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DISCOMFORT GLARE IS TASK DEPENDENT

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16. Abstract

This laboratory study evaluated the effect of task difficulty on discomfort glare. Two tasks were performed on each trial. The first was a gap-detection task, in which the subject indicated whether the gap had appeared on the top or the bottom edge of the outline of a briefly projected square. The difficulty of this task was manipulated by changing the size of the gap in the square. The second task was a discomfort-glare rating, in which the subject gave a numerical rating of the discomfort experienced from a glare source that was presented simultaneously with the gap-detection stimulus. The hypothesis was that the resulting changes in the difficulty of the gap-detection task would influence discomfort glare.

The results indicate that (1) as expected, discomfort glare was strongly influenced by glare illuminance, (2) an increase in the difficulty of the gap-detection task resulted in an increase in discomfort glare, and (3) the subjects with poorer overall gap-detection performance tended to assign more discomfort to the glare stimuli than subjects with better overall gap-detection performance. These results are consistent with the hypothesis that discomfort glare is related to task difficulty. Consequently, a valid evaluation of discomfort glare in a given situation requires the presence of the relevant concurrent visual task. One possible interpretation of these findings is that task difficulty influences discomfort glare by modifying an observer's perceived level of visual impairment (perceived disability glare).

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CONTENTS

INTRODUCTION

The presence of a bright light in the visual field can result in a phenomenon called glare. In the context of road safety there are many potential glare sources, such as vehicle headlamps, vehicle rear lights and signals, as well as street lighting. The traditional view (e.g., Holladay, 1926; Hartmann, 1962; Adrian, 1968) is that glare has two separate effects on the observer. The first aspect—disability glare—refers to an objective impairment in visual performance. Disability glare is thought to be primarily the consequence of veiling luminance resulting from light scattering in the optical media (Stiles, 1929; Fry, 1955). The other aspect of glare—discomfort glare—refers to a subjective impression of discomfort. Discomfort glare is thought to be related to the degree of the brightness inhomogeneity (difference) between the glare source and its background (Schmidt-Clausen and Bindels, 1974). However, the physiological origin of this psychological phenomenon is not known.

The nature of the relationship between discomfort and disability glare is not completely clear. Over the range of conditions that a driver typically experiences at night the two effects must be highly correlated: both discomfort and disability will increase monotonically with the illuminance at a driver's eyes from oncoming headlights and other glare sources. In spite of this overall agreement, the two effects may diverge enough that it might be necessary to measure them both in order to assess comprehensively the glare effects of a stimulus. For example, Schmidt (1966) argues that "all disability is also discomfort glare, but glare can cause discomfort without impairing visual functions" (p. 12). On the other hand, there is some evidence that disability glare can occur in situations that are thought to be unlikely to result in discomfort glare. For example, Mortimer and Olson (1974) obtained disability glare effects for low beam headlamps at 914 m (3,000 ft)—a distance that is considered to be too great to elicit any discomfort glare.

Despite the uncertainty about the relation of discomfort to disability glare, the concept of two separate effects of glare is dominant in the contemporary theory of lighting performance. For example, CHESS, currently the most frequently used computer model of headlamp performance, is based on both disability and discomfort glare considerations (Bhise, Farber, Saunby, Troell, Walunas, and Bernstein, 1976).

The idea that discomfort and disability glare are consequences of separate mechanisms has been reflected in the methods used to study discomfort glare. Although performance on a visual task is necessary for measuring disability glare, traditional studies of discomfort glare have been based on the assumption that discomfort is independent of visual task demands. In a typical discomfort-glare study, the subject is not shown a target to be detected or a stimulus to be identified. The subject is presented only with a glare source to be evaluated. There is reason to question the assumption on which such procedures are based. The discomfort that a subject feels when exposed to a glare source may depend partly on the difficulty of a visual task that the subject is concurrently engaged in. This could be the case if the subject (incorrectly) attributes poorer performance on a more difficult task to the influence of the glare source. If so, in order to be valid for road-safety applications, measurements of discomfort glare would have to be done in the context of an appropriate visual task. Also, an effect of task difficulty on discomfort ratings would indicate that the mechanisms responsible for discomfort and disability glare are not so distinct as previous investigations of discomfort glare have assumed.

