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DRIVERS' PERCEPTIONS OF HEADLIGHT GLARE FROM ONCOMING AND FOLLOWING VEHICLES

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16. Abstract

Recently, U.S. drivers have been expressing concern over the discomfort and reduced visibility that they experience from headlight glare from other vehicles. Drivers have focused their concern on the relatively new high intensity discharge lights, high mounted lights, and various auxiliary lights. In order to better understand this glare problem, the National Highway Traffic Safety Administration collected data on drivers' perception of glare from a representative sample of U.S. drivers. The survey was conducted through Omnibus Survey of the Bureau of Transportation Statistics. The present study is based on the information (data) collected on two types of glare: glare from oncoming and following vehicles.

The survey data were analyzed to find out how U.S. drivers perceive the two types of glare and if glare perception is associated with respondents' age and gender. Contingency analysis was conducted to establish these associations. The statistics showed that a sizeable number of respondents feel that glare was 'disturbing'. The percent frequency distributions were used to better understand the age and gender profiles of drivers who felt disturbed by the nighttime glare. It was found that the age group 35 to 44 had the highest percentage of night drivers as well as among those who felt glare 'disturbing'. In addition, female respondents of this age group were more of the opinion that the glare from oncoming and following vehicles was 'disturbing' as compared with other age groups of their own gender or even of the opposite gender.

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EXECUTIVE SUMMARY

Background and objectives

In recent years, an increasing number of drivers have complained to the National Highway Traffic Safety Administration (NHTSA) about headlight glare. A number of comments concerned objections to glare from fog lamps and high-mounted headlights on trucks and SUVs. The comments from the public to the NHTSA Docket 01-8885 helped to identify many of the glare concerns of the U.S. driving population. The large number of glare complaints demonstrated the extent to which the public was concerned with the glare from other vehicles. The number of comments was larger than those that NHTSA received on other safety concerns. However, the docket comments may not provide a true assessment of the glare concern of the driving population.

High intensity of headlights may extend the visibility of objects ahead, but it may also increase the discomfort that glare of the headlights may cause to drivers of other vehicles. Glare can also reduce visibility distances by reducing object contrast or causing drivers to avert their eyes from the roadway to avoid discomfort. The challenge for headlight designers and regulators is to maintain an appropriate balance between glare and visibility. While empirical research is often necessary to quantify these tradeoffs, such research can only study a small number of drivers under a limited set of real world conditions. This limits the extent to which findings can be generalized to the entire population of drivers as well as to real world driving conditions.

To help put the docket comments on glare into perspective, NHTSA asked the Bureau of Transportation Statistics (BTS) to include several questions pertinent to this issue in a series of nationwide telephone surveys titled 'Omnibus Survey'. These surveys were conducted monthly (January to December, 2002) with a new sample of subjects each month. However, the questions concerning glare were asked only during the first six months: January to June 2002. The questions pertaining to drivers' perceptions of glare from *oncoming* and *following* vehicles is the subject of this study.

Based on the survey, the primary objective of this study was to obtain a nationally representative assessment of drivers' perceptions of glare. Additionally, the objective was to confirm if drivers' perceptions of glare are associated with their age and gender and bring out the differences that might exist due to gender and age of the respondent.

Data and methodology

The analyses conducted in this study are based on the 'Omnibus Survey' data that consists of drivers' perceptions of glare expressed as: 'not noticeable', 'barely noticeable', 'noticeable but acceptable', 'disturbing', or 'crash or near miss' due to two types of glare: glare from oncoming and following vehicles.

Descriptive statistics were used to study variations with respect to glare perceptions that exist among drivers due to age and gender. Contingency analysis was used to test hypotheses related to the possible associations between glare ratings and age and gender. Bivariate distributions: Age x Glare perception and Gender x Glare perception were used to obtain a better idea about the glare perception.

Results and conclusions

The results show that for the majority of respondents (about 54%) glare was 'noticeable but acceptable'. However, the sizeable number of drivers (about 30%) who experienced nighttime glare as 'disturbing' cannot be ignored. The response data of drivers falling into this category was further analyzed to bring

out the differences that might exist due to the type of glare and age and gender of the respondent. In fact, the frequency distributions of the glare-disturbed respondents over age and gender groups, for oncoming and following glare, did not indicate any difference due to the type of glare; the distributions were found in close proximity with each other. There were, however, percentage differences among age and gender groups.

The age-wise comparison highlighted some differences and similarities among age groups. For instance, the distribution of the glare-disturbed respondents over age groups showed that most of the respondents who rated glare 'disturbing' were not old drivers. Also, the ratings of discomfort from glare for old drivers were not significantly different from that for the younger drivers. In general, the percentage of the glare-disturbed respondents was highest for the age groups 35 to 44 and 45 to 54. For oncoming glare, the 55 to 64 year old group had the highest percentage of the glare-disturbed respondents, while for following glare, it was the age group 18 to 24 that contributed most to the this category of drivers.

Through gender-wise comparison of respondents, it was observed that although male and female representation in the population of all respondents was the same, the females, in general, were found more glare-disturbed. Distributions of male and female respondents over age groups showed that among all night-driving and glare-disturbed respondents, 35 to 44 year old had the highest representation, with a higher female representation. Male-female comparison within each age group showed that among the night-driving respondents, males had much higher representation in the age group 75 and above, while in other age groups the differences in male-female representations were small. The gender-wise comparison was also done for the glare-disturbed respondents in each age group. Significant differences in male-female representations were observed within each age group of this category of respondents with much larger differences for the age groups 35 to 44 and 75 and above. It was also found that 35 to 44 year old females had much higher representation as compared with the males of this age group, even though the differences between the two genders of this age group among all respondents was not so large.

The statistics also show that for both oncoming and following glare, as the number of dark hours decreases from January to June, the percentage of 'concerned' respondents decreases. The largest decrease in the percentage of glare-disturbed respondents was observed from March to April. Only a slight change in the percentages of both 'concerned' and 'minimally concerned' respondents was observed in May and June.

