NIGHTTIME EFFECTIVENESS OF REARVIEW MIRRORS: DRIVER ATTITUDES AND BEHAVIOR

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16. Abstract

The availability of new technology for antiglare rearview mirrors has increased the importance of understanding how people react to glare from rearview mirrors, and what the tradeoffs between visibility and glare reduction should be. We conducted a survey of attitudes toward and use of prism mirrors to determine what guidance that information might offer for future mirror design. The major findings are that (1) there is a high level of awareness and use of prism mirrors, but (2) the benefits obtainable from the antiglare setting of the prism mirror are not fully utilized. The reasons for this suboptimal use appear to be (1) a lower than desirable level of reflectivity on the antiglare setting, and (2) failure to make the required manual adjustments of the mirror setting.

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INTRODUCTION

Day/night mirrors of the prism type have been common on cars in the United States for over twenty years. The driving public has had a large amount of exposure to these mirrors and many years of potential experience with their use. The fact that prism mirrors are nearly universal might be interpreted as evidence that they are an effective and well accepted antiglare measure. However, there are indications that prism mirrors have potentially undesirable characteristics that merit further investigation. This issue is of special interest now because of recent technical developments that allow electronic control of rearview mirror reflectivity as an alternative to the use of prism mirrors.

Two potential problems with prism mirrors are (1) the antiglare reflectivity level is fixed at a very low level (4%), and (2) although they are simple to operate they do require active adjustment by the driver. In the antiglare setting an image is seen by reflection from the front surface of the glass. The reflectivity of that surface is determined by the index of refraction of the glass, and will be fixed at about 4% provided that the index of refraction is about 1.5. Several studies have suggested that this reflectivity is too low. Mansour (1971) obtained subjective evaluations for mirrors of several reflectivities and concluded that the antiglare reflectivity level should be about 10 to 20%. Olson and his colleagues (Olson, Jorgeson, & Mortimer, 1974) conducted several experimental studies of glare and visibility as functions of reflectivity. Although they did not make explicit recommendations, their results indicate that reducing reflectivity below 14% provides only marginal further reduction in glare. Ueno and Otsuka (1988), recommended an antiglare reflectivity of 8 to 10%, although they were not explicit about the basis for their recommendation.

Prism mirrors are operated by manipulating a simple lever attached to the mirror mount. Although that is an easy task, it often must be performed while a driver is in heavy traffic and under high workload. Also, when glare from following cars changes frequently, as is typical in heavy expressway traffic, it is necessary for a driver to change the mirror setting repeatedly to get the best trade-off between visibility and glare protection. It is not clear how well drivers cope with those demands, but there is evidence that drivers do not do a very good job at what may be a similar task: using headlight high beams. Hare and Hemion (1968) surveyed use of high and low beams and found that only 25% of drivers in "open road" situations (neither following nor meeting another vehicle) used high beams. Because use of high beams in those situations would have provided better visibility without impairing other drivers, Hare and Hemion concluded that 75% of drivers were not behaving optimally; they suggested as probable factors for this behavior "driver inattention, refusal by the driver to be bothered with changing beam, and ignorance of the visibility improvement obtainable with use of high beam" (pp. 21-22). Selecting high or low beams is similar in cognitive and motor demands to the task of using a prism mirror, and in both cases the driver must make moderately frequent adjustments in response

to the presence of other vehicles. Given drivers' sub-optimal use of high beams, it would not be surprising if there were similar problems with their use of prism mirrors.

The purpose of the present study was to collect information about drivers' attitudes toward, and use of, prism-type day/night mirrors. Because of the concerns outlined above, we were specifically interested in drivers' opinions about their abilities to see to the rear when their mirrors were in the antiglare setting. We suspected that a substantial number of people would have complaints about inability to see to the rear, and that those complaints would be strong enough to reduce their use of the antiglare setting. We also wanted to assess the level of awareness of prism mirrors in the driving population, as well as the prevalence of their use.

In order to address these concerns, we conducted a direct-mail survey of residents of the city of Ann Arbor, Michigan, asking them about their attitudes and behaviors with regard to day/night rearview mirrors. The evidence from this study is thus based on the participants' retrospective self-reports, and interpretations of results should take into account the possibility of biases and inaccuracies in such reports.

