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Visual task difficulty and temporal influences in glare response

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ABSTRACT

The literature suggests that glare sensation may be influenced by visual task difficulty. Previous research by the authors provided reasons to infer that the perceived level of visual discomfort may vary with time of day and be affected by temporal and personal factors. The study presented here explores the postulated relationships between visual task difficulty, temporal variables, and glare response as the day progresses. Under controlled laboratory conditions, twenty subjects were exposed to a constant artificial source luminance at four times of day and gave glare sensation votes while completing twelve visual tasks of various difficulties. Self-assessments of temporal variables (fatigue, food intake, caffeine ingestion, mood, previous daylight exposure and sky condition) were provided by test subjects together with their glare judgements. Statistical analysis of responses confirmed that the time interval between test sessions showed a direct relationship to the increased tolerance to artificial source luminance along the day. The temporal variation of glare response was found to be influenced by the difficulty in extracting information from the visual stimulus. Moreover, statistically significant and substantive evidence was detected of a direct effect of fatigue and caffeine ingestion, and an inverse influence of food intake, on reported glare sensation. Consideration of inferential results from all test sessions led to hypothesise that some temporal variables may interact with each other and significantly affect the variation of glare response at different times of day.

1. Introduction

Discomfort glare is a phenomenon that has not yet been completely characterised [1,2]. Other than the factors typically embedded in glare formulas (e.g., source luminance, background luminance, solid angle, position index, etc.), several additional parameters have been associated with the occurrence and perceived magnitude of visual discomfort. Among others, various studies have investigated the potential relationship between task difficulty, visual performance, and subjective glare sensation.

Conventionally, the ability to extract information from a visual stimulus has been considered independently from *discomfort glare* [3]. In fact, in the literature, visual impairment and reduced performance have been predominantly linked to *disability glare*, whereas in the presence of discomfort glare the observer may not experience any immediate direct effect on task visibility [4]. Boyce [1] and Sivak et al. [3] stated that disability and discomfort glare may be regarded as part of the same phenomenon, and that the mechanisms behind these two types of glare may not be as different as commonly assumed, although they are generally discerned by the ranges of luminance in the visual field. Hitherto, in most cases, the magnitude of the perceived impairment resulting from discomfort glare is considered to be lower than disability glare [5].

According to Boyce [1], visual discomfort can result either from a combination of photometric conditions present in the environment or from the visual task itself. The variation of glare sensation has been associated to the size and contrast of the task; as these augment, visual performance (i.e., speed and accuracy) increases and discomfort reduces [6,7].

Ostberg et al. [8] provided evidence of a dependence of discomfort glare on the difficulty of the task that is being executed. In their study, the same luminous source was reported as more discomforting if the concurrent task was relatively difficult. In a subsequent study, Gunnarson and Ostberg [9] described an interaction whereby discomfort glare was rated greater at higher task difficulty, with objective lighting conditions held constant. Likewise, ratings of task difficulty changed with variation in the

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perception of glare.

Sivak et al. [3] demonstrated an effect of task difficulty on discomfort glare by varying the size of a gap that subjects had to detect in a stimulus that was presented simultaneously with a glare source. More discomfort was reported when the gap was smaller and, thus, harder to locate. In their study, however, the gap location task was always required, hence making it difficult to infer whether, or to what extent, the effect of gap size on discomfort ratings depended on the gap stimulus being made explicitly relevant. In a follow-up work [10], gap size was varied in factorial combination with whether the gap location task was required, also including changes in the luminance of the gap stimulus as a second way of varying task difficulty. The results confirmed that glare evaluation was affected by the presence and nature of a concurrent visual task. In addition, the findings suggested that stimulus luminance influenced discomfort ratings even when the stimulus was not relevant to task performance.

Dugas and Wierwille [11] studied whether measures of reading performance are affected by short exposure text on a visual display terminal (VDT) when glare is present. In a preliminary experiment, reading passages were ranked according to subjective difficulty. Their findings suggested the presence of a reliable interaction between glare and task difficulty, but also led to hypothesise that, when faced with glare on a VDT, subjects may choose some method of compensation for its effects, such as reducing their time of exposure to the stimulus.