The present study was designed to investigate whether discomfort glare ratings are influenced by visual task difficulty. Specifically, difficulty was manipulated for a task that had to be performed in conjunction with the discomfort rating of a simultaneously presented glare stimulus. The hypothesis was that an increase in task difficulty would result in an increase in reported discomfort glare for a given glare stimulus.

METHOD

Tasks

Two tasks were performed on each trial. The first was a gap-detection task, in which the subject indicated whether a gap had appeared on the top or the bottom of a briefly-projected outline square. The second was a discomfort-glare rating, in which the subject gave a numerical rating of the discomfort experienced from a light source which accompanied the presentation of the gap-detection stimulus.

Equipment

Schematic diagrams of the experimental set-up and the subject's view are shown in Figures 1 and 2. The subject was seated facing a rear-projection screen, at a distance of 6.1 m. Black tape (1.9 cm wide) delineated a 28 × 28 cm area bordering the left edge of the screen. A random-access slide projector located behind the screen was used to project a gap-detection stimulus (described below) into the center of the taped square. A second random-access slide projector, immediately adjacent to the left edge of the screen, provided the glare source. The center-to-center distance between the glare source and the projected gap-detection stimulus was 26.7 cm (a visual angle of 2.5 degrees as viewed by the subject). Neutral density filters mounted in slide holders provided the three levels of glare used: 3.09, 0.60, and 0.18 lx. Both slide projectors were equipped with automatic, remote-controlled shutters which were electronically coupled to provide synchronous 1-second presentations of the glare light and the gap-detection stimuli.

A large panel with a 9-point rating scale for discomfort glare, printed in black letters on a white background, was posted at a distance of 2.5 m from the subject. The letters were 1.9 cm high and subtended approximately 26 minutes of arc. This chart was offset so that it appeared to the right of the area in which the gap-detection stimulus appeared.

Ambient illumination was provided by a small 25 W lamp positioned in a corner of the room, behind the subject. The resulting, non-uniform, background luminance was measured at two locations with a Pritchard photometer. The luminance was 1.1×10^{-2} cd/m^2 at the position on the projection screen in which the stimuli appeared, and 7.2×10^{-2} cd/m^2 at the center of the response panel.

