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Temporal effects on glare response from daylight

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ABSTRACT

A previous series of experiments conducted by the authors under a controlled laboratory setting detected substantive evidence of an effect of time of day, and the influence of various temporal variables, on reported glare sensation from artificial lighting. To substantiate and generalise the postulated temporal effects on glare response, a semi-controlled study was set up in a test room with direct access to daylight and to an external view. Forty participants gave glare sensation votes at three times of day, randomised over different days, while engaging with visual tasks under two shading conditions. Self-assessments of several temporal variables – fatigue, hunger, caffeine intake, mood, prior light exposure, sky condition – were provided by test subjects with their glare assessments. A multilevel statistical analysis of the data – considering factors that were experimentally manipulated (fixed effects) and variables that changed over time (random effects) – confirmed a statistically significant and practically relevant effect of time of day on subjective evaluations of glare sensation. The influences detected showed a tendency towards an increasing tolerance to discomfort from daylight glare as the day progresses. In addition, the variances associated with temporal variables were found to partially confound the effect of time of day on glare response. The results from this study substantiate previous laboratory findings and support the conclusion that the conventional physical and photometric parameters utilised in glare indices and formulae might not be sufficient to consistently describe and predict the occurrence and magnitude of discomfort glare from natural and artificial lighting.

1. Introduction

The subjective sensation of discomfort generated from a glare source is not yet fully understood, and its robust prediction is still characterised by uncertainties, particularly in the presence of daylight [1].

Various studies have investigated whether there may be variables, other than those conventionally included in glare formulae, which might influence the occurrence and magnitude of discomfort glare. Among these, an influence of view interest on glare response was detected in laboratory tests and from a real window [2–4]. Research conducted by Kuhn et al. [5] showed that glare may be more frequently reported by older observers, while Pulpitlova and Detkova [6] found a higher tolerance to glare in Japanese than in European subjects. Akashi et al. [7], Cai and Chung [8], and Rowlands [9] also suggested that glare sensitivity may not be consistent across cultures. Moreover, a potential link between perceived thermal sensation and visual discomfort has recently been hypothesised [10].

A previous series of laboratory experiments conducted by the authors detected a tendency towards greater tolerance to luminance increases in artificial lighting as the day progresses [11]. A follow-up study explored the relationships between visual task difficulty, temporal variables, and glare response at different times of day, revealing that an increased time gap between test sessions resulted in lower glare sensitivity to a constant source luminance along the day [12]. Coherent with the literature [13], when luminance levels for each vote of glare sensation provided by test subjects were regressed, a large scatter was observed. This suggested that there could be other factors varying with time of day, not experimentally controlled, which could influence glare response. Among these variables, statistically and practically significant evidence was found of greater tolerance to source luminance for earlier chronotypes and for subjects not having ingested caffeine. Further trends were detected, postulating an influence of fatigue, sky condition, and prior daylight exposure on glare sensation [14].

On the basis of these earlier laboratory results, and of a

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comprehensive review of the literature presented by the authors in previous work [11,12,14], this study sought to explore the influence of time of day on glare response in the presence of daylight from a window, and analyse the effects of several temporal variables on the subjective evaluation of glare sensation as the day progresses.

2. Methods

2.1. Experimental design and procedure

To investigate temporal effects on glare response from daylight, an experiment was designed using a test room provided with a window and a view to an external natural scene (Fig. 1).

Forty subjects participated to the experiment, which was carried out between the months of March and April, a period of mixed weather varying from overcast to clear skies. Subjects were recruited by purposive sampling via an online advertisement. No criteria were used for the exclusion of volunteers. Participants were all postgraduate students, 12 male and 28 female, varying in nationality and cultural background (20 white, 17 Asian, 1 mixed, and 2 other), the mean age was 25.00 (SD = 2.59), 3 left-handed, 37 right-handed, 15 wore corrective lenses, and all were self-certified as having no other eye problems.

