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Workshop on Rearview Mirror Human Factors Research Needs: Summary of Recommendations

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16. Abstract

This document provides a summary of suggestions for research concerning rearview mirrors that were made at a workshop held at the University of Michigan on May 8 and 9, 1996. The workshop was sponsored by the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation, and conducted by the University of Michigan Transportation Research Institute (UMTRI).

The purpose of the workshop was to identify future human factors research needed for determining rearview mirror performance and design requirements that will insure that drivers can use rearview mirrors safely and effectively. Although the workshop was sponsored by NHTSA, it was intended to identify the most important research needs in the area of rearview mirrors quite broadly, whether or not it was related to NHTSA regulatory activities and independent of who might sponsor the research.

Forty-five individuals participated in the workshop, including representatives of the research community, the regulatory area, and the mirror and vehicle manufacturing sectors.

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Contents

Introduction

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The purpose of the workshop was to bring together as extensive a group of experts as possible to generate a broad range of proposals for research on rearview mirrors. The intent was to be as comprehensive as possible in generating ideas, rather than to discriminate among those ideas or set priorities. The formally stated goal was to "identify future human factors research needed for determining rearview mirror performance and design requirements that will insure that drivers can use rearview mirrors safely and effectively." Although the workshop was sponsored by NHTSA, it was intended to identify the most important research needs in the area of rearview mirrors quite broadly, whether or not they were related to NHTSA regulatory activities and independent of who might sponsor the research. Thus, the scope of the workshop included any research issues related to rearview mirrors. Nevertheless, the organizers anticipated that one of the major issues raised by the participants would be the possible benefits of nonplanar driver-side mirrors in passenger vehicles. That indeed turned out to be the case, as is evident in the following summaries. The scope of the workshop included commercial vehicles as well as passenger vehicles. The agenda for the workshop is given in Appendix A.

Forty-five individuals participated in the workshop, including representatives of the research community, the regulatory area, and the mirror and vehicle manufacturing sectors. The organizers attempted to make participation as broad as possible, while keeping the length of the meeting from being too burdensome on the schedules of the participants, and keeping the size of the group at a level at which interactive discussion of the issues was possible. A roster of the participants is given in Appendix B.

The meeting began on May 8 with background presentations intended to summarize the current state of our knowledge about driver performance with rearview mirrors. These were followed on May 9 by group discussions of several key questions about possible future research.

Background Presentations

A series of presentations on the first day of the workshop was designed to ensure that the entire group had been exposed to certain basic information as background for the discussions on the second day. There were seven presentations, as listed in the agenda for May 8 in Appendix A. Some of the presentations were very similar to previously published reports, which are cited below as additional documentation; others were oral-only presentations.

Michael Perel led off with a keynote presentation in which he defined the goal of the workshop as the identification of the data and research methods that would be required to address safety problems related to driver rearward visibility. He summarized the state of current knowledge concerning the nature of safety problems in rearward visibility, reviewed past NHTSA research on rearward visibility, and offered candidate recommendations for future research. He suggested that the participants should approach the workshop discussions as if there were no existing regulations, and simply identify what, in their view, were the research approaches most likely to lead to improved safety.

Michael Flannagan made a brief presentation summarizing the history of the introduction of passenger-side convex mirrors in the U.S., and reviewing some of the issues that were involved. A key event in that history was the General Motors Corporation petition to NHTSA, on May 26, 1976, to permit convex mirrors on the passenger sides of cars and light trucks. At that time only planar mirrors could be used in any position as original equipment on cars and light trucks in the U.S. In its deliberations, NHTSA considered the possibility that the reduced image sizes provided by convex mirrors would result in unsafe behavior by drivers who might overestimate the distance to vehicles in the rear. NHTSA determined that, with the addition of the warning label, "Objects in mirror are closer than they appear," convex mirrors with radii between 35 and 65 inches (89 and 165 cm) could be safely used on the passenger side. Federal Motor Vehicle Safety Standard (FMVSS) 111 was amended effective September 2, 1982 to allow such mirrors.