1. Introduction and background

In recent years, an increasing number of drivers have complained to the National Highway Traffic Safety Administration (NHTSA) about headlight glare. The complaints are documented in citizen submissions to Docket 01-8885, Notice 1. Since its publication in September 2001, the docket has received about 4,000 comments from all over the United States. A number of comments concerned objections to glare from fog lamps and high-mounted headlights on trucks and SUVs. However, the primary concern was glare from high intensity discharge (HID) lights. HID differ in several respects from more conventional halogen lamps. HIDs have a bluer spectral content, a wider beam pattern, and can have a smaller luminous area. While a few drivers with HID on their vehicles thought that their night visibility improved, the great majority of the comments expressed drivers' complaints about glare from HID-equipped vehicles.

Increasing intensity may extend the visibility of objects ahead but it may also increase the discomfort that glare of the headlights may cause to drivers of other vehicles. Glare can also reduce visibility distances by reducing object contrast or causing drivers to avert their eyes from the roadway to avoid discomfort. The challenge for headlight designers and regulators is to maintain an appropriate balance between glare and visibility. While empirical research is often necessary to quantify these tradeoffs, such research can only study a small number of drivers under a limited set of real world conditions. This limits the extent to which findings can be generalized to the entire population of drivers.

The comments from the public to the NHTSA docket helped to put the glare concerns of the driving population at large into perspective. The large number of glare complaints demonstrated the extent to which the public was concerned with the glare from other vehicles while driving on the roadways. The number of comments was much larger than the number of public comments that NHTSA has received on other safety topics. The drivers' descriptions of their glare problems helped to provide real-world insight into the safety-related problems being experienced on the roadways. For example, many drivers described being "blinded" for a few seconds after exposure to the glare and needed to slow down. The strong feelings of the public about being exposed to glare were also evident in their comments.

Despite the useful information provided by docket comments, they do not necessarily provide a representative assessment of the glare concerns of the U.S. driving population. The comments may be biased because drivers with glare problems are more likely to write as compared with those who have no such issues. It is also likely that many viewpoints were not represented because many drivers did not know about the docket.

To help put the docket comments on glare into perspective, NHTSA asked the Bureau of Transportation Statistics (BTS) to include several questions pertinent to this issue in a series of nationwide telephone surveys titled 'Omnibus Survey'. These surveys were conducted monthly (January to December, 2002) with a new sample of subjects each month. However, the questions concerning glare were asked only during the first six months: January to June 2002. The questions pertaining to drivers' perceptions of glare from oncoming vehicles and glare from the vehicles behind are the subject of this study.

2. Overview of the Omnibus survey

The Omnibus Survey is a stratified random national probability sample conducted monthly by the BTS to monitor expectations of, and satisfaction with, the transportation system, as well as to gather information on specific events and issues, using a Random-Digit-Dialed telephone methodology. Various sampling issues, such as selection of sampling design, sampling weights, precision of estimates, etc., were resolved before the interviews started. The target population of the survey consisted of U. S. non-institutionalized adult population of drivers who were 18 years of age or older. The average (over

six months) final completed sample size was 1,053 cases per month, of which on the average 870 were valid responses. Each respondent who drove at night during the previous twelve months was asked to express his/her perception of nighttime glare from: oncoming and following vehicles by selecting one of the five ratings: 'not noticeable', 'barely noticeable', 'noticeable but acceptable', 'disturbing', or 'caused a crash or near miss'.

The background information of the survey, sampling procedures, data collection, data elements and survey variables, response rates, final weights and standard errors of estimates are provided in the survey documentation of the Omnibus Survey issued by Bureau of Transportation Statistics [1].

3. Objective of the study and methodology

A descriptive analysis was conducted to get a comparative idea about different glare ratings. One of the objectives of this study was to confirm if the driver's perception of glare on driving is in any way associated with age and gender of the respondents. Contingency analysis was used to test hypotheses related to the possible association between glare ratings and age and gender. Contingency analysis [2] is one of the useful techniques to study the relation between two variables that can be arranged in a contingency table, such as Table A.1 (Appendix).

Bivariate percent frequency distributions were used to study the differences that exist among respondents of different age and gender groups in perceiving glare. These differences were depicted through percentage histograms and polygons.

4. Selection of variables for statistical analysis

As mentioned earlier, the present study is focused on 'glare from oncoming vehicles' and 'glare from following vehicles'. Accordingly, the analyses conducted in this study are based on responses of the interviewed persons to the following two questions:

Q1. In the last 12 months, while driving at night, has the glare from the headlights of an **oncoming vehicle** been '*not noticeable'*, '*barely noticeable'*, '*noticeable but acceptable'*, *'disturbing'*, or did it cause a '*crash or near miss"*?

Q2. In the last 12 months, while driving at night, has the glare from the headlights of a **vehicle behind** been '*not noticeable'*, '*barely noticeable'*, '*noticeable but acceptable'*, *'disturbing'*, or did it cause a '*crash or near miss"*?

The two glare types covered by questions Q1 and Q2 will be referred to, respectively, as oncoming and following glare. It is important to note that the above two questions do not cover the respondents of the survey who did not drive at night during the last twelve months. Such respondents are therefore not subject of this study. In addition, the respondents who 'refused' to answer the two glare questions or responded 'don't know', do not provide any information about the glare issue. Hence, such respondents will also be excluded from the analysis. Thus, the term 'respondent' used henceforth should be understood to mean a survey respondent whose response was one of the five choices. The respondents considered in this study can accordingly be classified in five categories: 'not noticeable', 'barely noticeable', 'noticeable but acceptable', 'disturbing', 'crash or near miss'.

5. Overall glare ratings of survey respondents

As a first step, a descriptive analysis was conducted to get an overall picture of how the U.S. drivers, in general, perceive glare from oncoming and following vehicles. Figure 1 presents percent frequencies of

respondents for responses (ratings): not noticeable, barely noticeable, noticeable but acceptable, 'disturbing', crash or near miss, aggregated for the six months (January to June). It can be seen in Figure 1 (box with broken line border) that according to majority of respondents, both oncoming and following glare is 'noticeable but acceptable'; the percent frequencies of respondents with this rating being the highest 57% and 54%, respectively, for the two types of glare.

