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A practical approach to glare assessment for train cabs

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ABSTRACT

The assessment of glare is a key consideration in the design of a railway driver's cab. However, unlike assessment of other factors, such as forward visibility, there are no standardised approaches for performing assessments of glare. This paper describes an approach for assessing the impact of glare in a full size mock-up of a railway cab. While it is unrealistic to evaluate every possible lighting condition that may potentially occur in the vehicle cab in service, a pragmatic and practical approach is taken to provide a good level of indicative information about the cab design's likely glare performance. This involves assessing internal light sources, such as internal lights and illuminated controls, and simulating external light sources (e.g. the sun, other trains' headlights) by illuminating the cab mock up windscreen, side and door windows with a single light source manually located in a sequence of discrete positions and orientations and assessing the resulting glare impacts. The paper describes a structured process for assessing and recording the impact of glare and recommending mitigations.

1. Introduction

Regardless of the mode of transport, be it trains, planes or automobiles, the link between cab or cockpit design and driver performance is clear. A well designed train cab provides reach to all controls, good visibility of well organised controls and instruments, and a suitable view of the external environment.

Well designed cabs have an established positive impact on safety, reliability and efficiency. On a physical level, cabs that provide suitable driving postures reduce the likelihood of a range of driver discomfort and musculoskeletal injuries. On a cognitive level, the layout of the cab has a clear link to performance.

To negate the need for modifications after the train is put into service; an iterative design process should be employed to optimise the design. In addition to reducing the need for rework, identifying potential issues early in the design cycle greatly reduces the overall cost of design. Designs typically start as CAD models and are evaluated through 2D projections and 3D digital models (e.g. Summerskill et al., 2008). As the design develops, simple, low-resolution models are normally built to allow the design to be explored in true 3D. Given the costs associated with the design of a train, full-size mock ups are also usually built. These non-functional models have representative controls and finishes allowing the cab to be assessed before committing to the full production version of the train.

Throughout the design process, some aspects of the cab are easier to assess and demonstrate than others. Reach envelopes and mannequins based on anthropometric data (e.g. Adultdata, 1998) can be used to assess the suitability of the design for the target user group. 2D projections can be used demonstrate reach and visibility of controls. Likewise, in terms of external visibility, standards exist (GM/RT2161 Requirements for driving cabs of railway vehicles, 1995) that describe largely unambiguous test criteria for assessing forward visibility. As such, with each of these aspects of the design, it is relatively simple to devise and test against test criteria to demonstrate the suitability of the design.

When attention is turned to assessing glare, however, the means of assessment is less clear. While it is a widely acknowledged concern (RSSB, 2009; Fullerton, 2009; Thompson et al., 2013), there are no prescribed methods for its assessment.

1.1. What is glare?

Glare is described in ISO 9241-6 as:

"Condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution of range of luminance, or to extreme contrast".

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Glaring sources can reduce our ability to see other objects ('disability' glare), or merely cause annoyance ('discomfort' glare; Vos, 2003). Glare hinders visibility by reducing the total amount of visible light seen. When the eye is exposed to glare, the pupils constrict and limit the amount of natural light transmitted to the retina, and therefore, limit the image that the eye perceives. Glare can also reduce the contrast of the rest of the visual scene by the scattering of the bright light within the eye (Bullough et al., 2002).

There is a large volume of published research material on the subjects of the theory and mechanisms of glare from point light sources under controlled laboratory or field test conditions. It is clear that susceptibility to glare is influenced most by the ambient lighting conditions (day/night), the size and intensity of the light source, the duration of exposure, and the age of the observer (RSSB, 2009). In naturalistic settings, glare from oncoming car headlamps has been the source examined most closely (Fullerton and Peli, 2009; Mace et al., 2001). As identified in a report by the RSSB (2009), there is no published material that may be considered directly relevant to UK train headlamps. However, generic research data on glare illuminance and the susceptibility to glare according to the age of the observer may be applicable.

