EFFECTS OF PRIOR HEADLIGHTING EXPERIENCE ON DISCOMFORT GLARE

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16. Abstract

This study investigated the effects of prior headlighting experience on discomfort-glare ratings in an actual driving situation. Specifically, discomfort-glare ratings of recently arrived West Germans in the U.S.A. (who were presumably used to the relatively low levels of glare associated with ECE headlamps in Germany) were compared with ratings of U.S.-born subjects. The West German subjects reported higher levels of discomfort glare than did the U.S. subjects. This finding is in agreement with the so-called range effect, in which subjective judgements are affected by the range of available stimuli. Consequently, although a language-based explanation cannot be ruled out, the present findings support the hypothesis that discomfort-glare ratings are affected by prior experience.

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CONTENTS

INTRODUCTION

Discomfort glare—subjective impression of discomfort from bright lights—is one of the main reasons for the differences in the U.S.A. and European (ECE) headlighting standards. Because of a greater concern in Europe with discomfort glare, the European headlights produce lower levels of illumination above and to the left of the lamps' axes (Olson, 1977). Thus, when properly aimed, European headlights deliver less light towards the eyes of the oncoming drivers. However, are European drivers indeed more bothered by glare than are their counterparts in the U.S.A.? Until now no comparable cross-national field data have existed.

The reason for the lack of relevant cross-national field data has been the absence of a standardized field methodology for evaluating discomfort glare. Consequently, the aim of our previous research (Sivak and Olson, 1988) was to collect information and experimental data towards the development of such a methodology. Three separate studies were performed: (1) an international survey of experts in headlighting and vision, soliciting opinions on desirable aspects of such a methodology; (2) a field evaluation of a proposed methodology at a speed of 50 km/hr; and (3) a field evaluation at 100 km/hr. The findings of this research suggest that the proposed methodology (a) is easy to set up and implement; (b) provides reliable data (there were no differences in glare ratings over replications); (c) provides valid data (the glare ratings were related to the amount of light reaching the eyes of the observer and were sensitive to the glare angle); and (d) is efficient with respect to data collection (glare ratings were the same whether the rater was a driver, center-front passenger, or right-front passenger).

The aim of the present study was to investigate whether prior experience with a given headlighting system will affect the discomfort-glare ratings obtained using the field methodology proposed in our earlier research. To evaluate the effect of prior experience, the data were obtained from recently arrived West German students in the U.S.A., and age-matched U.S.-born subjects.

METHOD

Discomfort-glare methodology. The following methodology for evaluating discomfort glare was used (Sivak and Olson, 1988):

- The observer vehicle is driven at 40 km/hr (25 mph) on a straight, level roadway towards a stationary glare vehicle in the adjacent lane.
- The lamps of the glare vehicle are illuminated for the vehicle separation of 400 to 300 m, and then again for the vehicle separation of 150 to 50 m.
- Glare is rated on the de Boer scale (de Boer, 1973). This is a 9-point scale with qualifiers only for the odd points:

  1 unbearable
  2
  3 disturbing
  4
  5 just acceptable
  6
  7 satisfactory
  8
  9 just noticeable

- Two ratings are obtained for each run, one for the vehicle separation of 400 to 300 m, and the other one for the vehicle separation of 150 to 50 m. Subjects memorize the first rating, and record both ratings after the second exposure.

Test site. The test was performed on a private road with no significant illumination. Each lane of this two-lane, asphalt roadway is about 3 m (10 feet) wide.

Test vehicles. The subjects were driving or riding in a 1983 GM full-size station wagon. The stationary glare car was a 1981 full-size Ford station wagon.

Illuminance levels. On each trial, subjects were shown one of the following four glare stimuli: (1) standard U.S. high beams, (2) standard U.S. high beams filtered with neutral density filters having transmissivity of 18%, (3) standard U.S. low beams, and (4) standard U.S. low beams filtered with neutral density filters having transmissivity of 18%.