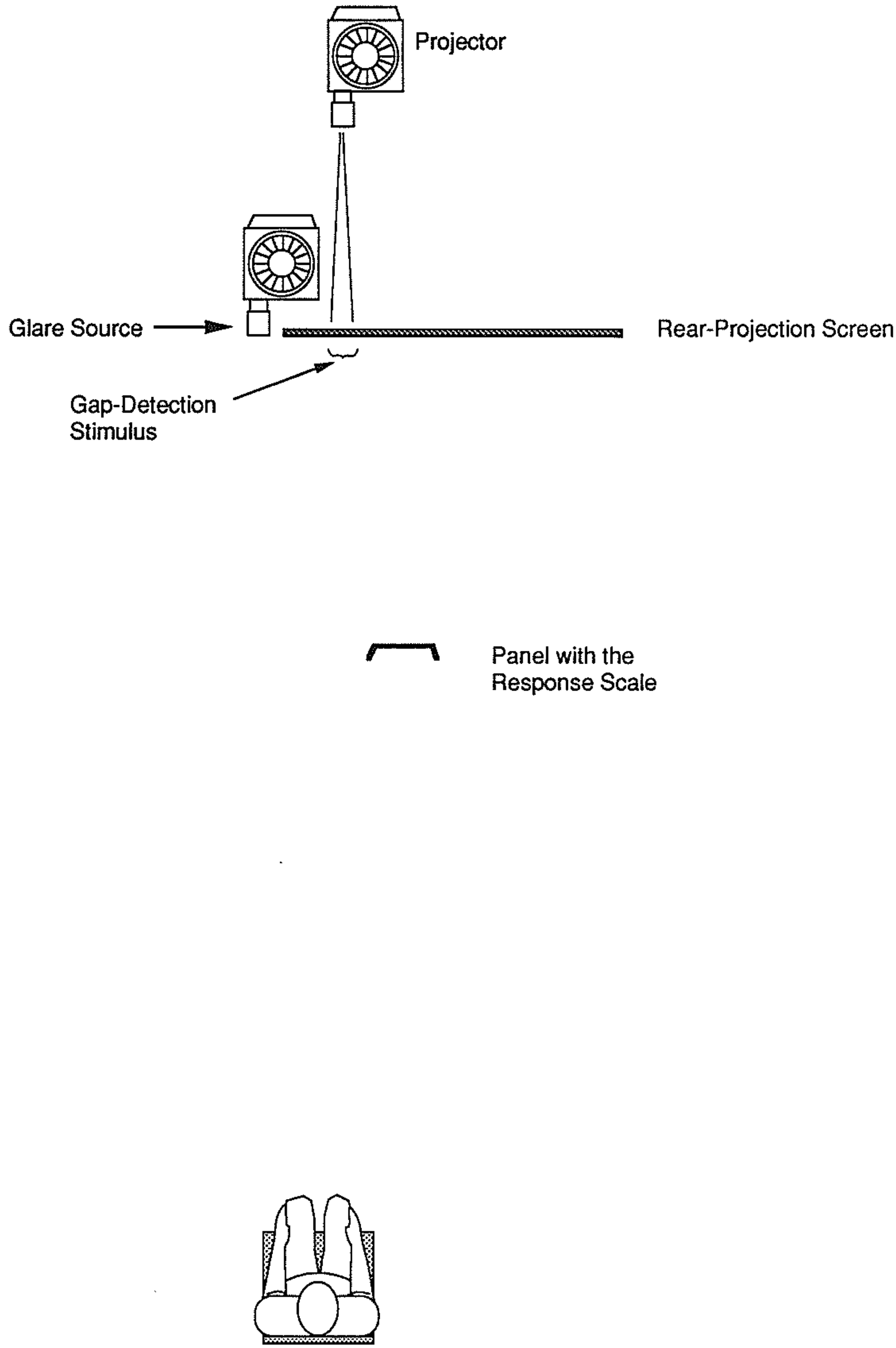

Figure 1. A schematic diagram of the experimental set-up.

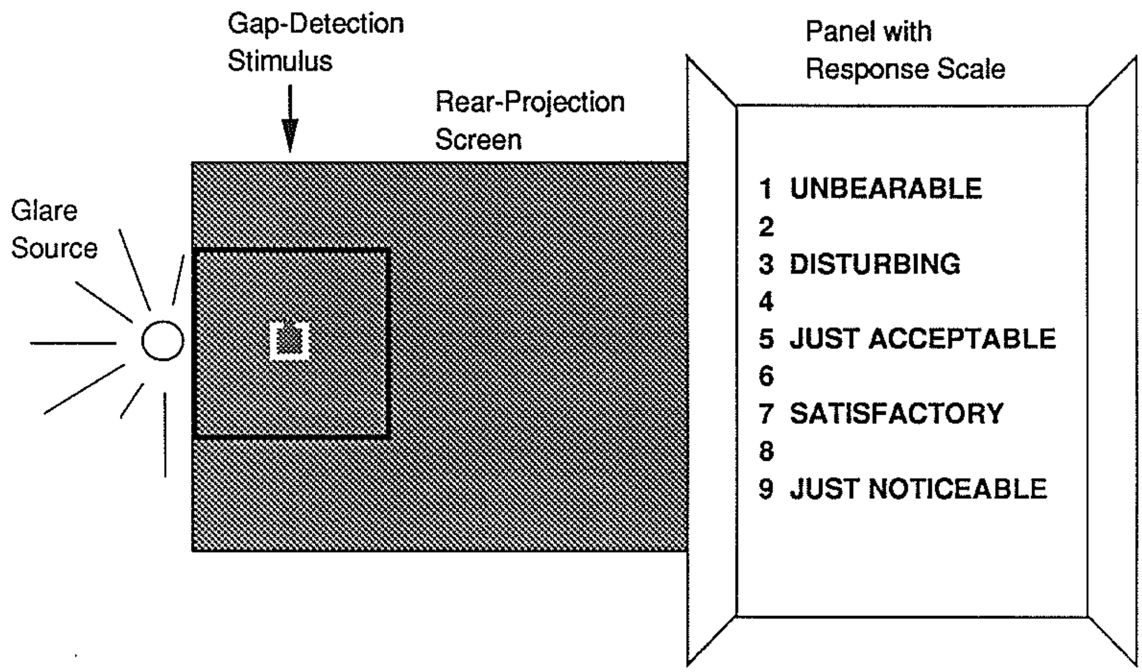

Figure 2. A schematic diagram of the subject's view.