In a study conducted under artificial lighting conditions and utilising a visual display terminal containing paragraphs of randomly generated pseudo-words, Osterhaus and Bailey [12] found reduced visual performance under high levels of glare sensation. Their study also emphasised that decreases in task performance were likely to be expected with longer exposure to the glare source due to fatigue and potential distraction. Lynes [13] also contemplated a relationship between glare and distraction, which could affect the processing of visual information. In this context, however, Boyce [14] stated that human factors may be more important than physical factors in affecting visual performance, and suggested that discomfort glare studies based on task difficulty should remove the effects of distraction and motivation since they may have an indirect influence on visual task efficiency.

Rodriguez and Pattini [15] used a Reading Span Task (RST) displayed on a visual display terminal to show that measurable dependent differences in glare sensation could be detected upon consideration of task-related and behavioural factors, and changes in visual fixation point between the VDT and the glare source. Coherent with previous work [16], the size of the glare source was found to have statistically significant effects on the RST.

Similarly, Ko et al. [17] studied the effect of age, font size, and reflected glare from bright LED task light on performance for visually demanding text-based tasks on a computer screen. The VDT location was fixed, but subjects were allowed to move their posture. The results indicated that, as font size increased, so did performance, accuracy, and viewing distance, while perceived task difficulty decreased regardless of subjects' age. Adding reflective glare on the VDT led to a reduced viewing distance but had no effect on performance or accuracy.

In essence, a review of the literature suggests likely connections between visual performance, perceived task difficulty, and luminous conditions that could lead to discomfort glare [18]. However, the variation of such relationships over the time of day has not yet, to the authors' knowledge, been explored in detail.

Previous research by the authors [19,20], conducted under a controlled laboratory setting, provided significant and substantive evidence of growing tolerance to luminance increases in artificial lighting as the day progresses. This trend was found to be particularly apparent for earlier chronotypes (a personal attribute reflecting individual circadian phases that indicates at what time of day physiological functions are activated [21]) and for subjects not having ingested caffeine. In interpreting these findings, it was hypothesised that the abstraction caused by the artificial lighting glare source, and the request to report visual discomfort in terms of Glare Sensation Votes (GSVs, i.e. benchmarks corresponding to the level of glare sensation experienced: 'Just Perceptible', 'Just Noticeable', 'Just Uncomfortable', and 'Just Intolerable'), could be among the causes for the large scattering detected when individual glare responses were regressed against the source luminance. In fact, although in the tests the GSV criteria were linked to time-span descriptors to aid participants giving more meaningful judgements [22], subjects had no task-related stimulus to associate their visual perception to.

On the basis of the literature and of previous findings, the study presented here sought to investigate the influence of inclusive features and difficulty of the visual task, and the potential effect of several temporal variables, on the subjective evaluation of glare sensation as the day progresses.

2. Method

2.1. Experimental design

A systematic experimental design approach was adopted to respond to three research aims:

1. The first aim consisted in searching for temporal variations in the perceived level of glare sensation when subjects performed twelve visual tasks at distinct times of day. Individually for each visual task, differences between glare responses along the day were analysed so as to substantiate (or challenge) the previously detected increase in tolerance to artificial source luminance as the day progresses [19].
2. The second aim involved comparing temporal differences in glare response across groups of visual tasks at various times of day. Thus, the influence of task manipulation and difficulty over the postulated effect of time of day on glare sensation was analysed.
3. The third aim intended to study the influence of several temporal variables on the glare response provided by test subjects while engaging with visual tasks. This was to deepen the exploration of the role of temporal factors on glare sensation along the day [20].

The experimental method developed for this investigation derived from the procedures that Tuayacharoen and Tregenza [23] and Flannagan et al. [10] adopted to analyse the influence, respectively, of view interest and task difficulty on the perception of discomfort glare. An apparatus similar to earlier experiments was retained for this study [19].

The lighting chamber was semi-hexagonal in plan, with interior surfaces (2.70 m in height) painted matte white (Fig. 1). Three 3 W LED lamps, mounted from above, produced a background luminance of 65 cd/m^2 with a warm white light (2700 K). The subject's eye position was located at a height of 1.20 m from the floor, facing a glare source represented by a small diffusive screen (8 cm $\times$ 4 cm) made from two sheets of tracing paper; this was mounted in front of a projector connected to a computer controlled by the experimenter. The source of glare subtended an angle at the eye of 0.009 steradians. The visual stimulus comprised reading tasks of various difficulty that subjects were requested to perform at different times of day when providing votes of glare sensation. To refine the setup, a series of pilot tests (N = 3) was completed to determine the