METHOD

Subjects

We randomly selected 1008 residents of the city of Ann Arbor from the 1988 Polk City Directory (R.L. Polk, 1988). This directory is intended to contain the names of all residents of the city who are 18 or older, including the names of all related or unrelated adults who share addresses. Selection was made so that each individual in the directory had an equal chance of being selected, with the exception that the numbers of men and women were constrained to be equal. The sample size was approximately 1% of the population of the city.

The city of Ann Arbor

We chose the city of Ann Arbor as the site of this survey primarily because we expected that the reputation of the University of Michigan within the city would insure a high level of cooperation with the survey. Ann Arbor is the location of the main campus of the University. It is a medium size town in southeastern Michigan, about 40 miles (64 km) west of Detroit. In the 1980 United States census it had a population of 108,000 (United States Bureau of the Census, 1989). The population of Ann Arbor is somewhat younger, wealthier, and more educated than the population of the country as a whole. According to the 1980 United States census, the median age of residents of the country was 28.8 years (USBC, 1983) and the median age in Ann Arbor was 25.8 years (USBC, 1982). Per capita income during 1985 has been estimated at $11,862 for the United States as a whole and $14,670 for Ann Arbor (USBC, 1989). According to the 1980 census the proportions of residents of the country who had graduated from high school and college was 34.6% and 16.2%, respectively (USBC, 1989). At the same time high school and college graduates made up 80.9% and 36.0% of the population of Washtenaw County (which includes Ann Arbor and some smaller, nearby towns) (Verway, 1987).

Survey form

We constructed a two-page survey form, including questions about (1) various background characteristics of the participants such as age, sex, and driving experience, and (2) about attitudes and behaviors with regard to rearview mirrors. The form was pretested on 64 members of the staff of the University of Michigan Transportation Research Institute (UMTRI) to insure that the items were clear. The form was mailed with a cover letter that requested voluntary cooperation with the survey. A stamped envelope addressed to UMTRI was included for the participant to use in returning the form. The survey form and cover letter are reproduced in the appendix.

Mailing

All 1008 forms were mailed on September 5, 1989. The survey was anonymous, so it was not possible to determine which individuals returned the forms. For that reason, and because compliance rate was unexpectedly high, no reminder notices were sent.

RESULTS

Survey forms were received and tabulated at UMTRI. The results are summarized here under four headings: (1) response rate, (2) background characteristics of the participants, (3) attitudes and behaviors toward mirrors, and (4) certain relationships among responses that provide information about individual differences in drivers' use of day/night mirrors. A few subjects left some items blank. Sometimes the reason for this was clear (e.g., some subjects indicated that they were unfamiliar with prism mirrors), but in a small number of cases there was no obvious explanation. Because of occasional missing pieces of data, the number of subjects will vary slightly among the analyses reported here.

Response rate

Of the 1008 forms mailed, 162 were returned by the post office undelivered. Of the remaining 846 forms, which can be assumed to have been delivered, 424 were filled out and returned. Thus the compliance rate was just over 50%.

Background characteristics

The numbers of men and women responding were almost identical; 213 men and 209 women responded. The distribution of respondents by age is shown in Figure 1, along with the distribution of the population of the United States by age from the 1980 census (USBC, 1983). Both sets of age data have been summarized as the number of individuals in five-year intervals and then normalized to the maximum interval count. As can be seen in the figure, the survey sample underrepresents the United States population in the 20 to 29 age range. This may have been caused by underrepresentation of that age range in the Polk directory (perhaps because people in that age range move more often and are therefore harder to maintain current addresses for), or by a lower compliance rate for younger people. With that exception, the age distribution in the survey sample matches the United States population reasonably well.

For several of the analyses reported below, the effect of age was assessed by splitting subjects into three broad categories based on age: (1) 20 to 39, (2) 40 to 59, and (3) 60 and older. Table 1 shows the proportions in each of those categories for the survey sample and the United States population. Even at this coarser level the underrepresentation of younger people can be seen.

The use of corrective lenses, broken down by the three broad age categories described above, is shown in Table 2. As might be expected, use of some form of correction increased with age, and contact lenses were much more common for younger drivers.

The respondents' estimates of annual mileage driven and proportion of night driving are shown in Figures 2 and 3, broken down by the same three age categories and by sex. Older people report less

driving and proportionately less night driving. Women also report less driving and proportionately less night driving. For reported percentage of night driving there is a strong interaction between sex and age, such that older women report particularly little night driving.