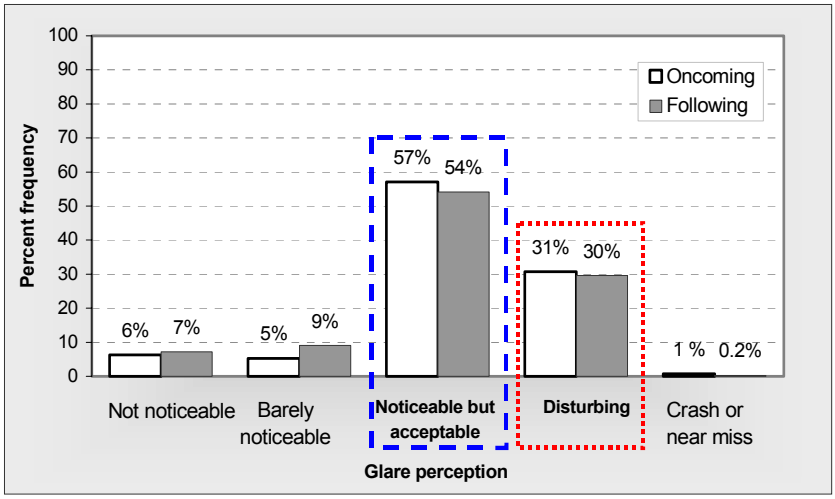


Figure 1. Percent frequency distributions of respondents over five glare ratings for oncoming and following glare (Data source: Omnibus Survey 2002, BTS).

Figure 1 also shows that for small percentages (6% and 7%) of respondents, oncoming and following glare types were 'not noticeable' and so was the case with respondents who rated glare as 'barely noticeable'; the latter formed only 5% and 9%, respectively, for the two types of glare. The respondents who were seriously concerned about glare and had significant representation among respondents were the ones for whom glare was 'disturbing'. About 31% of respondents perceived oncoming glare 'disturbing' and about 30%, following glare. Since temperament plays an important role in perception, the class of respondents who felt disturbed from glare was considered as a special class for further analysis. The following analysis is focused on detecting the differences that might exist in terms of the contribution of different age- and gender-based groups to the class 'disturbing'. These respondents will be referred to as 'glare-disturbed' respondents.

6. Association between glare perception and respondent's age and gender

Perception is a process whereby sensory stimulation in humans is translated into organized experience and so is the glare perception. Therefore, in order to get a deeper insight into the glare issue, it is important to investigate if the human attributes: age and gender of the respondents can have influence on his/her perception of the glare. To confirm this, contingency analysis was conducted to test the hypothesis of independence between glare perception and respondent's age as well as between glare perception and respondent's gender for both oncoming and following glare. As the Omnibus survey was based on stratified simple random design, the statistical software SUDAAN® was used for contingency analysis of the survey data, which takes into account the underlying sampling design. The analysis will be supplemented by what is called Ph-coefficient, which measures the strength of association between two categorical variables.

The analysis for testing independence between glare perception and age yielded the value 64.08 of Chi-square with 24 degrees of freedom and p-value 0.000001. These statistics confirm that respondent's age

possibly influences how he/she perceives oncoming glare. The value 0.3 of Phi-coefficient with its lower and upper attainable bounds 0 and 0.9, respectively, shows a strong association between respondent's age and his/her perception of oncoming glare. Similarly, the test statistics: 25.56 of Chi-square with 4 degrees of freedom and p-value 0.00001 show that gender of the respondent, too, has bearing on oncoming glare perception. The value 0.2 of Phi-coefficient with its lower and upper attainable bounds 0 and 0.7, respectively, shows a strong association between respondent's sex and the rating of oncoming glare.

The hypothesis of independence between glare perception and age as well as between glare perception and gender was also tested for following glare. The value 60.38 of Chi-square with 24 degrees of freedom and p-value 0.0000001 shows that respondent's age has influence on how he/she perceives following glare. The value 0.3 of Phi-coefficient with its lower and upper attainable bounds 0 and 0.9, respectively, shows a strong association between respondent's age and the rating of following glare. Similarly, the test statistics: 37.97 of Chi-square with 4 degrees of freedom and p-value 0.000001 show that gender of the respondent, too, has bearing on oncoming glare perception. The value 0.2 of Phi-coefficient with its lower and upper attainable bounds 0 and 0.7, respectively, shows a strong association between respondent's sex and the rating of following glare.

It was found in Section 5 that the glare-disturbed respondents formed the second largest category among all respondents in case of both oncoming (31%) and following (30%) glare. These rather large percentages of the glare disturbed respondents and the influence that age and gender can have on glare perception, lead to further investigation as to how these dependencies reflect on the glare perception 'disturbing'. In the subsequent analysis, we bring out differences among different age groups as well as between male and female glare-disturbed respondents for oncoming and following glare.

7. Age-wise distribution of respondents with the rating 'disturbing'

The survey data were first analyzed to obtain the distribution of the rating 'disturbing' for each of the two glare types over seven age groups: 18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74 and above 74. The results for glare from oncoming and following vehicles are plotted as percentages and cumulative (in reverse order) percentages, respectively, in Figure 2(a) and Figure 2(b). While interpreting results presented in these figures, it should be noted that the statistics shown at the end of hanging bars are to be read in reference to the x-axis secondary labels, such as the label >=18, >=25 etc. Thus, this figure not only gives an idea about the percentage of respondents of different age