Gap-detection stimuli

The stimuli for the gap-detection task were outlines of squares subtending 10.2 minutes of arc in height and width, with a stroke width of 2.3 minutes. There were three gap sizes (2.59, 1.38, and 0.17 minutes of arc), each of which appeared in both positions (in the center of top or bottom edge of the square). Each of the stimuli projected about 2×10^{-6} lx towards the eyes of the subject.

Response scale

Subjects were asked to use a 9-point scale for their assessment of discomfort glare. This scale, which is a minor modification of a scale used by de Boer (1967), has qualifiers only for the odd points as follows: 1 (unbearable), 2, 3 (disturbing), 4, 5 (just acceptable), 6, 7 (satisfactory), 8, 9 (just noticeable).

Subjects

Twelve subjects, six males and six females, participated in this study. Their ages ranged from 21 to 29 years. Subjects were paid for their participation.

Design

There were 18 trial types (3 glare levels × 3 gap sizes × 2 gap positions). A block of trials consisted of a random arrangement of these 18 trial types. Each subject was given one practice block followed by five experimental blocks of trials.

Procedure

Subjects were tested individually. Subjects were told that on each trial a small white outline of a square would appear briefly in the center of the taped fixation area of the projection screen. The square would contain a small gap in the center of either the top or the bottom edge. In addition, there would also be a light to the left of the stimulus. The square and the light appeared simultaneously for 1 second. Subjects were asked to keep their fixation close to the center of the area bordered by the tape, and not to look directly at the glare source. Subjects responded verbally on each trial, first by saying "up" or "down" to indicate the position of the gap, and then by giving a number (1 to 9) to indicate the subjective discomfort from the glare source. The inter-trial intervals were approximately 15 seconds. At the start of the experimental blocks of trials, subjects had been adapted for about 8 minutes to the prevailing ambient illumination.

RESULTS

Glare ratings

The mean glare ratings by glare illuminance and gap size are shown in Figure 3 and Table 1. The results of an analysis of variance on discomfort-glare ratings (with glare illuminance, gap size, and sex of the observer as factors) were as follows: The effect of glare illuminance was statistically significant, $F(2,20) = 149.7$, $p < 0.0001$, as was the effect of gap size, $F(2,20) = 27.66$, $p < 0.0001$. The effect of sex of the observer (not shown in Figure 3 or Table 1) was not statistically significant, $F < 1$. From among the interactions, only the effect of glare illuminance × gap size was statistically significant, $F(4,40) = 18.63$, $p < 0.0001$.

Gap detection

The percentages of correct responses on the gap-detection task by glare illuminance and gap size are shown in Figure 4 and Table 2. The results of an analysis of variance on percentages of correct responses (with glare illuminance, gap size, and sex of the observer as factors) were as follows: The *general* effect of glare illuminance was marginally not significant, $F(2,20) = 2.64$, $p > 0.05$. (However, the *linear* effect of glare illuminance on percentages of correct responses was statistically significant, $t(20) = 2.25$, $p < 0.05$.) The effect of gap size was statistically significant, $F(2,20) = 50.69$, $p < 0.0001$. The effect of sex of the observer (not shown in Figure 4 or Table 2) was not statistically significant, $F(1,10) = 1.12$, $p = 0.32$. No interaction was statistically significant.

Relationship between glare ratings and gap detection

The relationship between the mean glare ratings and percentages of correct responses on the gap-detection task by individual subjects is shown in Figure 5. The correlation coefficient for all 12 subjects was $r(10) = 0.44$, $p > 0.05$. If, however, the one subject with the outlying correct responses (see Figure 5) is not included, then $r(9) = 0.81$, $p < 0.01$.