Most respondents drove late-model cars. The distribution of cars driven by model year is shown in Figure 4. The distribution of cars by make is shown in Table 3.

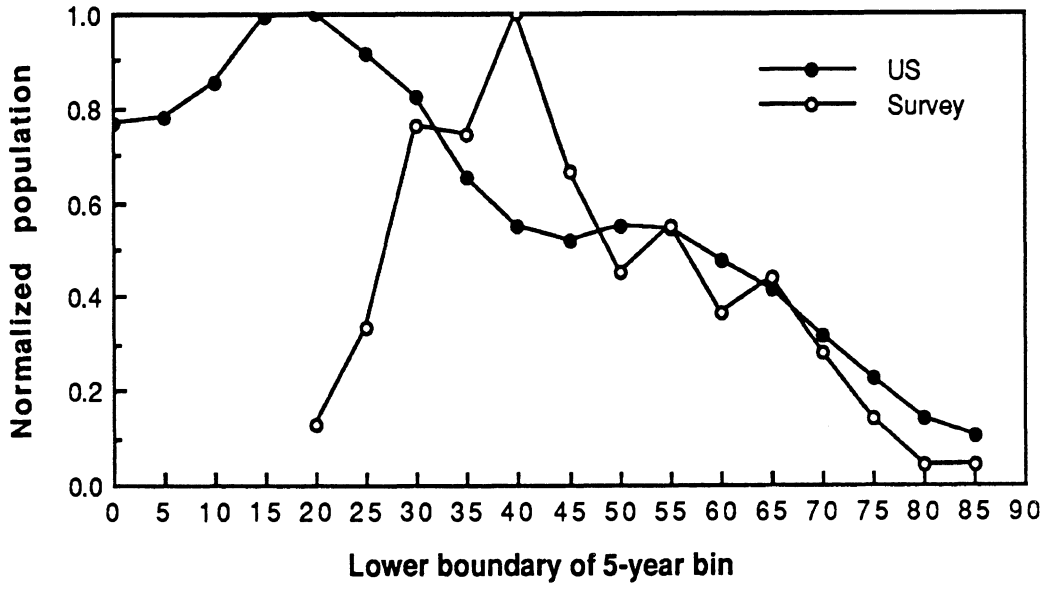

Figure 1. Normalized age distributions of the survey sample and the United States population from the 1980 census.

Table 1

Proportions of people in three age categories for the survey sample and the United States population.

Age range	Survey sample	U.S. population
20-39	.33	.47
40-59	.45	.30
60 +	.22	.23

Table 2

Proportions of each age group using each type of corrective lenses.

Age range	Glasses	Contact lenses	None
20-39	.34	.28	.38
40-59	.56	.12	.32
60 +	.75	.04	.21

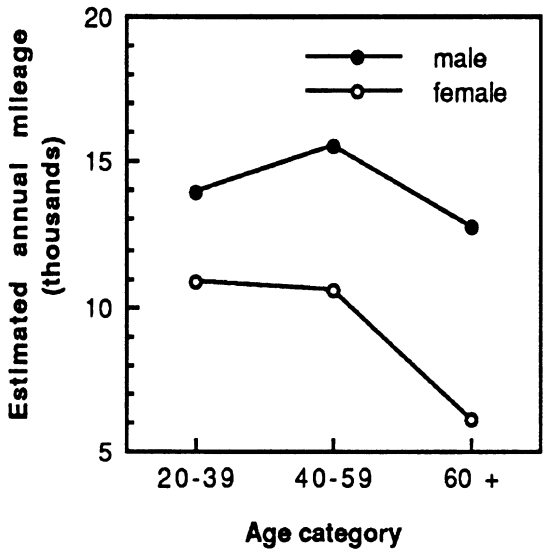

Figure 2. Estimated annual miles driven for males and females of three age categories.