Stig Pilhall reviewed a large number of concepts for rear vision systems that had been considered during the development of the Volvo aspheric mirror (Pilhall, 1981). He emphasized the potential benefits of international harmonization of rearview mirror requirements. He reported that the development and introduction of the Volvo aspheric mirror did not involve formal collection of driver performance data because the advantages of the larger field of view were considered obvious.

George Platzer presented a proposal for reaiming conventional planar mirrors to address the blind zone problem and reduce glare from rearview mirrors (Platzer, 1995).

He suggested the reaiming approach as an alternative to the use of nonplanar mirrors with larger fields of view, pointing out that it does not require a change in equipment. Most people probably aim exterior mirrors so that a small portion of the rear of the vehicle appears at the edge of the mirror. Platzer's suggestion is to aim the exterior mirrors so that the outside edges are rotated slightly forward from this conventional position. The fields of view provided by the exterior mirrors are thereby rotated into the middle of what would be the blind zone with conventional aiming. This leaves two smaller blind zones, neither large enough to conceal a vehicle, on either side of the reoriented mirror field of view. Because the fields of view are rotated away from the rearward direction, the headlamps of following vehicles do not appear in the mirrors until they are relatively close. At the distances at which the headlamps do appear in the mirror, the light striking the mirrors is from the peripheral, relatively weak, part of the headlamp beam patterns. The reaiming thus reduces glare from exterior mirrors as well as eliminating the large blind zone that is present with conventionally aimed planar mirrors.

Josef Schumann presented results from two UMTRI studies of European accident data that were designed to assess the overall safety effects of planar and nonplanar driver-side mirrors. The studies used similar methods but different sets of data, one from Finland (Luoma, Sivak, & Flannagan, 1995), and one from Great Britain (Schumann, Sivak, & Flannagan, 1996). These countries were chosen because they had both a mixture of driver-side mirror types and detailed accident records. The key piece of information required in the accident records was the lateral direction of movement (left or right) for the driver who was considered to be at fault in a lane-change accident. The main analysis compared the numbers of accidents with movement toward the passenger side (for which all of the vehicles involved in the study had convex mirrors) to the numbers of accidents with movement toward the driver side (for which some vehicles had planar mirrors and some had nonplanar mirrors). In both studies, this analysis indicated that there were fewer driver-side accidents (than would be expected based on the rates of passenger-side accidents) for cars with nonplanar driver-side mirrors. However, in neither study did this result reach statistical significance. Although neither study can be considered conclusive, together they provide moderately strong evidence that the advantages of nonplanar mirrors (reductions in the blind zone) outweigh their disadvantages (minification of images).

Loren Staplin presented a number of methodological issues that must be addressed in dynamic evaluations of rearview mirrors, as well as specifics of a candidate approach to such evaluations. Among the issues that he identified were: what traffic situations will yield data on driver behavior that are most relevant to safety (e.g., "imminent conflict" situations versus more routine driving), the level of practice that subjects should be given in an experimental evaluation, the proper way to structure the task demands of the experimental situation to reflect a driver's state of attention in real driving, and the required level of realism in visual simulation of driving scenes. Staplin described the DEVISE (Dynamic Evaluation of Visibility and Information System Effectiveness) simulator that has been developed under NHTSA sponsorship. The simulator consists of a light truck cab mounted on a fixed platform. Laser videodisk players present dynamic road scenes for three fields of view: the forward field, the field of the inside rearview mirror, and the field of the driver-side exterior rearview mirror. Although the simulator is open-loop with regard to road and traffic events, subjects can use the steering wheel to perform a tracking task embedded in the forward scene.