These four glare stimuli produced (at two vehicle separations) eight illuminance levels as shown in Table 1. These measurements were taken at the end of the glare exposure (i.e., at vehicle separations of 300 m and 50 m) inside of the subject's car at the approximate location of the eyes of the center-front passenger. The measurements evaluated the sum of the illuminance from the glare car and the ambient illuminance. The headlamps of the subject's car were off during these measurements. (Because of the scattering of the light by the filters, the lux values for the filtered low beams are substantially above what would be predicted based only on the transmissivity of the filters.)

TABLE 1
Illuminance levels produced by the eight combinations of vehicle separation, beam, and filter.

Vehicle separation	Beam	Filter	Illuminance (lux)
400–300 m	Low	Yes	0.021
400–300 m	Low	No	0.049
400–300 m	High	Yes	0.055
150–50 m	Low	Yes	0.160
400–300 m	High	No	0.320
150–50 m	Low	No	0.375
150–50 m	High	Yes	0.650
150–50 m	High	No	4.500

The eight levels in Table 1 were selected because in a previous research a similar range yielded glare ratings covering most of the response scale (Sivak and Olson, 1988). (All eight illuminance levels were produced from the same physical units—a total of two large rectangular sealed beams [No. 6052]. Consequently, subjects could not identify which stimulus was being shown based on the location, number, or size of the illuminated headlamps.)

Adaptation illuminance. The adaptation illuminance was measured inside of the subjects' car (with the headlamps of the subjects' car on, and the headlamps of the glare car off), at the approximate position of the eyes of the center-front passenger. This illuminance was approximately 0.064 lux.

Glare angles. The glare angles were computed for the center-front passenger at the ends of the glare exposures. These angles were 0.6° at 300 m, and 3.8° at 50 m. (In the present design the effect of glare angle is confounded with the effect of vehicle separation, since there is a one-to-one correspondence between the glare angle and vehicle separation.)

Subjects. A total of 18 volunteers participated as subjects. Nine subjects (five females and four males) were West German students at the University of Michigan who had arrived in the U.S. within two months of the testing. (The number of days in the U.S. at the time of the testing varied from 21 to 60, with a mean of 40.3). Their ages ranged from 20 to 27, with a mean of 23.3.

The remaining nine subjects (five females and four males) were U.S.-born current or recent students at the University of Michigan. Their ages ranged from 19 to 26, with a mean of 22.4.

Procedure. Three subjects were tested at a time: the driver, the center-front passenger, and the right-front passenger. (We have shown [Sivak and Olson, 1988] that discomfort-glare ratings are unaffected by the rater's position in the front seat.) Each subject had a clipboard with a response sheet that had the response (de Boer) scale printed on the top, and a miniature flashlight to be able to record the responses without major changes in the level of dark-adaptation. The driver was instructed to drive at about 40 km/hr (25 mph). All subjects were asked to look straight ahead, but not directly into the headlights of the glare car.

Two experimenters ran the study. One was seated in the back seat of the subjects' car. His task was to signal to the second experimenter, via a hand-held radio, when the subjects' car passed each of four cones at four vehicle-separation landmarks (i.e., 400, 300, 150, and 50 m). Specifically, he indicated "on" at 400 m, "off" at 300 m, "on" at 150 m, and "off" at 50 m. The second experimenter, seated in the stationary glare car, turned on the glare car's headlights at 400 m and turned them off at 300 m. The same process was repeated at 150 m ("on") and 50 m ("off"). Additionally, this experimenter selected, for each trial, the beam to be shown and inserted/removed the filters.

Six replications of each stimulus were shown to each subject at each vehicle separation. This design resulted in 48 trials per subject (2 beams × 2 filters × 2 vehicle separations × 6 replications). Each experimental session, including four practice trials and short breaks, lasted about 90 minutes.

Language considerations. The response scale was written in English for both groups of subjects. Consequently, there is a possibility that any obtained effect would be due to differences in language, as opposed to prior experience. This possibility is further elaborated upon in the Discussion section.

RESULTS

The results of the analysis of variance on discomfort-glare ratings (with glare stimulus and country as factors) were as follows:

Glare stimulus. The effect of glare stimulus (Table 2) was statistically significant, $F(7,112) = 227.11, p < .001$.

TABLE 2
Mean glare ratings by glare stimulus.

