "Scheibenwurzel-Display" (Fig. 1, patent WO 2012084123).

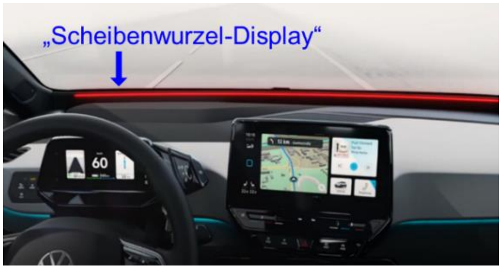

Fig. 1 *Light guide showing red of VW ID.4 [1] with RGB LEDs between dashboard and windscreen; Source: VW.*

This is used today for infotainment such as notification of incoming calls but can as well be used for safety relevant features such as directional warnings. However, requirements such as safe perception have to be fulfilled. The light guide showing blue (Fig. 2) is hard to notice. This is the motivation of our work: Required luminance and RGB ratio.

Fig. 2 *Example of a "dark" appearance and questions for the design and our evaluation; Source: CONTINENTAL.*

2 Mock-Up

For the acquisition of RGB luminance values under different lighting conditions by subjects (humans), we designed and built a full-scale mock-up ("Sitzkiste") shown in Fig. 3. We can simulate light conditions from night with headlights to blinding sunlight. The RGB light guide had a white luminance of 13,000 cd/m². The design, measurements, and evaluation base on [2] - [4].

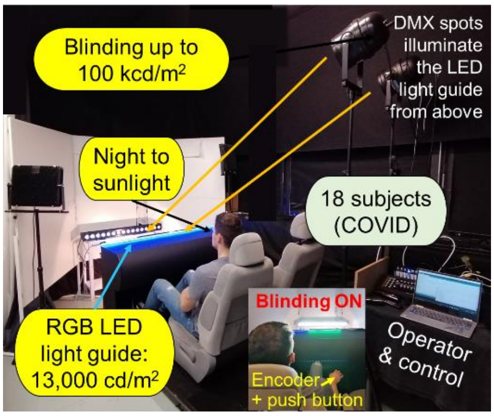

Fig. 3 *Our full size mock-up & ambient light simulation.*

The subjects (60 planned, 18 due to COVID restrictions) had to adjust the luminance of the RGB LED light guide for different tasks (see §3) by a rotary encoder and a push button (attention test).

3 Evaluation Tasks

The subjects had to perform a four-step test (Fig. 4):

1. Pre-test for introduction to same brightness adjustments at home and at the lab (same monitor).
2. Setting of the luminance for different colors and light conditions by the subjects for "noticeable", "pleasant" and "annoying".
3. Adjustment to the same perceived brightness by the subjects showing two colors on the light guide for different lighting conditions.

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4. Evaluation of the attention threshold: The subject had to watch breathtaking video clips and the light guide reproduced colors from black to maximum intensity. The subjects had to press the push button when they noticed light first.

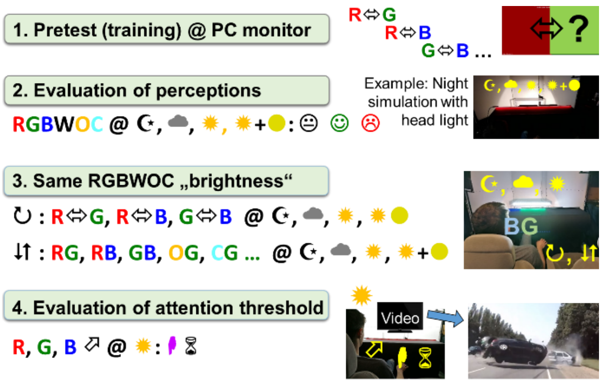

Fig. 4 *Visualization of the four steps of our evaluation.*

4 Results of the Evaluation with Subjects

The 18 subjects consisted of 11 males and 7 females. Eight persons were between 20 and 30 years old, six over 40 years. About half of the participant had an engineering background.