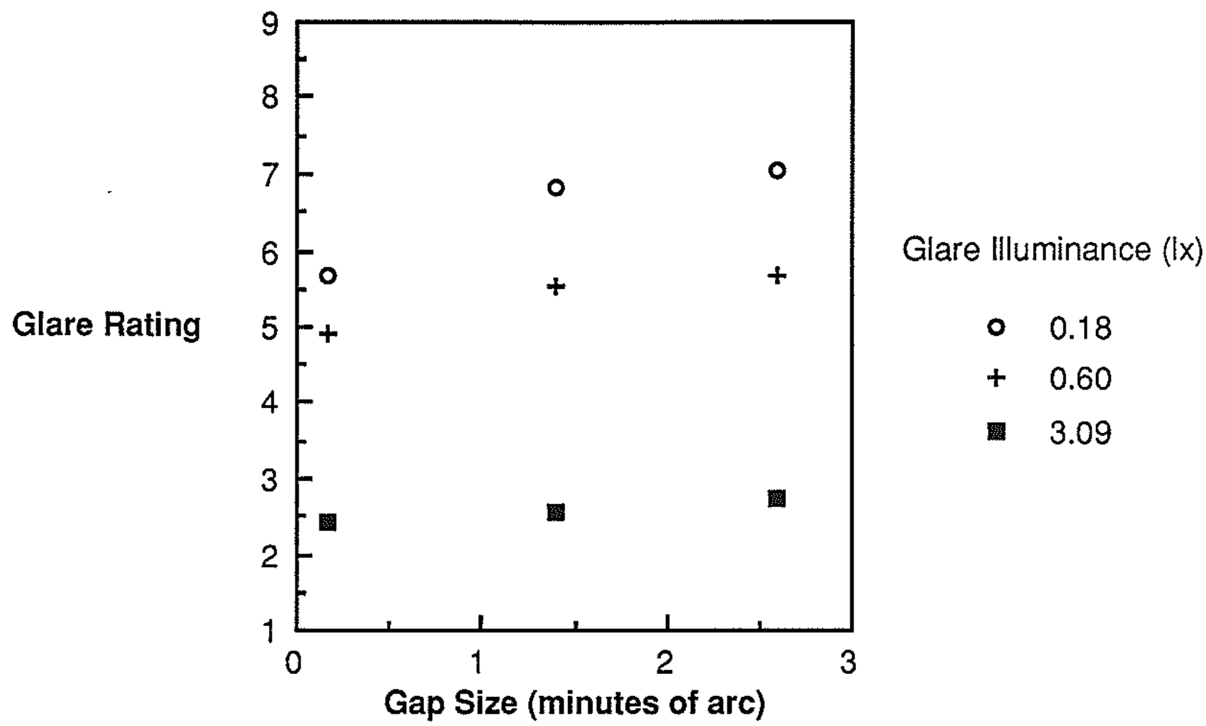

Figure 3. Mean glare ratings by glare illuminance and gap size.