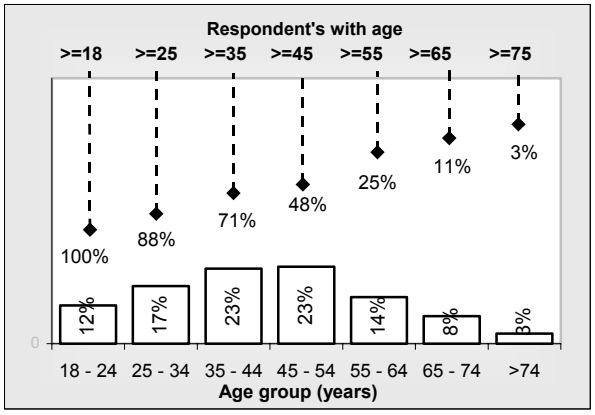


Figure 2(a). Oncoming glare

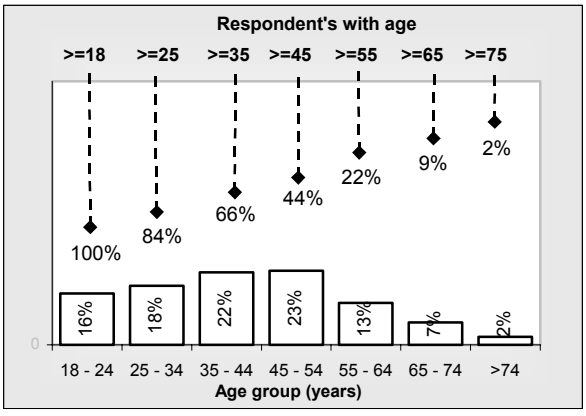


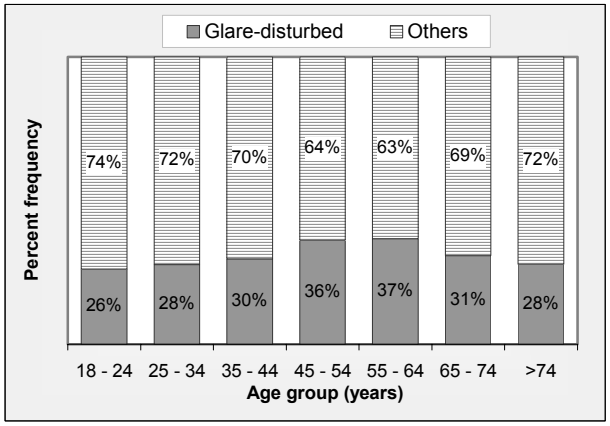
Figure 2(b). Following glare

Figure 2. Percent frequency and cumulative percent frequency (reverse order) distributions of glare-disturbed respondents over seven age groups (Data source: Omnibus Survey 2002, BTS).

groups in the 'disturbing' category, but also shows the percentage of respondents in that category whose age is greater than or equal to 18, 25, 35, 45, 55, 65, or 75. It can be seen in these figures that the frequency distributions of respondents with the perception 'disturbing' for oncoming and following glare are in close proximity with each other. Figure 2(a) shows that most of the people who rated oncoming glare 'disturbing' were not older drivers. In fact, only 11% of respondents who rated oncoming glare 'disturbing' were above 65 as compared with 45% (22 + 23) between 35 and 54. The distribution for glare from following vehicles (Figure 2(b)) shows almost the same statistics: 9% of the respondents with the rating 'disturbing' were above 65 and 46% (23 + 23) between 35 and 54.

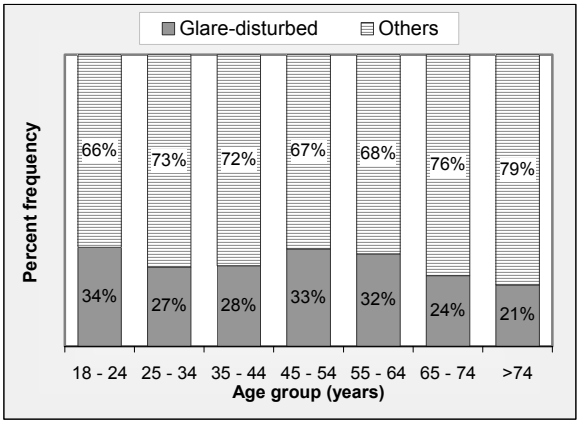
Although older drivers eyes are particularly susceptible to the adverse affects of glare on judging distance, it is possible that the effects of glare on driver's discomfort are not age dependent. The results of the current analysis of the survey data supports the findings of several research studies in which it has been noted that the ratings of discomfort from oncoming glare for older drivers (65 and above) are not significantly different from younger drivers (18 to 24); being 11% and 12%, respectively.

In addition to looking at the age profile of glare-disturbed respondents, it is informative to compare different age groups with respect to their rating 'disturbing'. This was done by taking into account the age group sizes and computing percent frequencies relative to these sizes. The results for oncoming and following glare are presented, respectively, in Figure 3(a) and Figure 3(b). These results show that for oncoming glare, 55 to 64 year old respondents had the highest percentage (37%), while for following glare, it was the age group 18 to 24 that contributed most (34%) to the this category of drivers. In general, the percentage of glare-disturbed respondents was highest for age groups: 45 to 54 and 55 to 64 for both types of glare.



RESPONDENT CATEG.	AGE GROUP						
	18-24	25-34	35-44	45-54	55-64	65-74	>=75
Glare-disturbed	26	28	30	36	37	31	28
Others	74	72	70	74	63	69	72
Total	100	100	100	100	100	100	100

Figure 3(a). Oncoming glare.



RESPONDENT CATEG.	AGE GROUP						
	18-24	25-34	35-44	45-54	55-64	65-74	>=75
Glare-disturbed	34	27	28	33	32	24	21
Others	66	73	72	67	68	76	79
Total	100	100	100	100	100	100	100

Figure 3(b). Following glare.

Figure 3. Percent frequencies of glare-disturbed respondents and the rest in each of the seven age groups. (Data source: Omnibus Survey 2002, BTS).

A comparison of Figure 3(a) and Figure 3(b) shows that except for 18 to 24 year old drivers, the percentages of drivers with rating 'disturbing' was higher for oncoming glare as compared with

following glare. The younger drivers were more concerned with glare from following vehicles; 34% of them rated this type of glare as 'disturbing', while 26% rated oncoming glare as 'disturbing'.