According to Fullerton and Peli (2009) light scatter inside and out of the eye (i.e., in the windshield) causes a veiling glare which reduces retinal contrast across the visual scene and thus reduces visibility. Different drivers will experience glare in different ways (Ortiz et al., 2013). Changes in the ocular media, brought about by age, eye surgery, cataract or the use of contact lenses and spectacles can all worsen the 'veiling luminance' upon the retina responsible for disability glare. Likewise, according to the RSSB (2009) the level of glare is dependent upon the optical characteristics of the light source and the optical properties of the atmosphere and windscreen between them.

Within a train cab, two types of glare need to be considered; direct glare and reflective glare. A range of light sources can cause direct glare; e.g. the sun, headlights from other trains, internal lights, illuminated controls, and screens. The impact of glare on the driver's performance is influenced by the size, intensity and position of the light source.

Reflective glare is caused by light bouncing off a surface (e.g. a driver's shirt, a display screen, a window, etc). In addition to the above factors related to the light source, the colour and surface finish of the reflective surface influence the impact of reflective glare (RSSB, 2012). The angle of the reflective surface also impacts the intensity and presence of glare. As illustrated in Fig. 1, the angle of incidence equals the angle of reflection. As such, controlling the angle of surfaces in the cab can reduce glare. To maximise readability, controls should be located as close as possible to perpendicular to the driver's eye line.

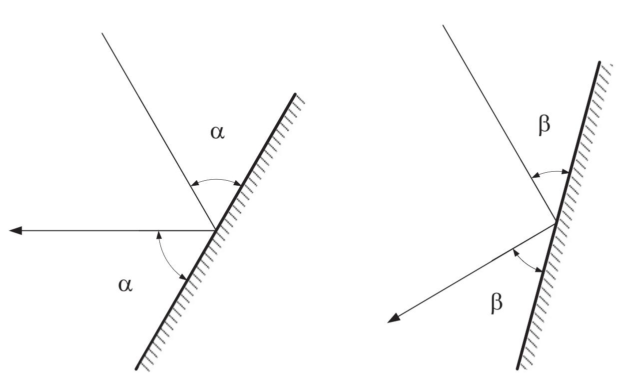

Fig. 1. Reflected light (illustrating the impact of surface angle for the same light source).

1.2. Case study

The approach described in this paper was developed to support the design of the Intercity Express Programme (IEP) Driver's Cab. The project involves the design and manufacture of 122 new trains for the UK's East Coast and Great Western mainlines, increasing capacity and reducing journey times. The first trains are planned to go into service in 2017.

The current design was developed through an iterative process of assessing the developing design's compliance with relevant standards and specifications. Part of the assessment work undertaken involved stakeholder and end user assessments of the proposed design based on paper drawings, low-fidelity mock-ups, and ergonomic rigs (see Jenkins et al., in press) for a description. This process resulted in the design and build of a full size mock up of sections of the passenger saloons and the driver's cab (see Fig. 2 and Fig. 3).

1.3. Design of assessment

There are a number of factors that influence glare. The intensity of the light source, its location, the ambient light conditions, and the atmospheric conditions all impact the level of glare, as does the characteristics of the driver's eye. As a result, the number of potential glare conditions in a naturalistic setting means it is impractical to simulate and assess each in turn. However, a pragmatic and practical approach was taken to provide a good level of indicative information about the cab design's likely glare performance.

The described process divides the glare assessment into two stages; the first assesses the glare caused by internal lighting and the second assesses glare caused by external light sources. The wide range of external light sources was simulated by illuminating the cab mock up windscreen, side and door windows with a single light source manually located in a sequence of discrete positions and orientations and assessing the resulting glare impacts.

The discussed approach relies upon assessing each of a number of conditions in turn, and assessing the level of glare using subjective ratings. More objective measures of glare have been developed. Murray (1999) have made use of the knowledge that discomfort glare is accompanied by a strong flinch in the extraocular (facial) muscles surrounding the eye (i.e., the orbicularis

Fig. 2. Internal view of the train cab mock up.