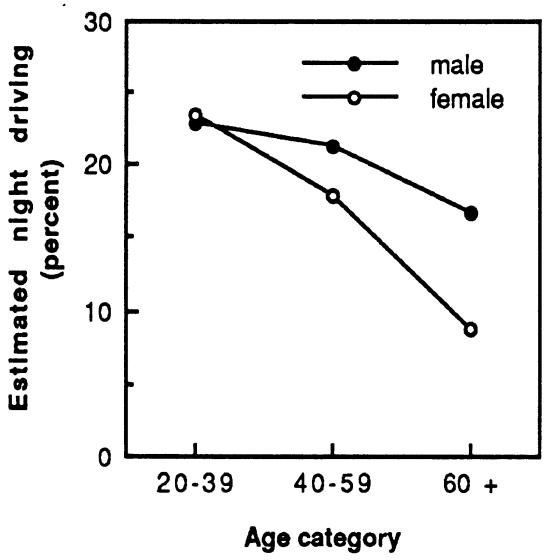

Figure 3. Estimated percentage of driving done at night for males and females of three age categories.

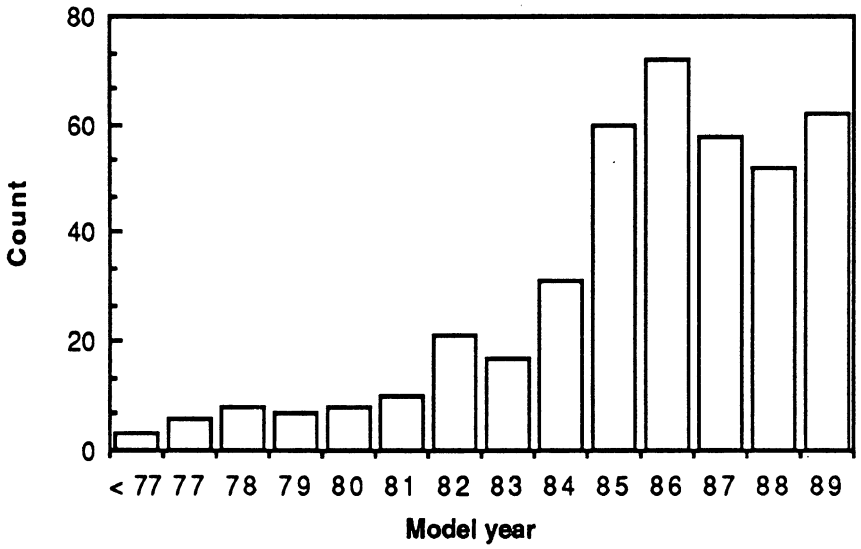

Figure 4. Distribution by model year of the cars that respondents drove most.

Table 3

Frequencies by make of automobiles

used by participants in the survey.

Make	Percentage
General Motors	31
Ford	24
Chrysler	17
Honda	10
Toyota	7
European	6
Other Japanese	5

Mirror attitudes and behaviors

The respondents were overwhelmingly familiar with prism type day/night mirrors: 97.5% reported that they were familiar with them, and only 2.5% (11 individuals) said they were not. A somewhat smaller, though still high, percentage reported having a prism mirror in the car that they usually drove: 91% said that they had one, 6% said they did not, 1% were not sure, and 2% reported that they had automatic day/night mirrors.

When asked to categorize their use of day/night mirrors using the descriptions in Table 4, they responded with the frequencies shown. (See survey form in the appendix for exact descriptions of these categories.) Most people reported that they used day/night mirrors, and the most common pattern was active switching of the mirror in response to changing conditions. A substantial minority (19%) reported never using day/night mirrors.

Respondents were asked to make a number of ratings by marking a position on a horizontal line with verbal anchors at each end (and in one case a middle anchor as well). Details of how those lines were presented can be seen in the reproduction of the survey form in the appendix. Responses to those items were scored by measuring the position of marks made by the respondents. Each of the lines was 50 mm long, and the position of marks was read to the nearest millimeter. The numerical value assigned to a response was its distance in millimeters from the left end of the line. Values could therefore range from a minimum of 0 for marks at the extreme left end of a line, to 50 for marks at the extreme right end. Mean responses for each of the nine scales with that format are given in Table 5.

Reported use of the antiglare setting was highest for expressway driving, intermediate for rural roads, and lowest for city streets. Expressway use may be higher than rural road use because of a higher traffic density, which would cause glare from the rear to be more frequent. City streets may have the lowest rate of use because they often have a high ambient illumination level from fixed lighting, which would decrease the effects of glare stimuli.

