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E-mobility: challenging the human sensory system

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Abstract

Within the upcoming decade, we are going to witness the worldwide breakthrough of e-mobility. Thus the future research and development will focus on this mobility concept. The purpose of this paper is to address potential challenges and consequences of this technological quantum leap with regard to the human sensory system: vision, senses of hearing, touch, position, locomotion/acceleration and their cross-modal interactions.

Most of our information about the world around us comes from our visual system. Future dashboard and interface concepts of e-mobiles intend to distribute visual information over a wide range of the inferior visual field, including the center console and even the interior surfaces of the driver's and passenger's doors. The concept critically interferes with the optical characteristics of progressive additional lenses (PAL) that are the preferred type of correction in elderly, presbyopic motorists: The optical design of varifocals is characterized by a considerable peripheral surface astigmatism, resulting in a remarkable image degradation – especially within the nasal and temporal segments of the lenses. In addition, there are attempts to replace conventional rear-view mirrors of cars by video cameras and video display units (VDU). However, in contrast to mirrors, VDUs are demanding with respect to accommodation (“near-focusing”).

As the aspect of car sharing will gain relevance in the upcoming decade, e-vehicles will interactively sense the motorists’ individual capabilities, needs and preferences. Furthermore they will be able to adapt their usability and physical performance setting to drivers’ individual habits (and not vice versa, as in current concepts). One third of all fatal traffic accidents occurs at nighttime: Future lighting solutions of e-mobiles will have to sense and consider the individual capabilities and handicaps of drivers and adapt their illumination algorithms accordingly.

About 1.5% of the German population suffers from visual impairment (for demographic reasons, the prevalence will increase considerably over the upcoming decades). Visually impaired patients, aged subjects as well as the majority of commuting motorists are eagerly awaiting the realization of assisted or even autonomous driving concepts, which will go hand in hand with the introduction of e-vehicles. This type of drive technology shows remarkable acceleration characteristics. Therefore, individual stress tests are mandatory to assess the critical limitations of translational and radial acceleration/deceleration in order to avoid car sickness in vehicle occupants due to misalignment between the visual and the vestibular input.

Keywords: navigation, research, simulation, automated, user behavior

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1 Physiological Background

In humans, more than 80% of the environmental information is processed by the visual system [1]. For efficiency reasons, only the central visual field region is processed with high spatial resolution, which shows a steep decline towards the periphery [2]. Nighttime driving with dimmed (low beam) headlights is usually performed under mesopic conditions. Human contrast sensitivity and visual acuity decline (by approx. 15 dB, corresponding to a factor of about 30) under dim light conditions, when purely cone-mediated retinal activity is shifted to rod/cone-(mesopic) or even pure rod-mediated (scotopic) function [3, 4, 5].

Due to demographic reason, ageing is the most relevant entity with a considerable impact on mobility. Ageing results in a (individually variable) decline of almost all visual functions. The deterioration of accommodation (i.e. focusing of the human lens towards near objects) starts within the fifth decade and gradually declines towards its minimum at the end of the sixth decade (DUANE´s curve, [6]). As a result, visual detail within close or intermediate distances (e.g. dashboard, video display units for navigation systems etc.) can only be recognized and processed by the help of an adequate near correction.

Rapid gaze movements, so-called saccades, allow for shifting the comparatively small central (foveal) region of the retina – ensuring a sufficient spatial resolution – within a few hundred milliseconds towards individually selected, task-specific regions of interest. However, contrast sensitivity and, as a consequence also visual acuity, decrease considerably during the period of saccadic eye movements by approximately 6 dB (corresponding to a fourfold reduction) [7].

2 Implications on E-vehicles

The number of e-vehicles in Germany has increased exponentially over the past decade: more than 25.000 of this class of vehicles were registered in 2016 [8] and the government is supporting a further (presumably exponential) gain of this number. Due to its accessibility, e-mobility may be of special interest for the increasing group of aged drivers.

As a consequence, e-vehicles will be the main application field for new mobility concepts, including autonomous driving, advanced human machine interfaces (HMI) and innovative lighting features.

Considering the capabilities of the human visual system and the optical design of eyeglasses (with especial reference to progressive additional lenses), relevant information should be condensed, task-specifically adapted and presented within the paracentral visual field, with minimum demands on ocular motility and accommodation. As advanced autonomous driving (level 3 or higher) most probably will not be available in (e-)vehicles over the next decade, high demands on the motorist's sensory and especially visual system

will continue. This holds especially true for nighttime driving (see also Chapter 1 "Physiological Background").
A new driving simulator concept is introduced, generating well-defined environmental and driving conditions – especially heading at nighttime settings, with and without glare: This simulator, situated in the Aalen Mobility Perception & Exploration Laboratory (AMPEL) [9,10], is equipped with two high performance projecting units (Velvet 1600, ZEISS Inc., Jena/FRG), which usually serve for generating special effects/animations on an absolutely dark background in a planetarium. These features are perfect for generating virtual reality environments in driving scenarios under low mesopic or even scotopic luminance levels, as in nighttime driving (see **Figure 1**).

Figure 1: Nighttime driving scenario in the driving simulator of the Aalen Mobility Perception & Exploration Laboratory (AMPEL), created by two high performance projecting units (Velvet 1600, ZEISS Inc., Jena/FRG) illuminating a cylindrical screen in crosswise projection

As usual in any projection setting, the headlights of approaching vehicles are no more than white circular areas of varying sizes with limited luminance levels, corresponding to the (maximum) luminous intensity level of the projecting unit (see **Figure 2**).

Figure 2: Approaching vehicle under virtual reality nighttime driving conditions in the AMPEL lab: A close-to reality glare simulation cannot be achieved within the usual projecting setting: The two headlights of the approaching vehicle are no more than two white circular areas that do not induce any glare sensation. The yellow arrow points to an optotype (LANDOLT C) which is presented via the modified Head up Display (HUD) of the car for dynamic assessment of visual acuity

Thus, close-to reality glare conditions cannot be realized in this kind of setting. In the AMPEL lab, mobile glare sources with varying luminance levels and varying diameters (corresponding to the increase of the viewing angle during the vehicle approach) are used to overcome this problem (see **Figures 3a-c**).

Figure 3a-c: Approaching motorcycle at three different distances (a-c) with a superimposed glare source of varying, adapted diameters and luminance levels, inducing a close-to reality glare sensation. For further details, please see also caption of Figure 2

Electric power trains will realize driving at a minimum noise impact: This is curse and blessing, as the gain of comfort is accompanied by a reduced acoustic feedback to both, motorists and pedestrians. On the other hand, a generally reduced noise level should foster the complementary use of informative as well as reasonable acoustic input with high spatial/directional resolution as a complement to exclusively visual information transfer.

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