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Daylight simulation for the evaluation of rear lamps

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1 Abstract

The backward light signals of motor vehicles are submitting relevant information about the driver's behavior to the proximate traffic. The perceptibility of the discrete light functions of rear lamps is variably influenced by different environmental impact. Considering the lighting conditions at day, twilight and night one can easily imagine that the luminance of a signal light should be adjusted to reach the highest conspicuity. Going into daylight situations, the situation is likely to get even worse. At a non-activated state, a signal light might be generated by the reflection of sunlight, straightly illuminated on rear lamps (phantom light). On top of that the actual signal light is superposed by the reflected sunlight. This could cause a color shift of the signal light (washout effect) and obstructions of the distinct perceptibility.

Figure 1: Extrinsic illumination at the BMW 3 series

According to the actual ECE regulations stop lamps and direction indicators can be designed with different luminance levels for day and night time. In the near future, those two separated light levels will be merged into one range. To define the ideal perceptibility of signal lights, the luminous intensities have to be considered in conjunction with the adaptation luminance.
Hence the occurring luminance distributions have to be recorded and classified.
With a facility for sky and sunlight simulation it is possible to determine the luminous intensities of rear lamps and the rating of the daytime appearance. In addition the simulation can be used for the examination of different lamp concepts regarding the impacts of a superposition with extrinsic light.

2 Adaptation luminance and lighting conditions

Throughout the adaptation process the visual system is capable to cope with a very large range of luminance by continuously changing its sensitivity. This unconscious procedure involves the change in pupil size, the photochemical process of bleaching and regeneration of the photoreceptor pigments and the neural adaptation by synaptic interactions.
The duration of this process depends largely on the magnitude and the direction of the change in retinal illumination as well as the involvement of different photoreceptors. Neural adaptation itself is sufficient to deal with a change in retinal illumination of about 2 to 3 log units in less than a second. Assuming that the occurring luminance distribution induces the state of mere photopic vision, the adaptation process to higher changes than 3 log units of retinal illumination will last a few minutes. Switching from cone to rod photoreceptor operation, the adaptation process might hold up for tens of minutes, while changes from low to high level retinal illumination will be handled much more rapidly.

Considering the fluctuating range and distribution of the perceivable luminances while driving (compare figure 2 to 4), one can easily determine that there is no possibility to describe the actual adaptation status of the driver's visual system. On this account the equivalent adaptation luminances are estimated from the average luminance of road scenes, derived from numerous image-resolved luminance measurements, classified after time of day, solar position and sky cover. The recording was accomplished with the camera mounted behind the windshield, close to the driver's eye location according to the regulations 77/649/EWG, SAEJ941 and SAEJ1050 /1,2,3/. Correction factors are used to compensate the measured transition loss and color shift of the windshield. Due to the insufficient angular range of the used lens (± 29°H and ± 22°V), the recorded luminan ce distribution must be expanded with an appraisal to fit the human field of view.

Figure 2: Road scene at night and luminance distribution with smoothed isolines

Figure 3: Road scene at twilight and luminance distribution with smoothed isolines