Figure 4 gives a comparative picture of the representations of different age groups in the entire population of respondents and in the 'disturbing' category. In case of oncoming glare (Figure 4(a)), all age groups had lower representation in the 'disturbing' category, except for the age groups 45 to 54 and 55 to 64, whose representations in this category were 23% and 14%, respectively, as compared with their respective percentages 20% and 12% in the population. For following glare, the picture was slightly different. In addition to higher representations (23% and 13%, respectively) of these two age groups in the 'disturbing' category, the age group 18 to 24, too, had a higher percentage (16%) in the glare-disturbed category as compared with their representation (14%) in the population of respondents. Figure 4(a) and Figure 4(b) show that except for age group 18 to 24, the distributions respondents over age groups were the same for both oncoming and following glare.

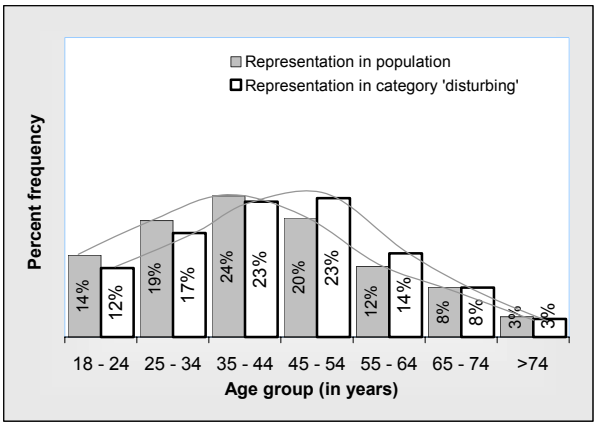


Figure 4(a). Oncoming glare.

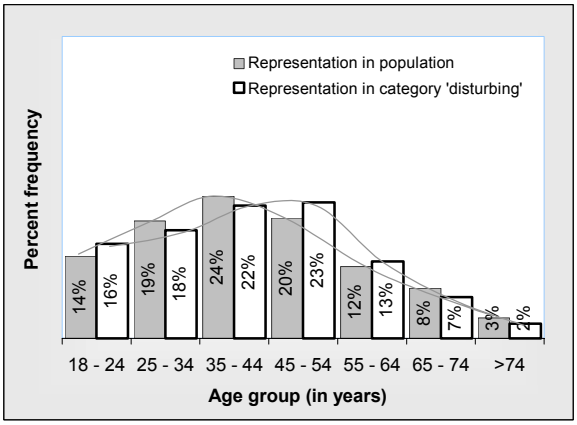


Figure 4(b). Following glare.

Figure 4. Percent frequency distributions of glare-disturbed and all respondents over seven age groups. (Data source: Omnibus Survey 2002, BTS).

8. Gender-wise distribution of respondents with the rating 'disturbing'

It has been established in Section 6 that the glare perception has dependence on the respondent's gender. It is, therefore, important to see the way in which male and female respondents differ from each other with respect to their glare perception. Figure 5 shows male and female representations in the population of all respondents as well as in the subpopulation of glare-disturbed respondents. The statistics in Figure 5(a) show that for oncoming glare, although the two gender groups had almost the same (50.3% and 49.7%, respectively) representation in the population, the female respondents had a higher representation (55.5%) among the glare-disturbed as compared with 44.5% male respondents. Similarly, in case of following glare, with the same representation of the two gender groups in the population, the female representation in the 'disturbing' category was higher (53.4%) as compared with the male representation (46.6%).

Even though male and female respondents had almost the same representation in the population of respondents (Figure 5), for oncoming glare a higher percentage (33.9%) of female respondents were found glare-disturbed as compared with male respondents, among whom 28.8% were found in the 'disturbing' category. Similarly, for following glare, 33.1% of female respondents were in the 'disturbing' category as compared with 26.2% of male respondents who fell into this category. This leads to the conclusion that females, in general, feel more disturbed from both types of glare. A

comparison of similar statistics related to oncoming (in Figure (a)) and following (in Figure 5(b)) glare perception shows that there is virtually no difference between these two types of glare. Following this observation, in the subsequent sections we will present and discuss the results only for oncoming glare.

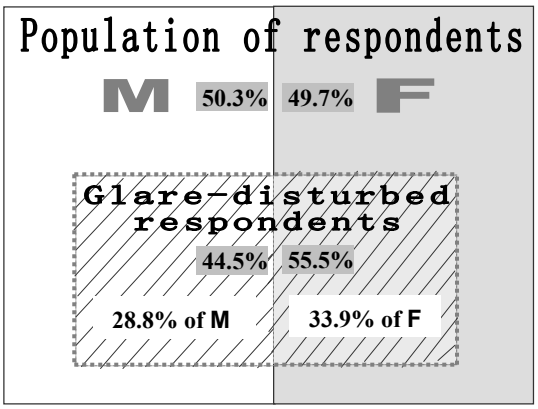


Figure 5(a). Oncoming glare.

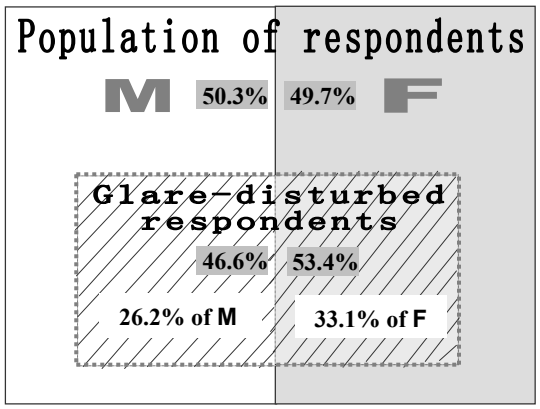


Figure 5(b). Following glare.

Figure 5. Venn diagram showing percentages of male and female respondents among oncoming and following glare-disturbed and all respondents. (Data source: Omnibus Survey 2002, BTS).