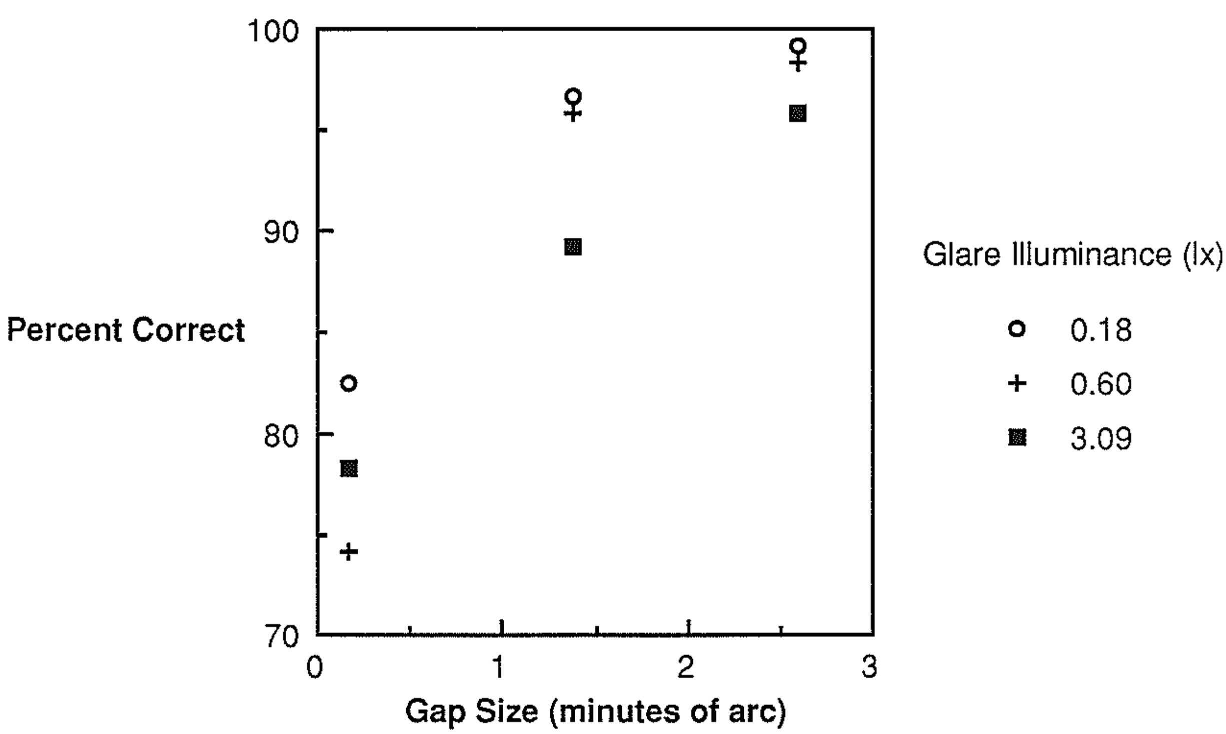

Figure 4. Percentages of correct responses by glare illuminance and gap size.

Table 1
Mean glare ratings by glare illuminance and gap size.

Gap size (minutes of arc)	Glare illuminance (lx)			Mean
	0.18	0.60	3.09	
0.17	5.67	4.93	2.40	4.33
1.38	6.83	5.54	2.57	4.98
2.59	7.06	5.66	2.72	5.14
Mean	6.52	5.38	2.56	4.82

Table 2
Percentages of correct responses by glare illuminance and gap size.

Gap size (minutes of arc)	Glare illuminance (lx)			Mean
	0.18	0.60	3.09	
0.17	82.5	74.2	78.3	78.3
1.38	96.7	95.8	89.2	93.9
2.59	99.2	98.3	95.8	97.8
Mean	92.8	89.4	87.8	90.0

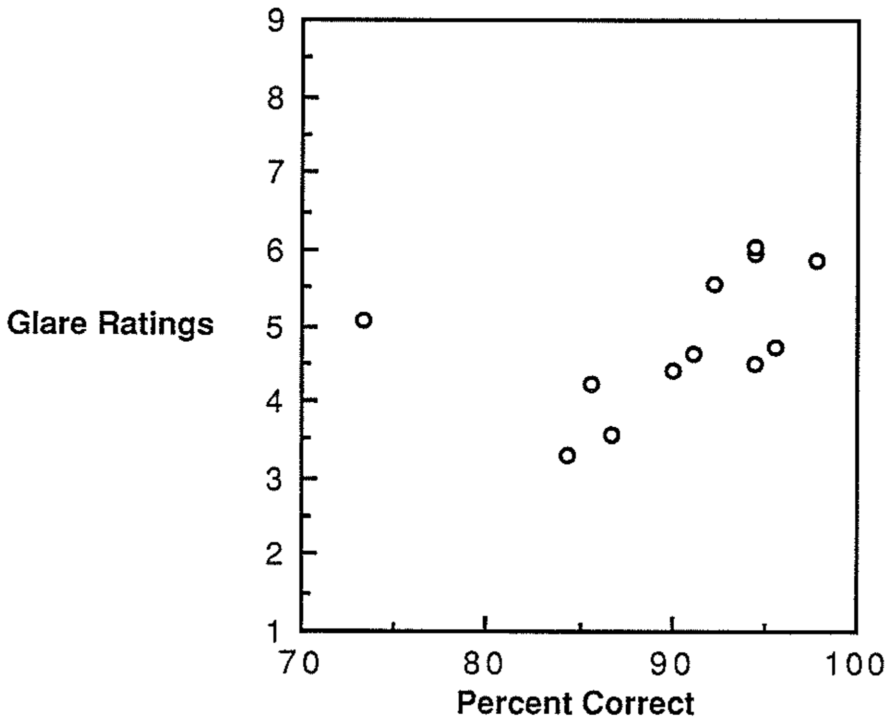

Figure 5. Mean glare ratings and percentages of correct responses by subjects.