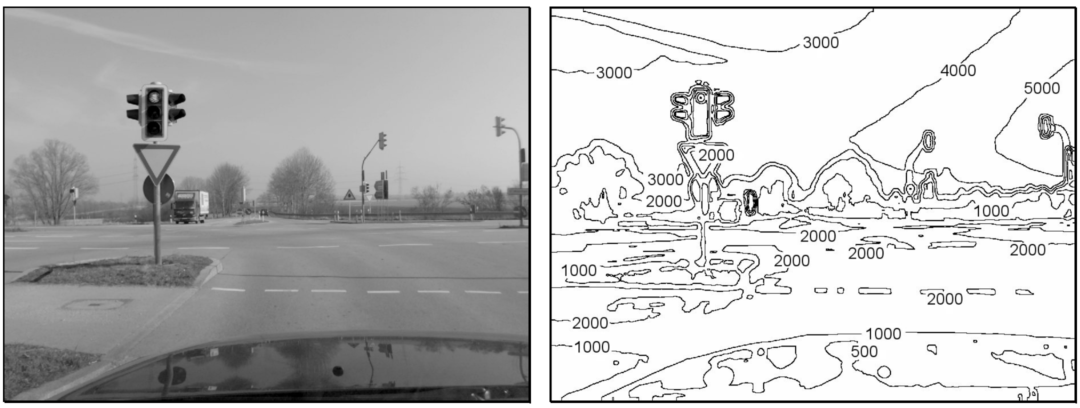

Figure 4: Road scene at day and luminance distribution with smoothed isolines

3 Daylight simulation

So far the reproduction of daylight is restricted to a clear visibility (no rain or fog). The simulation ranges from situations with diffuse lighting due to cloudy skies to bright sunny days with a clear sky.

3.1 Reproduction of the sky

To reproduce the luminance distributions seen by a driver, a perpendicular light wall with a width of 10m and a height of 5m has been installed. The light is produced by 34 horizontal rows made of 6 luminaries, each equipped with two fluorescent lamps. Two rows at a time can be leveled as one unit. Therefore the light distribution is built up by 17 horizontal rows. To generate a homogenous light distribution, a scattering fabric can be positioned in front of the light wall. This assembly is capable to produce a homogenous luminance of more than 10.000 cd/m^2 with a correlated color temperature of 4.400 K.
Figure 5 shows a mock up with several white drapes drawn in to enhance the reflection capabilities of the surroundings.