9. Male-female comparison in subpopulations of night-driving and glare-disturbed respondents

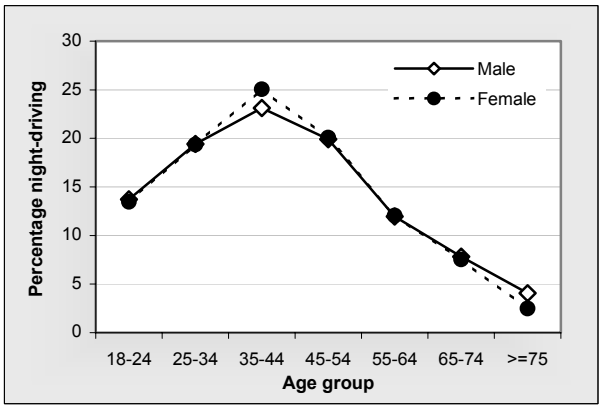
To gain better insight into the glare issue, the differences that have been observed among respondents' glare perception due to age and gender differences must be viewed in comparison with such differences that exist among the night-driving respondents. The following statistical analysis yields statistics that can be used for this purpose.

9.1 Male and female night-driving respondents over age groups

Figure 6 (a) presents statistics that show a comparison of male and female subpopulations of night-driving respondents. The same profile can be seen for the two gender groups, over seven age groups (Figure 6(a)). In both cases, the percentages of the night-driving respondents keep increasing until the age group 35 to 44 and starts decreasing thereafter with minimum for the age group 75 and above.

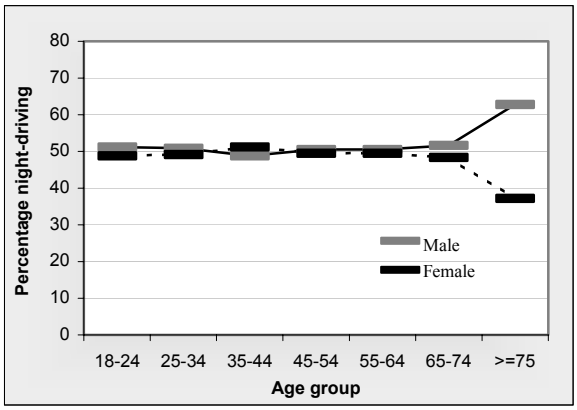
However, there are differences between two genders for some age groups. One difference is that a slightly higher percentage (24.9%) of 35 to 44 year old females drive at night as compared with their male counterparts (23.0%). The difference between the two genders, in terms of night driving, can be seen also for the age group 75 and above, though in this case a higher percentage (3.9%) of males reported driving at night as compared with females (2.7%).

Figure 6(b) shows male-female comparisons within each age group of respondents who drove at night. A slightly higher male percentage was observed for age groups 18 to 24 and 25 to 34. A visible difference (48.9% males and 51.1% females) was observed for the age group 35 to 44. For the rest of the age groups, increasingly higher percentage of male night-driving respondents can be seen with a markedly large difference (60.4% males and 39.6% females) for 75 and above respondents.



GENDER	AGE GROUP							Total
	18-24	25-34	35-44	45-54	55-64	65-74	>=75	
Male	13.3	19.4	23.0	20.3	12.2	7.8	3.9	100
Female	13.4	18.9	24.9	20.3	11.8	8.2	2.7	100

Figure 6(a). Percentage frequency distributions for male female night-driving respondents, over age groups.



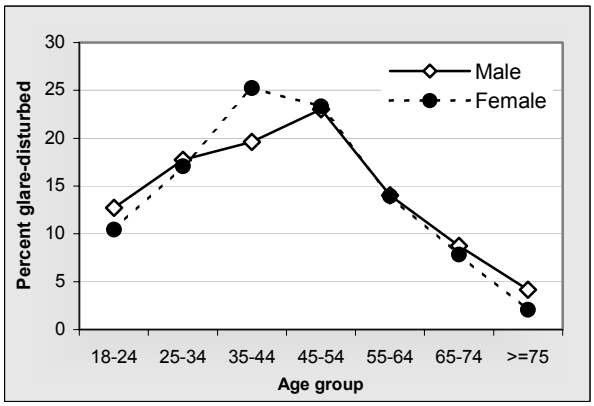
GENDER	AGE GROUP						
	18-24	25-34	35-44	45-54	55-64	65-74	>=75
Male	50.7	51.6	48.9	50.8	51.9	49.5	60.4
Female	49.3	48.4	51.1	49.2	48.1	50.5	39.6
Total	100	100	100	100	100	100	100

Figure 6(b). Male and female percentages of night- and driving respondents in each of the seven age groups.

Figure 6. Percentage frequency distributions of night-driving respondents (Data source: Omnibus Survey 2002, BTS).

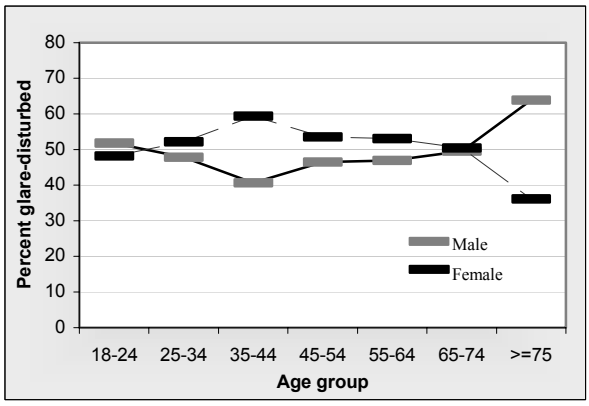
9.2 Male and female glare-disturbed respondents over age groups

Unlike the night-driving respondents, the age profiles of male and female glare-disturbed respondents are different. A comparison of male and female subpopulations of glare-disturbed respondents over age groups in Figure 7(a) shows that a higher percentage of males of age groups 18 to 24, 65 to 74, and 75



GENDER	AGE GROUP							Total
	18-24	25-34	35-44	45-54	55-64	65-74	>=75	
Male	12.4	17.1	20.2	23.0	14.3	9.2	3.9	100
Female	11.5	17.3	24.4	23.2	13.6	7.7	2.3	100

Figure 7(a). Gender-wise comparison.