Flannagan presented results from a study of driver perceptual adaptation to nonplanar mirrors (Flannagan, Sivak, & Traube, 1996). Subjects made magnitude estimates of the distance to a car seen in a driver-side rearview mirror. Three different mirrors were used: plane, aspheric (with a large spherical section having a radius of 1400 mm [55 in]), and simple convex (with a radius of 1000 mm [39 in]). The study measured the effect of feedback (in the form of subjects being allowed to look over their shoulders for a direct view of the rearward car) on subjects' estimates of distance. Initially subjects showed substantial overestimation of distance with the nonplanar mirrors relative to the planar mirror. Feedback quickly, but only partially, reduced this overestimation. After about one hour of experience the nonplanar mirrors still showed significant overestimation relative to the planar mirror. Flannagan suggested that the study indicated the existence of a rapid, but incomplete, form of adaptation, leaving open the question of whether there is a further form of adaptation that might be slower but more complete. He suggested that if substantial adaptation is indeed possible, the concern that nonplanar mirrors may lead to underestimation of distances and unsafe judgments in driving would be reduced.

Suggestions for Research

On the second day of the workshop, the participants were presented with a series of questions designed to prompt suggestions for specific research projects. (See the agenda for May 9 in Appendix A for the complete list of questions.) For each question, after a period of general discussion about the current state of knowledge concerning that question, the participants were asked to suggest research projects that might lead to better answers to the question. Those suggestions are summarized on the following pages in sections headed by the original questions.

The suggested research projects presented here were derived from lists that the moderator kept on overhead projector transparencies as items were brought up in the discussions. The lists presented here have been edited from those original lists, incorporating notes from the UMTRI staff members who attended the meeting, as well as written comments that all participants were invited to submit at the conclusion of the workshop. In compiling these summaries we have tried to reflect the ideas that were discussed in the workshop as directly as possible, and to resist the temptation to editorialize. For some items, we have added a few pertinent references to the literature. At the beginning of the workshop it was announced that, in order to encourage the free exchange of ideas, no statements would be attributed to specific individuals or organizations. In keeping with that ground rule, all of the following suggestions have been summarized anonymously. It is probably inevitable that, in a set of discussions as wide ranging as occurred at the workshop, some valuable ideas were missed. We deeply regret any such omissions.

The intent of the workshop organizers was to elicit as comprehensive a set of suggestions as possible, rather than to produce a specific research plan. Although the participants were asked for their informal thoughts about research priorities, no formal attempt was made to set priorities for the suggestions given in the workshop. The order in which suggestions are listed here should not be interpreted as reflecting judgments about their importance. The suggestions are listed approximately in the order in which they were introduced in the oral discussions.

What are the extent and nature of safety problems with current rearview mirrors?

1. Collect data to quantify the magnitude of the problem of rear end crashes that are caused by a following driver not attending to the forward direction, while seeking information about traffic to the rear or to the side (using either rearview mirrors or direct view). This problem might be ameliorated if rearview mirror systems can be improved in ways that reduce the amount of time drivers must divert their attention from the straight ahead.

2. Conduct a study of crashes and critical incidents with descriptions that are detailed enough to determine when rearview mirrors are involved. The descriptions that go into current crash databases are not coded in enough detail to assess the role of rearview mirrors. Although a study such as suggested here would probably have to be much smaller than most general purpose crash databases, it might nevertheless provide adequate data if critical incidents, rather than actual crashes, were recorded. There are several alternative methods that are worth considering for such a study: (1) The study might involve "black box" recording, or logging by drivers, in a preselected fleet of vehicles. (2) Drivers from the general population might be surveyed and asked to retrospect about incidents related to mirrors. (3) People who were involved in crashes that were reported in the standard ways might be surveyed to find out further details about the extent to which rearview mirrors were involved.

3. Conduct a task analysis of driving to determine when rearview mirrors are critical.

4. Compare crash statistics across countries that have different mirror types. Some work of this type has already been done (Luoma, et al., 1995; Schumann, et al., 1996).

5. Find out about any technical considerations that were involved in NHTSA abandoning the late-1970s proposal for a 90-degree rearward field of view. Consider whether such a proposal should be further evaluated.