The test room was located at the University of Nottingham, UK (latitude: 52°56′19″N; longitude: 1°11′42″W), and had internal dimensions of 3.45 m × 2.55 m and a ceiling height of 2.35 m. It featured a south-east facing window (azimuth = 165°) of 0.87 m width and 1.47 m height. The room surfaces had reflectance properties of: $\rho_{wall} = 0.6$, $\rho_{ceiling} = 0.8$, $\rho_{floor} = 0.2$. The window was equipped with user-controlled venetian blinds mounted on the internal wall. Each slat of the shading system was convex in shape, with dimensions of 110 cm × 2.5 cm, and a distance of 2.5 cm between each slat. The slats were white in colour, with reflectance of: $\rho_{upper} = 0.90$ and $\rho_{lower} = 0.72$. A workstation (desk, chair, and desktop computer) was placed inside the room at a 45° position from the window. The surface of the desk had reflectance of $\rho = 0.42$, dimensions of 120 cm × 60 cm, and a height of 72 cm from the floor. A flat screen 19″ iiyama ProLite B19065 liquid crystal display (mean self-luminance = 201.64 cd/m^2) was used as the Visual Display Unit (VDU) to present a series of visual tasks to test subjects (Fig. 2).

Fig. 1. Internal view of the test room.

A diagonal arrangement of the workstation was selected instead of a desk positioned parallel or perpendicular to the window, since previous studies conducted under similar layouts found that, when asked to provide a glare assessment, subjects would often deviate their sight from the display and look at the window, while photometric instruments would capture the luminous condition of the VDU [5,15,16]. Conversely, a desk positioned 45° clockwise from the window allowed to mitigate the risk of unwanted head movements between the VDU and the window when glare assessments were made.

The selection of the desk position was also confirmed by a pilot study (N = 10), where a parallel and a diagonal arrangement of the workstation were explored. Coherent with the literature [5,15,16], it was observed that, under the parallel position, subjects would often look directly at the window when asked to provide a glare assessment, while this behaviour was less apparent with the desk placed diagonally. Also, under the parallel set up, there was an unwanted visual parallax effect associated with the location of the workstation, such that the computer screen would partially obstruct certain parts of the window view. These unwanted effects could be minimised under the diagonal arrangement.

The experimental procedure requested subjects to participate to three test sessions, whose order was randomised over three consecutive days, distributed at 3-h intervals:

- Morning: 09:00 or 09:30
- Midday: 12:00 or 12:30
- Afternoon: 15:00 or 15:30

At each test session, subjects were asked to perform two series of three visual tasks [17]. Each series was completed under a different shading setting: a *default* shading, with blinds set at a cut-off slat angle that ensured predominantly diffuse daylight conditions, yet allowing a perception of the external view; and a *user-set* shading, where blinds were adjusted to the subject's own preferences (Fig. 3).

The procedure was consistent with the laboratory tests described in Kent et al. [11,14] and Altomonte et al. [12], although the evening session (18:00 or 18:30) was excluded from this study due to seasonal variation in day length and sunset occurring before its starting time.

During the tests, subjects were asked to make glare assessments using as benchmarks the adaptations of Glare Sensation Votes (GSVs) used by Iwata et al. [18,19], Iwata and Tokura [20], and Mochizuki et al. [21]. These glare criteria correspond to the sensation of visual discomfort experienced: 'Just (Im)Perceptible', 'Just Noticeable', 'Just Uncomfortable', and 'Just Intolerable'. To reduce the risk of self-interpretation, and ensure that the GSVs could be understood by subjects according to the intentions of the experimenter [1], each criterion was linked to a time-span descriptor [22,23].

In the selection of the GSV scale it was considered that, when forcing a continuous dependent variable (e.g., a glare index) into discrete categories associated with subjective levels of glare sensation (i.e., the 4-point GSV scale), there is a risk of unintentionally making respondents report a stimulus that does not accurately reflect their perceived evaluation of that stimulus [1].