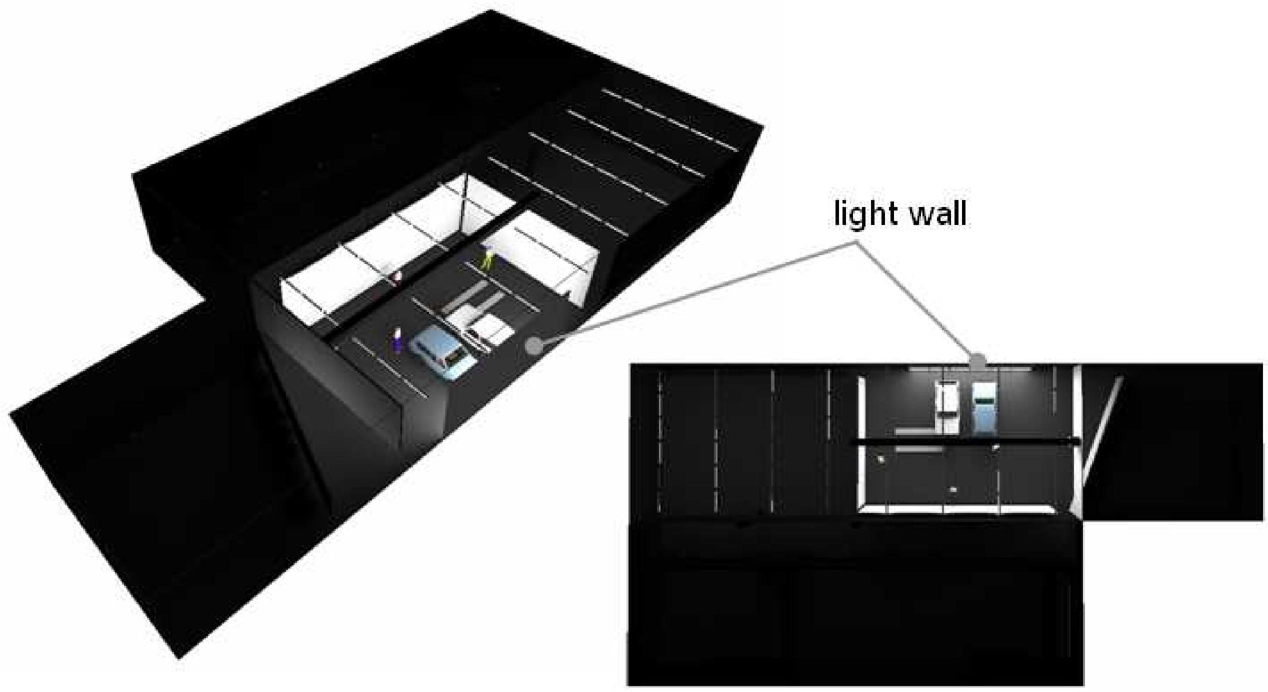

Figure 5: Mock up of the sky simulator

Due to the connection of the rows, the reproduction of luminance distributions comes along with some restrictions. Luminances can only be reproduced horizontally with no sharp cutting lines between the rows. Furthermore the color shift occurring while leveling the fluorescent lamps is inevitable.

The most abstract simulation displays the calculated equivalent adaptation luminance from all over the recorded road scene (see figure 6A). Dividing the recorded scene into 17 rows, the luminance of each row can be calculated and reproduced by the light wall (see figure 6B). On first glance one can make out the two luminance areas above and below the horizon. Setting up such a horizontal division and using two additional polygonal shaped scattering fabrics with different transmission, it is possible to reproduce a scene with almost realistic luminance distributions (see figure 6C). The all over luminance of all three figures are equal. All simulations include the rear view of a car at 25 m distance with stop lights on. For the investigations both a plane, true to scale rear view of a car and a true to scale rapid prototyping volume model might be used.

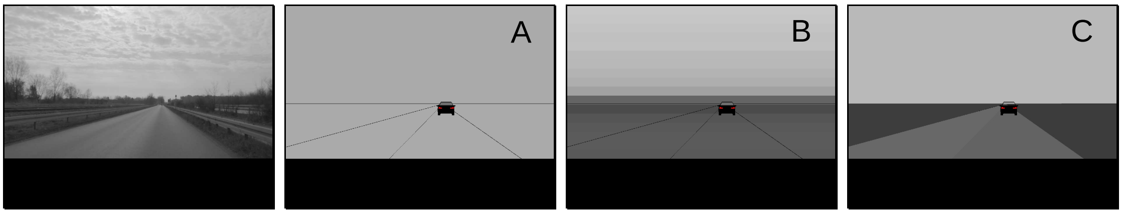

Figure 6: Luminance distribution (grayscale) at day and different simulations

3.2 Reproduction of sunlight

The proposal for an annex to the ECE Regulation Nr. 7 for the measurement of signal color washout determines the extrinsic light source with a correlated color temperature of between 5.000 K and 6.500 K and an illuminance on the surface of the signaling lamp of 40.000 lx with a uniformity of 10 % /4/. To meet these demands a 12.000 watts HMI discharge lamp is used. With a spectral distribution similar to daylight, it is possible to generate an illuminance of about 88.500 lx at a spot of 6° and 10 m distance t o the illuminated object. The lamp can be electronically leveled and special filters might be attached to the housing to simulate different daytime situations. On top of that the lamp is mounted on a moveable lift with a remote-controlled moving head to change the position of the lamp according to different angles of solar illumination.

In combination with a goniophotometer, the lamp can be used to evaluate the extrinsic influences on rear lamp designs.

4 Conclusion

The presented daylight simulation allows the investigation on the most suitable intensities of signal lights according to an estimated equivalent adaptation luminance and the influences of extrinsic light impact. Supplemental to the intensity of a signal light the size of the lamp, the surrounding luminance, the color and luminance contrast as well as adjacent light functions have to be taken into account to qualify the perceptibility of a signal light to the following driver. In view of that another test procedure will be designed to verify the gained results. Furthermore the results have to be transformed into the dynamic world of driving. To define the most effective signal light at all circumstances, daylight simulation is one of the most important tools. But on top of the lamp related influencing factors the actual visibility must be included as it affects the driver's cognition to a great amount.

5 References

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/4/ K. Manz, Colour Washout Test Procedure for Signalling Lamps, Proceedings of the ISAL 2005 Symposium, Darmstadt, 2005