6. Conduct a study of driver eye movements in heavy vehicles that focuses on the use of rearview mirrors and direct views away from the straight ahead. The configuration of heavy vehicles (including blind zones behind the vehicle and near the vehicle, higher eye positions, and different mirror configurations) limits the extent to which eye movement data collected in smaller vehicles can be generalized.

7. Investigate the type of training and the level of skill that drivers currently have in the use of rearview mirrors, and determine whether improvements in driver training might yield higher skill levels and safer use of mirrors.

8. Conduct a comprehensive analysis of requirements for direct and indirect fields of view. A number of previous studies should be reviewed as part of any such effort (e.g., Henderson, Smith, Burger, & Stern, 1983; Kelley, & Prosin, 1969).

9. Quantify the tradeoff between quantity and quality of field of view.

What are the needs of special populations of drivers, such as the elderly?

1. Identify and quantify the types of drivers who may have special needs.

2. Determine the extent to which the needs of special populations might be addressed by improving training rather than, or in addition to, by modifying equipment.

3. Study how the elderly, or other special populations, currently use standard mirrors. This might provide insight into how indirect vision systems could be modified to meet their needs.

4. Investigate the possibility that the tradeoff between quality and quantity of field of view is different for elderly drivers than for younger drivers.

5. Conduct a task analysis of driving with special focus on identifying components that require the use of mirrors and are forced-pace. Elderly drivers are often able to compensate for reduced basic perceptual and motor skills by learning appropriate strategies, but such strategies often require extra time, and therefore break down when tasks are forced-pace.

6. Consider how various display types and locations are suited to the reduced visual accommodation abilities of elderly drivers. Elderly drivers cannot focus their eyes as close as younger drivers, and when they use special optical correction (bifocals, etc.) to help with this problem, their ability to see near objects in focus is usually limited to the lower part of the visual field. The images seen in convex mirrors are optically much closer than the objects themselves (only a little further from the driver than the surface of the mirror, depending on the mirror radius), and electronic displays normally present images that require focusing at the distance of the display screens themselves (perhaps on the instrument panel). A technical analysis of the accommodation issue is provided by Seeser (1974).

7. Investigate whether elderly drivers would have more trouble adapting to innovative mirrors (e.g., convex mirrors on the driver side).

8. Determine how the reduced "useful field of view" (e.g., Ball, Owsley, & Beard, 1990) of elderly drivers may affect their use of rearview mirrors.

9. Determine whether the perceptual effects of nonplanar (convex and aspheric) mirrors are different for younger and older drivers.

10. Investigate drivers of heavy vehicles as a special-needs population. They may "age" faster in certain ways because the job is physically taxing. For example, do they have more difficulty in making head movements to check mirrors because of chronic neck and back pain?

11. Survey drivers or new-vehicle dealers to determine if the elderly, people with impaired mobility, or other groups of drivers tend to select certain rearview mirror options. The limited range of mirror options on new vehicles would diminish the value of such a survey to the extent that it was focused on such options. However, a variety of convex mirrors are available as after-market equipment, and a survey of drivers might reveal whether such mirrors are used more by certain classes of drivers.

What optical alternatives to standard mirrors exist for providing indirect vision?

1. Develop a performance-based evaluation of indirect-vision systems. This would be particularly valuable when a greater variety of systems, including some that are very different from mirrors, is to be evaluated.

2. Investigate the image resolution needed for adequate visual performance. The issue of image resolution is more critical for electronic imaging systems than for conventional mirrors.

3. Investigate how to match the characteristics of imaging systems to the visibility requirements for various areas around a vehicle (e.g., are video systems particularly appropriate for the blind zone behind semitrailers?).

4. Study the failure modes or degraded modes of nonmirror systems. Electronic systems or more elaborate optical systems will have different problems than conventional mirror systems.

5. Survey vehicle manufacturers and their suppliers for information about alternatives to mirrors that are being seriously considered.

6. Study the benefits and problems that have been encountered with nonmirror systems that are currently in use.

7. Conduct a comprehensive study of the effect of the locations of displays. Because the constraints on locations are generally weaker with nonmirror displays, this becomes a more important research issue when such displays are considered.