GENDER	AGE GROUP						
	18-24	25-34	35-44	45-54	55-64	65-74	>=75
Male	48.3	46.3	41.8	46.2	47.8	50.8	59.9
Female	51.7	53.7	58.2	53.8	52.2	49.2	40.1
Total	100	100	100	100	100	100	100

Figure 7(b). Age-wise comparison.

Figure 7. Percent distributions of glare-disturbed respondents (Data source: Omnibus Survey 2002, BTS).

and above perceive glare as 'disturbing' as compared with females belonging to these age groups. A shift was observed for the age group 35 to 44 in that a higher percentage (24.4%) of female glare-disturbed respondents was observed as compared with 20.2% of male glare-disturbed respondents. It can also be seen in this figure that the highest percentage (23.0%) of glare-disturbed males was observed for the age group 45 to 54, while that of the glare-disturbed females (24.4%) was for the age group 35 to 44.

Figure 7(b) shows male-female comparison of glare-disturbed respondents within each age group. Higher percentages of female glare-disturbed respondents were observed for age groups 25 to 34, 35 to 44 and 45 to 54 with a maximum difference (41.8% males and 58.2% females) for 35 to 44 year old glare-disturbed respondents. Although, a large difference was also observed for the age group 75 and above, more males (59.9%) were found glare-disturbed as compared with 40.1%. females.

10. Temporal profile of glare ratings

Glare ratings may be influenced by the length of time that drivers are exposed to vehicle lights. For example, the fewer the number of daylight hours, the greater is the number of hours during which drivers will be exposed to headlight glare at night, i.e., oncoming and following glare. In view of this fact, the temporal variations with respect to glare ratings were studied over six months: January, February, March, April, May, and June.

For that purpose broader categories of glare ratings were considered that were representative of the level of concern of the respondents, defined as:

$$\text{Level of concern:} \begin{cases} \text{Minimally concerned, if response is 'not noticeable',} \\ \text{'barely noticeable', or 'noticeable but acceptable'.} \\ \\ \text{Concerned, if response is 'disturbing' } \textit{or} \text{ 'crash or near miss'.} \end{cases}$$

Figure 9 shows temporal profiles of 'minimally concerned' (dark dotted line) and 'concerned' (light dotted line) respondents over six months (January to June). In order to obtain an idea about the trend over six months, moving averages were computed. In this figure, these are plotted as a dark solid line for 'minimally concerned' and as a light solid line for 'concerned' respondents.

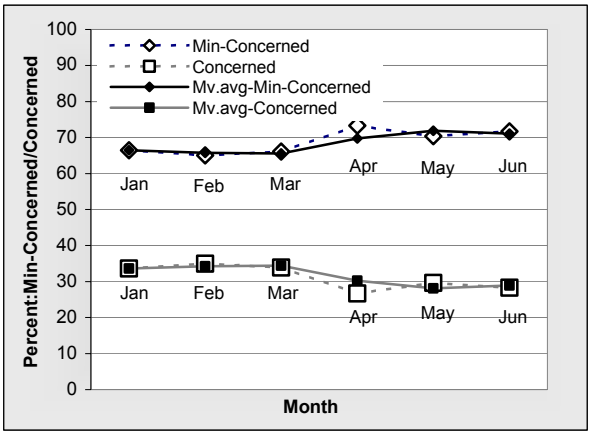


Figure 9(a). Oncoming glare.

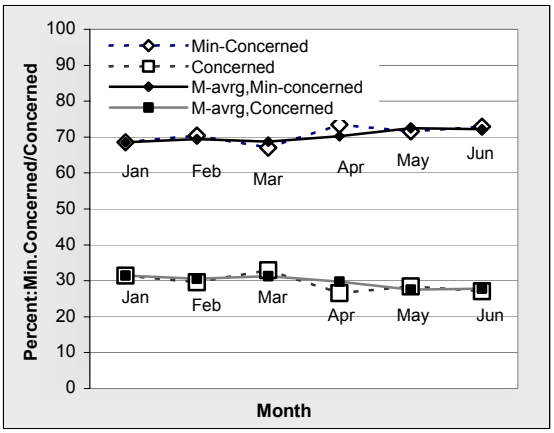


Figure 9(b). Following glare.

Figure 9. Temporal profiles of glare ratings of respondents for oncoming and following glare over six months (January to June) (Data source: Omnibus Survey 2002, BTS).

The two profiles are complementary to each other. The moving average plots in these figures show that for both oncoming and following glare, as the number of daylight hours increases (January to June), the percentage of 'Concerned' respondents decreases (increases for minimally concerned) slightly from January to February, but generally decreases from the darker winter months to the brighter spring and early summer months. The largest decrease (the largest increase for minimally concerned) in the percentage of glare-disturbed respondents was observed from March to April.

11. Summary and conclusions

The results show that for the majority of respondents (about 54%) glare was 'noticeable but acceptable'. However, the sizeable number of drivers (about 30%) who experienced nighttime glare as 'disturbing' cannot be ignored. The response data of drivers falling into this category was further analyzed to bring out the differences that might exist due to the type of glare and age and gender of the respondent. In fact, the frequency distributions of the glare-disturbed respondents over age and gender groups, for oncoming and following glare, did not indicate any difference due to the type of glare; the distributions were found in close proximity with each other. There were, however, percentage differences among age and gender groups.

The age-wise comparison highlighted some differences and similarities among age groups. For instance, the distribution of the glare-disturbed respondents over age groups showed that most of the respondents who rated glare 'disturbing' were not old drivers. Also, the ratings of discomfort from glare for old drivers were not significantly different from that for the younger drivers. In general, the percentage of the glare-disturbed respondents was highest for the age groups 35 to 44 and 45 to 54. For oncoming glare, 55 to 64 year old had the highest percentage of the glare-disturbed respondents, while for following glare, it was the age group 18 to 24 that contributed most to the this category of drivers.