DISCUSSION

General

The major finding of this study is that task difficulty affects discomfort glare: smaller gap sizes in a gap-detection task resulted in more discomforting glare responses concerning a simultaneously presented light source. This finding is incompatible with any conceptualization of discomfort glare that ignores the concurrent visual task the observer is engaged in. In other words, the present results suggest that discomfort glare is task dependent. Consequently, valid assessment of discomfort glare requires inclusion of the relevant visual task the observer is involved in during the presentation of the glare stimulus.

The effect of task difficulty on discomfort glare was greater at low levels of glare illuminance than at high levels of glare illuminance. This finding is consistent with a so-called *ceiling/floor* effect: at high glare-illuminance levels discomfort glare is already high for large-gap conditions (see Figure 3), and thus any additional increases in the discomfort glare are restricted by the nearness of the end of the response scale.

What is the mechanism of the influence of task difficulty on discomfort glare? One possibility is that task difficulty influences the perceived level of visual impairment which, in turn, is (incorrectly) attributed by the observer to the influence of the glare source. In other words, this hypothesis states that task difficulty affects discomfort glare by modifying the observer's perceived level of visual impairment (*perceived* disability glare).

The effect of task difficulty on discomfort glare appears to hold both within and between subjects. At the within-subject level, a given glare source was rated as more discomforting when it accompanied a difficult visual task than when it accompanied an easy visual task. At the between-subject level, subjects with poorer overall visual performance tended to assign more discomfort to a given glare source than subjects with better visual performance.

Consequences for models of discomfort glare

The influence of concurrent task difficulty on discomfort-glare ratings has not been considered in developing models of discomfort glare. For example, the equation for discomfort-glare ratings proposed by Schmidt-Clausen (1974) has parameters for three stimulus conditions: (1) intensity of the glare source, (2) luminance of the background, and (3) the angle between the glare source and the observer's fixation point. Interestingly, Schmidt-Clausen and Bindels did include a visual task in the procedure that they used to collect the discomfort-glare data on which their model is based, but the task was used only to insure that subjects maintained fixation at the proper location. They made no attempt to include task difficulty in their model.

The inclusion of task difficulty in a model for discomfort glare leads to interesting differences in predictions for how certain variables will affect discomfort. For example, consider the types of visual conditions that would lead to greater scattering of light and a resulting greater veiling luminance across the visual field. Such conditions include fog, a dirty windshield, cataracts, and a high level of opacities in the vitreous body (one of several characteristics of the eyes of older drivers). Those conditions would be expected to increase the disability effects of a glare source because increased veiling luminance would decrease target contrast (Fry, 1955), but how would they affect discomfort?

A model such as that of Schmidt-Clausen and Bindels predicts that discomfort should increase when glare intensity increases or when average background luminance decreases. That agrees with intuition because discomfort is predicted to be greatest when the distribution of light in the visual field is least homogenous, i.e., when there is a small, intense source in an otherwise dark field. In that situation, the scattering of the light from the glare source by a condition such as fog or vitreous opacities should have two effects on the pattern of retinal illumination. It should decrease the peak intensity of the image of the glare source, and it should increase the illuminance of the rest of the retina. Both of those conditions should decrease the level of discomfort glare according to models (such as Schmidt-Clausen and Bindels') that consider glare intensity and background luminance, but not task difficulty. If there is a concurrent task, however, its difficulty will be increased because of the veiling luminance. Thus a model that incorporates an effect of task difficulty on discomfort might actually predict the opposite effect: increased discomfort due to light-scattering conditions. The actual direction of the effect would clearly depend on the relative strengths of the opposed influences of task difficulty and homogenization of light distribution. Further study, with attention to the effect of disability on discomfort glare, may be able to clarify the situation.

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