8. Study the effect of the number of displays, specifically whether there are benefits of having a single display location for the entire rearward scene.

9. Investigate the importance of image size in nonmirror displays.

10. Investigate the need for, and benefits of, training drivers in the use of innovative indirect-vision systems. All drivers are experienced in the use of rearview mirrors, but nonmirror systems may present new training needs.

How complete, accurate, and user-friendly are existing procedures, standards, and techniques for measuring, quantifying, and displaying fields of view?

1. Establish standardized reporting requirements for fields of view. The Society of Automotive Engineers has developed recommendations for quantifying fields of view for both direct and indirect vision (SAE, 1994) that might serve as the basis for standardized reporting requirements.

2. Develop standard software for quantifying and displaying fields of view. Make this software widely available, perhaps as freeware over the Internet.

3. Investigate whether the ambinocular or binocular field of view is more critical. The ambinocular field is what can be seen by either eye (the union of the individual eye fields); the binocular field is what can be seen by both eyes (the intersection of the individual eye fields).

4. Conduct further work on driver eye position. The Society of Automotive Engineers recommended practice that describes the "eyellipse" is currently the most standard summary of data on driver eye position (SAE, 1992). This recommended practice is applicable to both passenger cars and large vehicles, such as buses and heavy trucks.

5. Investigate the role of the vertical extent of the field of view for both safety and driver comfort.

6. Study the reliability and validity of various ways of measuring the field of view. Different methods may have different sensitivities to various sources of error, and they may differ in how well they predict driver visual performance and comfort.

7. Establish a public database of vehicle dimensions that are needed to determine fields of view. This might include heavy trucks as well as smaller vehicles. Ideally, this would be updated regularly.

What are the most important current issues concerning rearview mirrors on commercial vehicles?

1. Study the effect of the vertical extent of the field of view with the high driver eye heights that are typical of large commercial vehicles.

2. Investigate the extent to which drivers of heavy trucks use flat mirrors during forward movement. It may be that those mirrors are primarily used during backing, and that the convex mirrors are the primary means of rearward vision during forward movement.

3. Investigate what stimulus size is required for each of the variety of visual tasks that a driver must perform. Are the stimulus-size requirements different for backing and for forward movement?

4. Conduct studies of driver eye locations and head movements in heavy vehicles.

5. When tractor-trailers are turning, the fields of view of the rearview mirrors can be blocked by the trailer. Determine the fields of view required by drivers during these maneuvers, and how they are affected by this blocking. Evaluate the possible benefits of using motorized mirrors that automatically change their aim during turns to avoid being blocked by the trailer.

6. Because rearview mirrors block part of the forward field of view there is always a tradeoff between direct and indirect fields of view. Evaluate this tradeoff for drivers of commercial vehicles. Consider the fact that mirrors on heavy vehicles often create large forward blind zones, especially when they have aerodynamic housings.

7. Evaluate the differences in forward blind zones for cabover and conventional truck tractors. A formal treatment of this issue can be found in Burger, Mulholland, Smith, and Bardales (1980).

8. Consider how driver training textbooks should be revised.

How can rearview mirrors be optimized for use in backing commercial vehicles?

1. Collect data on off-road backing and maneuvering crashes. This might be done by selecting a fleet of vehicles and logging crashes and critical incidents. (For a summary of existing data on backing crashes in general, including those involving trucks, see Wang and Knipling [1994]. For an assessment of some countermeasures see Tijerina, Hendricks, Pierowicz, Everson, and Kigel [1993].)

2. Evaluate the relative performance in backing permitted by planar versus nonplanar rearview mirrors. It may be that the unit magnification provided by planar mirrors is particularly beneficial for the judgments of distance and speed required in backing.

3. Perform a task analysis to determine the competing demands of ancillary tasks during backing (e.g., the need to monitor other traffic when backing in potential conflict with other traffic, such as when crossing a road or driveway).