When asked to rate the severity of glare from various sources, respondents gave nearly equal ratings to glare from oncoming headlights and from inside rearview mirrors. Glare from left outside mirrors was rated lower than glare from inside mirrors or oncoming headlights, but higher than glare from right outside mirrors. Glare from right outside mirrors was rated very close to the "no problem" end of the scale. Ratings for glare from inside rearview mirrors in the antiglare setting were similar to ratings for the right outside mirror, indicating that on average people consider prism mirrors very effective in reducing glare.

For ability to see to the rear while using the antiglare setting, ratings averaged very near the special middle anchor used on this scale of "just acceptable."

Subjects were provided a checklist on which to indicate any reasons that they might not use the antiglare setting of a day/night mirror. Each subject could check as many reasons as might apply. The frequencies with which the various reasons were cited are shown in Table 6. The most frequent "other" reason was difficulty in judging the distances of following cars, cited by 15 respondents.

Table 4
Proportion of respondents in
each category of mirror use

Category	Proportion
never	.193
constant	.156
switching	.626
other	.025

Table 5

Mean responses to scale items.

Item	Mean response
Use of antiglare setting on[1]:	
city streets	27.2
expressways	36.7
rural roads	32.5
Severity of glare from[2]:	
oncoming headlights	25.4
inside mirror	24.6
left outside mirror	18.1
right outside mirror	8.2
inside mirror/antiglare	7.2
Ability to see to the rear[3]	24.5

Notes: (1) 0 = never, 50 = always

(2) 0 = no problem, 50 = unbearable

(3) 0 = very well, 25 = just adequately,
50 = unacceptably poorly

Table 6

Numbers of respondents citing each of several reasons for sometimes not using the antiglare setting.

Reason	Number of people citing (percentage of 424)
can't see well to the rear	141 (33%)
don't remember to switch	99 (23%)
too much trouble to switch	53 (13%)
don't have day/night mirror	13 (3%)
doesn't help with glare	12 (3%)
don't know about mirrors	6 (1%)
other	34 (8%)

Relationships among Items

One of the hypotheses that led to this project was that some people reduce their use of the antiglare setting, and endure more glare than they otherwise would, because the reflectivity of the antiglare setting is too low to provide a level of visibility that is acceptable to them. In order to generate an estimate for each individual's overall use of the antiglare setting, the three antiglare use ratings reported in Table 5 were averaged for each subject. This overall use index was then regressed on ratings of ability to see to the rear (the last scale reported in Table 5). The regression was highly significant, $F(1,358) = 24.14$, $p < .0001$, $r = .25$. The direction of the relationship was as predicted by the hypothesis outlined above: greater rated difficulty in seeing was associated with less use of the antiglare setting.

It is possible that some of the individual differences in use of the antiglare setting can be accounted for by individual differences in glare susceptibility. We constructed an overall mirror glare severity

index for each subject by averaging their severity ratings for inside, left outside, and right outside mirrors (scales reported in the middle of Table 5). A multiple regression of the overall use index on rated ability to see to the rear and on the overall glare index was performed. The overall regression was significant, $F(2,352) = 34.80$, $p < .0001$, $r = .41$. Each of the predictors was significant; for rated seeing, $t(352) = 5.00$, $p < .0001$, and for the glare index, $t(352) = 6.57$, $p < .0001$. The relationship between glare and use was such that higher glare susceptibility was associated with greater use of the antiglare setting.

Mean values for the overall use index, the overall glare index, and rated ability to see to the rear are given in Table 7 for each of the three broad age categories discussed above. One-way analyses of variance indicate that the effect of age on overall use is not significant, $F(2,380) = 0.53$, $p > .50$, that the effect of age on glare susceptibility is significant, $F(2,386) = 5.69$, $p < .01$, and that the effect of age on rated seeing to the rear is significant, $F(2,366) = 4.60$, $p < .05$. Older people gave less severe glare ratings and reported less trouble seeing to the rear with the antiglare setting.

Table 7

Average ratings for each age group of: overall use of the antiglare setting, overall severity of glare from mirrors, and rated ability to see to the rear with the antiglare setting.