Vehicle separation	Beam	Filter	Mean glare rating
150–50 m	Low	Yes	8.0
400–300 m	Low	Yes	8.0
400–300 m	High	Yes	6.4
400–300 m	Low	No	5.9
150–50 m	Low	No	5.6
150–50 m	High	Yes	4.4
400–300 m	High	No	2.9
150–50 m	High	No	1.3

Country. The effect of country (Table 3) was statistically significant, $F(1,16) = 5.18, p < .05$.

TABLE 3
Mean glare ratings by country.

Country	Mean glare rating
U.S.A.	5.7
West Germany	5.0

Interaction of glare stimulus and country. This interaction (Table 4) was not statistically significant, $F(7,112) = 1.26$, $p > .25$.

TABLE 4
Mean glare ratings by glare stimulus and country.

Vehicle separation	Beam	Filter	Mean glare rating	
			West German subjects	U.S. subjects
150–50 m	Low	Yes	7.8	8.3
400–300 m	Low	Yes	7.8	8.2
400–300 m	High	Yes	5.8	7.1
400–300 m	Low	No	5.4	6.4
150–50 m	Low	No	5.1	6.1
150–50 m	High	Yes	4.1	4.6
400–300 m	High	No	2.5	3.3
150–50 m	High	No	1.2	1.4

Relation of glare ratings to illuminance. The glare ratings were significantly related to the illuminance, $r(14) = .73$, $p < .01$, and to the logarithm of illuminance, $r(14) = .82$, $p < .01$. (The data for these two analyses were the eight means by glare stimulus.)

Glare angle/vehicle separation. An analysis of covariance was used to evaluate the confounded effect of glare angle/vehicle separation. The results indicate that when controlling for the effect of logarithm of illuminance, the effect of glare angle/vehicle separation (Table 5) was statistically significant, $F(1,13) = 66.1$, $p < .001$. (The data for this analysis were the sixteen means by glare stimulus and country.)

TABLE 5
Mean glare ratings by glare angle/vehicle separation, *adjusted* for the effect of logarithm of illuminance.

Glare angle	Vehicle separation	Mean glare rating
0.6°	400–300 m	3.6
3.8°	150–50 m	7.0

DISCUSSION

The aim of this study was to investigate whether prior experience with a given headlighting system affects reported discomfort glare. Specifically, of interest was the following hypothesis: Do drivers who are used to a relatively low-glare headlighting system report higher levels of discomfort glare than drivers who are used to a relatively high-glare headlighting system? To test this hypothesis, glare ratings in a field situation of recently arrived West German students at the University of Michigan were compared to the ratings of age-matched U.S.-born subjects. The results of this study indicate that, indeed, West German subjects reported significantly higher levels of discomfort glare than did U.S. subjects.

There are two possible explanations of this effect. The first possible explanation is that the effect is a consequence of the so-called range effect. It is well known that subjective judgements are influenced by the range of stimuli presented (Lulla and Bennett, 1981). In the automotive context, we have shown that judgements concerning discomfort glare from vehicle headlights are affected by the range of illuminances presented (Olson and Sivak, 1984). Specifically, we have found that reducing the upper limit of the presented illuminances resulted in a higher level of reported discomfort glare for a given stimulus. In the present context, this explanation is viable if one assumes that the relatively lower level of glare experienced in Germany is used as a range while making the discomfort-glare ratings in the present study.

The second possible explanation for the obtained effect is language based. While all West German subjects were fluent in English (they were all enrolled at the University of Michigan), it is possible that for native German speakers the English adjectives in the response scale (e.g., *unbearable, disturbing*) communicate slightly different meanings than they do to native English speakers. To exclude this possibility, recently arrived European subjects would have to be tested using a German translation of the rating scale.

In addition to the country of origin, glare illuminance, and glare angle confounded with vehicle separation also had significant effects on glare ratings. The relation of illuminance and glare ratings was in the predicted direction, with higher levels of illuminance yielding higher levels of discomfort glare. After controlling for illuminance, the condition with the smaller glare angle and greater separation distance resulted in a higher level of glare than the condition with the greater glare angle and smaller vehicle separation.

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