The pretest (#1) verified the lightness threshold $\Delta L^* = 1$ [3] for nearly all subjects when comparing neighboring colors. Fig. 5 shows the results for test #2, where the subjects had to adjust the luminance for different lighting conditions. For all subjects, the “usual” order of luminance (B < R < G, see e.g. Tab. 1) was observed. The most essential value for systems design in “sun + blinding” where males reached about 1,000 cd/m² for blue as “annoying”. The value for females was a factor of five lower which applies for all of these tests.

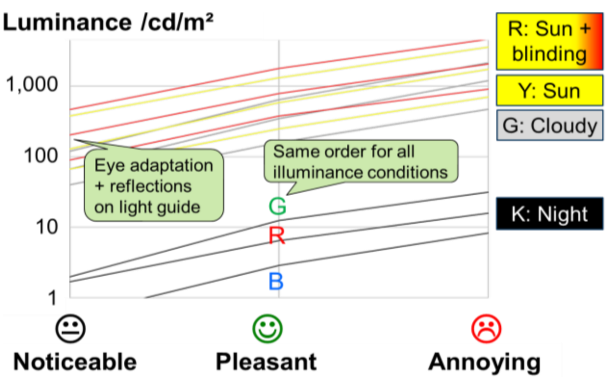

Fig. 5 *Luminance values (#2) for different light conditions.*

The next step (#3) in the user study was to set the color on the right side of the light guide to the same perceived brightness as the left one (reference). The results are visualized in Fig. 6: The judgement (brighter, same, darker) is plotted over the measured luminance ratio for the combinations B & G, R & B and G & R. A RGB ratio of 32 : 44 : 24 was extracted but with large deviation (“hard to adjust”).

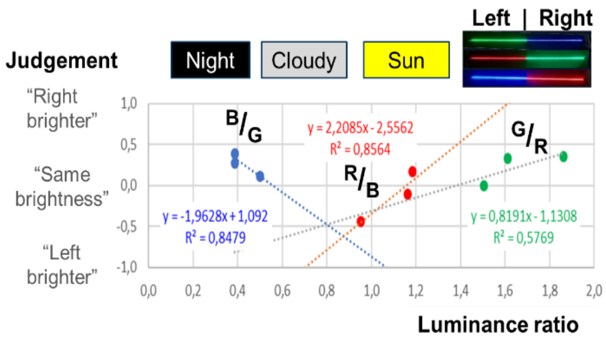

Fig. 6 *Results of the same brightness (#3) for RGB.*

The attention threshold test (#4) resulted in a minimum luminance at sunlight for blue of about 40 cd/m², 200 cd/m² for green and 100 cd/m² for red (values for men as being twice of women).

5 Summary

The most important findings of our evaluation are:

1. Luminance for white: 3,300 cd/m² for (blinding) sunlight conditions which is lower as the minimum for traffic signs [2] of 8,060 cd/m² @ 40,000 lx. The explanation is that “Scheibenwurzel-Displays” have a partially black dashboard and the hood as background compared to bright sky inclusive white clouds.
2. The RGB ratio (see Tab. 1) is comparable to traffic signs but differs largely form automotive RGB LEDs. In consequence, those LED need to double the blue intensity.

RGB ratio /% of white	Red	Green	Blue
RGB LEDs	28	65	7
Display (typical)	30	60	10
Traffic signs	39	46	15
Our findings	35	50	15

Tab. 1 *RGB ratios of applications vs. our findings*

Our results provide valuable design parameters for “Scheibenwurzel-Displays”. Those light guides increase traffic safety for manual driving. Further evaluations with more subjects and in real environment including cars are recommended.

References

[1] “How the Volkswagen ID.4 communicates with light” *https://media.vw.com/en-us/releases/1466*

[2] European Standard EN 12966-1 “Vertical road signs”

[3] M. D. Fairchild, *Human Color Vision*, (John Wiley, New York, 2013). DOI:10.1002/9781118653128

[4] K. Blankenbach, F. Hertlein, S. Hoffmann: “Advances in automotive interior lighting concerning new LED approach and optical performance,” in *Journal of the Society Information Display* **28**, 655-667(2020). *https://doi.org/10.1002/jsid.887*