Age range	Use of antiglare	Glare severity	Ability to see
20-39	33.2	20.0	26.1
40-59	31.4	17.6	24.9
60 +	31.5	15.2	20.7

DISCUSSION

It appears that drivers are highly aware of day/night mirrors (only 3% report being unfamiliar with them), and that most drivers (81%) use them at least some of the time. It is possible that these estimates are biased by selective compliance with this survey; people who are more knowledgeable about day/night mirrors, or who value them more, may have been more inclined to return the survey form. However, the overall rate of compliance (50%) was high for surveys of this type, suggesting that the survey was successful in tapping peoples' general willingness to help, and that any bias is minor.

These results are consistent with the position that an antiglare reflectivity level of 4% is too low. A substantial proportion of people (33%) reported that they sometimes did not use the antiglare setting because they could not see well enough to the rear. Also, individual differences in rated ability to see to the rear predicted part of the individual variation in rated use of the antiglare setting. These results cannot be used to derive a quantitative recommendation for what the antiglare reflectivity should be, but two aspects of the results can be used to give some guidance. First, subjects rated glare from rearview mirrors in the antiglare setting close to the bottom of the available scale, slightly lower than glare from right outside mirrors. This suggests that 4% reflectivity is extremely effective in reducing glare, and that the tradeoff between glare reduction and visibility could be shifted toward greater visibility without unacceptably increasing glare. Second, there are individual differences in peoples' preferences concerning that tradeoff. There were individual differences in subjects' ratings of how well they could see in a 4% reflectivity mirror and in how much difficulty they experienced with glare from mirrors. The simple fact of variability in responses such as these is not sufficient evidence for the existence of true individual differences; variability could be unreliable, simply the result of error of measurement. However, in this case there are orderly relationships among the individual differences in rated seeing, glare susceptibility, and use of mirrors. This orderliness indicates that the differences in responses represent real individual preferences.

Two effects of age in this study were somewhat unexpected. First, older people gave less severe glare ratings than did younger people. This is not consistent with a general pattern of evidence that suggests older people have more trouble with glare (Olson, 1988), but it is in agreement with some recent experimental findings by Sivak and Olson (1989). They conducted a dynamic field study in which older subjects reported less discomfort glare from opposing headlamps than did younger subjects. This direction of effect is consistent with the tendency of older people to respond in a manner that they believe meets with the approval of others (Campbell, Converse, & Rogers, 1976).

Second, older people reported less trouble seeing to the rear with the antiglare setting. Although this effect might also be a manifestation of the tendency to meet with the approval of others, it could be that people responded to this question not in absolute terms, but in relation to seeing without the

antiglare setting. If older people benefit more from the antiglare setting, then reporting the relative improvement would account for this finding.

Summary

The results of this study indicate that prism day/night mirrors are effective in reducing glare, and that they are widely used by drivers. However, their effectiveness and rate of use are reduced by two problems. First, for many people the antiglare setting provides inadequate visibility to the rear. Second, substantial proportions of subjects reported that they made less use of prism mirrors because they did not remember to switch settings (23%) and because it was too much trouble to switch the mirror manually (13%). The results suggest that recent developments in electronically controlled rearview mirrors could provide significant benefits to drivers. Because they provide the capacity to vary reflectivity continuously they may be able to achieve a better tradeoff between visibility and glare reduction than prism mirrors. If proper controls can be provided for drivers, electronic mirrors may also be able to accommodate individual preferences for that tradeoff. Automatic control of reflectivity level may also be a significant advantage because of the problems people report with operation of manual prism mirrors.

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APPENDIX

The cover letter and survey form sent to participants in this study.

The University of Michigan
Transportation Research Institute
2901 Baxter Road, Ann Arbor, Michigan 48109-2150

August 15, 1989

Dear Ann Arbor resident:

Please help us with a few minutes of your time! At the University of Michigan's Transportation Research Institute we are conducting a survey of how people use their car's rearview mirrors. The survey consists of the form that is enclosed with this letter. We would greatly appreciate it if you could take a few minutes to fill out the form and return it to us in the enclosed envelope which is already stamped and addressed to me at the Transportation Research Institute.

The Institute is located on the University's North Campus. We have about 140 faculty and staff members, and we do research in many areas relevant to the safety and efficiency of transportation. The mirror survey is being conducted by the Institute's Human Factors Division. The study of "human factors" in transportation is concerned with how to make cars and other vehicles easier or safer to use by designing them to fit people's natural abilities. Some human factors issues that we have studied here include how car instrument panels should be designed so that people can read them quickly and accurately, how big and bright highway signs should be, and how quickly people can react and make decisions in high-speed traffic.