Through gender-wise comparison of respondents, it was observed that although male and female representation in the population of all respondents was the same, the females, in general, were found more glare-disturbed. Distributions of male and female respondents over age groups showed that among all night-driving and glare-disturbed respondents, 35 to 44 year old had the highest representation, with a higher female representation. Male-female comparison within each age group showed that among the night-driving respondents, males had much higher representation in the age group 75 and above, while in other age groups the differences in male-female representations were small. The gender-wise comparison was also done for the glare-disturbed respondents in each age group. Significant differences in male-female representations were observed within each age group of this category of respondents with much larger differences for the age groups 35 to 44 and 75 and above. It was also found that 35 to 44 year old females had much higher representation as compared with the males of this age group, even though the differences between the two genders of this age group among all respondents was not so large.

The statistics also show that for both oncoming and following glare, as the number of dark hours decreases from January to June, the percentage of 'concerned' respondents decreases. The largest decrease in the percentage of glare-disturbed respondents was observed from March to April. Only a slight change in the percentages of both 'concerned' and 'minimally concerned' respondents was observed in May and June.

12. References

[1] Bureau of Transportation Statistics, *Survey Documentation for the Bureau of Transportation Statistics Omnibus Survey Program,* January to May 2002.

[2] Kendall, M.G. and Stuart A., The Advanced Theory of Statistics, Vol. 2, Hafner Publishing Company, New York, 1967.

13. Appendix A. Bivariate frequency distributions: Age vs. Glare rating and Gender vs. Glare rating for oncoming and following glare

This section provides statistics that were produced by SUDAAN cross tabulation procedure for oncoming and following glare types.

Table A.1 and Table A.2 present bivariate frequency distribution of age- and sex-based groups of respondents, based on their responses to question Q1, related to perception of glare from oncoming vehicles.

Table A.1. Bivariate frequency distribution: Age vs. Oncoming glare rating

Age group	Oncoming glare rating						Total
	Statistic	Not noticeable	Barely noticeable	Noticeable but acceptable	Disturbing	Crash or near miss	
18 to 24	Weighted Size	1567461	1391752	12936571	5948684	123298	21967765
	Sample Size	5	5	43	23	0	76
25 to 34	Weighted Size	2423762	1413269	18612288	8602074	481899	31533292
	Sample Size	12	8	97	45	2	163
35 to 44	Weighted Size	2446880	1889094	22761159	11232660	225161	38554954
	Sample Size	12	11	121	61	1	206
45 to 54	Weighted Size	1579715	1673743	17943060	11546292	250794	32993604
	Sample Size	9	10	102	67	1	189
55 to 64	Weighted Size	1419958	1002579	9994766	6959966	25247	19402515
	Sample Size	8	6	65	42	0	122
65 to 74	Weighted Size	833226	831486	7980846	4200666	0	13846223
	Sample Size	5	5	42	24	0	76
75 and above	Weighted Size	729448	302509	3009410	1501529	29075	5571970
	Sample Size	5	2	17	9	0	33
Total	Weighted Size	11000448	8504433	93238099	49991871	1135472	163870322
	Sample Size	56	46	487	270	5	864

(Data source: Omnibus Survey 2002, BTS)

Table A.1. Bivariate frequency distribution: Sex vs. Oncoming glare rating

Sex	Oncoming glare rating						Total
	Statistic	Not noticeable	Barely noticeable	Noticeable but acceptable	Disturbing	Crash or near miss	
Male	Weighted Size	6919885	4458832	48022133	23427247	654746	83482844
	Sample Size	33	22	236	117	3	410
Female	Weighted Size	4107626	4045601	46311448	27130845	480726	82076246
	Sample Size	23	24	255	156	3	460
Total	Weighted Size	11027512	8504433	94333582	50558092	1135472	165559090
	Sample Size	56	46	491	272	5	870

(Data source: Omnibus Survey 2002, BTS)

Table A.3 and Table A.4 present bivariate frequency distribution of age- and sex-based groups of respondents, based on their responses to question Q2, related to perception of glare from oncoming vehicles.

Table A.3. Bivariate frequency distribution: Age vs. Following glare rating

Age group	Following glare rating						Total
	Statistic	Not noticeable	Barely noticeable	Noticeable but acceptable	Disturbing	Crash or near miss	
18 to 24	Weighted Size	1842399	2143349	10343279	7638739	0	21967765
	Sample Size	7	7	37	25	0	76
25 to 34	Weighted Size	1803748	2850946	18068017	8601540	270002	31594253
	Sample Size	10	16	94	43	1	164
35 to 44	Weighted Size	2554046	3077828	22510358	10354634	87490	38584356
	Sample Size	14	17	117	58	1	206
45 to 54	Weighted Size	1999600	2687472	18000123	10406958	18130	33112283
	Sample Size	11	15	101	64	0	190
55 to 64	Weighted Size	1596738	1689228	10307519	5993286	0	19586770
	Sample Size	10	11	64	38	0	123
65 to 74	Weighted Size	1564391	1335354	7443577	3513997	0	13857320
	Sample Size	9	7	40	20	0	76
75 and above	Weighted Size	948667	677948	2721257	1196800	0	5544672
	Sample Size	6	4	16	7	0	32
Total	Weighted Size	12309590	14462125	89394129	47705953	375622	164247418
	Sample Size	66	76	468	255	2	866

(Data source: Omnibus Survey 2002, BTS)

Table A.4. Bivariate frequency distribution: Sex vs. Following glare rating

Sex	Following glare rating						Total
	Statistic	Not noticeable	Barely noticeable	Noticeable but acceptable	Disturbing	Crash or near miss	
Male	Weighted Size	7101625	8321053	46970149	21286678	80835	83760340
	Sample Size	35	41	229	106	1	411
Female	Weighted Size	5286631	6290957	43203578	27155553	294787	82231505
	Sample Size	31	35	242	152	2	461
Total	Weighted Size	12388255	14612010	90173727	48442231	375622	165991845
	Sample Size	66	76	471	258	2	873

(Data source: Omnibus Survey 2002, BTS)