We are conducting the mirror survey because many new anti-glare mirror designs are becoming available, making use of innovative electronic and optical technology. The survey is the first step in a research project to determine how people feel about current mirrors and which of the possible new designs would best address peoples' needs.

Let me encourage you again to complete the survey form and send it to us. The form is very simple, but the results will be of great interest to us, and we hope they will ultimately contribute to safer mirror designs. There is no need to put your name or address on the form; the survey is completely anonymous.

If for any reason you choose not to return the survey form, please simply throw it away rather than ask a friend or family member to complete it. Although the survey is anonymous, we originally randomly picked 1000 specific names (including yours) from a list of Ann Arbor residents, and we would like the final pool of respondents to be as representative of that group as possible.

Please feel free to enclose a note with your survey form or to call me at the Institute if you have any questions or comments about the survey. Thank you in advance for your help!

Sincerely,

Michael Flannagan, Ph.D.
Human Factors Division
936-1091

Page 1 of the survey form.

The University of Michigan

Transportation Research Institute
Rearview mirror survey

Many cars have a lever on the inside rearview mirror to switch between "day" and "night" positions. In the "day" position the mirror is highly reflective (bright), and that level is intended for use during the day, or when there are no car headlights behind at night. In the "night" position, the mirror is much less reflective (dimmer), and that level is intended to be used at night when there is glare from the headlights of following cars. The purpose of this survey is to find out what people think of such mirrors, and how they use them.

Are you familiar with "day/night" mirrors? [ ] yes [ ] no [ ] not sure

Please record your:

Age _____ Sex: [ ] male [ ] female

Years of driving experience _____ Estimated annual driving mileage _____

Percent of your driving that is at night _____

Do you wear: [ ] glasses [ ] contact lenses

For the car that *you drive most*, please indicate:

Make _____ Model _____ Year _____

Does your car have a "day/night" rearview mirror (as described in the above introduction)?

[ ] yes [ ] no [ ] not sure

If you have a day/night mirror, please indicate which of the following statements best describes how you use it:

[ ] I never, or almost never, use the day/night feature. I simply leave the mirror at the same setting for all day and night conditions.

[ ] I use the "day" setting constantly during the day, and the "night" setting constantly at night.

[ ] I use the "day" setting constantly during the day, and at night I switch back and forth depending on whether I am bothered by glare from a car behind me.

[ ] Other. (Please describe here in your own words if none of the above applies.)

***** Please fill out the back too! *****

Page 2 of the survey form.

For this question consider only cases when (1) it is night, and (2) a car is behind you and causing glare from your rearview mirrors. **Under those conditions**, about what proportion of the time do you use the night setting of your inside rearview mirror while driving on:

(please mark a vertical line on each scale where appropriate)

	Never	Always
city streets	|----------	----------|
expressways	|----------	----------|
rural roads	|----------	----------|

On the following scales, please rate how much of a problem you experience with glare from each of the four sources. Make one vertical mark on each scale, placing them so that they reflect the **relative** severity of glare that you experience from each source (i.e., if one source is more of a problem than another, its mark should be further to the right).

	No problem	Unbearable
Oncoming headlights:	|----------	----------|
Inside rearview mirror:	|----------	----------|
Left outside mirror:	|----------	----------|
Right outside mirror: (Leave blank if not applicable.)	|----------	----------|

If you have any experience with day/night mirrors, how much of a problem is glare from inside rearview mirrors **when the "night" setting is used**? If you have no experience, please check here: [ ].

No problem	Unbearable
|----------	----------|

If you have any experience with day/night mirrors, how well can you see to the rear when the mirror is in the "night" setting? If you have no experience, please check here: [ ].

Very well	Just adequately	Unacceptably poorly
|----------	----------|	

If you sometimes **do not use** the night setting of a day/night mirror when you are experiencing discomfort from rearview mirror glare, why not? (Check all that apply.)

[ ] Don't have a day/night mirror.
[ ] Don't know about day/night mirrors or not sure how to use them.
[ ] Glare is a problem, but day/night mirrors don't help.
[ ] I sometimes don't remember to switch the mirror.
[ ] It is sometimes too much trouble to switch the mirror.
[ ] I can't see well enough in the mirror at the "night" setting.
[ ] Other (please describe in your own words).

Thank you for your help!