4. Investigate how the tradeoff between forward and rearward visibility may be different for low speed maneuvering versus normal forward movement.

What does existing research tell us about the safety effects that would result from use of nonplanar driver-side mirrors in the U.S.?

and

What issues should be addressed by future research to assess the safety effects that would result from use of nonplanar driver-side mirrors in the U.S.?

Because the above questions are closely related, responses to them have been combined in the following summary.

1. [Most of the discussion of this item actually occurred during the discussion of the first question of the day, the one concerning the extent and nature of safety problems with rearview mirrors in general. However, because it was directly related to the use of nonplanar mirrors, we have made the editorial decision to present it here. The fact that it arose early is probably an indication of the high level of interest that many participants had in the issue of nonplanar mirrors on the driver side.] Conduct a fleet study of the effects of nonplanar mirrors on the driver side in the U.S. Groups of vehicles could be equipped with various nonplanar mirrors on the driver side and compared to a control group equipped with planar mirrors. Given the wide variety of nonplanar mirrors that have been discussed, the issue of which nonplanar mirrors to investigate deserves considerable attention. The mirrors in a major fleet study should be based on some form of preliminary determination of what mirrors are most suitable to the study, rather than using "mirrors of convenience." Several possible dependent variables were discussed. Rates of certain kinds of accidents are probably the most valid indicators of safety, but, because accidents are rare, reliable estimation of those rates would require a large number of driver miles. Critical incidents might provide adequate information with far fewer driver miles, but they are by their nature more ambiguous than actual crashes and therefore would be harder to measure reliably (possibly by driver logs or "black box" instrumentation of the vehicles). Various driver-behavior variables (e.g., rate of changing lanes, sizes of gaps accepted in changing lanes) might be reliably measured with even fewer driver miles, but they may be less valid indicators of safety than accidents or critical incidents, and some of them would

require sophisticated vehicle instrumentation. It would be important in such a study to assign drivers to the various mirror conditions randomly.

2. Study the effect of radius of curvature of convex mirrors on judgments of distance and speed to determine what radius of curvature is effectively planar or "unit magnification" in terms of its effects on driver perception. FMVSS 111 requires that exterior mirrors on the driver side have unit magnification. An aspheric mirror could be considered to meet this requirement if it incorporated a planar, unit-magnification section that by itself met the requirements of FMVSS 111. However, it is difficult to manufacture mirrors that combine planar and nonplanar sections. Manufacturing difficulty would be greatly reduced if the nominally unit-magnification section actually had a slight curvature, perhaps even if that curvature was slight enough not to have significant effects on driver visual perception. There may be a radius of curvature high enough to have negligible effects on speed and distance judgments (probably significantly higher than 2000 mm, which is approximately the maximum radius of current convex mirrors), but that would still permit reliable manufacturing. A review of past work on the effect of radius of curvature on distance perception is provided in Flannagan (1988).

3. Quantify the tradeoff in terms of safety between: (1) the wider field of view, with distorted images, provided by nonplanar mirrors, and (2) the undistorted images, with blind zones, provided by planar mirrors. It is difficult to do this from basic human-performance studies because of the need to translate measures such as the time the eyes are away from the forward scene (e.g., Helmers et al., 1992) or changes in distance judgments (e.g., Mortimer, 1971) into predicted accident rates.

4. Investigate driver acceptance of aspheric rearview mirrors, considering such possible factors as image size, accommodation distance, flow of images as other vehicles pass or are passed by the observer's vehicle, and difference in image sizes for the two eyes. Driver acceptance is, to some extent, a separate issue from safety. It is not completely unrelated because drivers' satisfaction with mirrors may affect their behavior, thus indirectly affecting safety. For example, if drivers experience visual discomfort with mirrors, they may not check them as often as they should.

5. Identify the best design for aspheric mirrors. The curvature of a spherical convex mirror can be described by a single parameter—the radius of curvature. In contrast,

the design of aspheric mirrors may involve many parameters. The aspects of aspheric mirrors that should be investigated include:

- The possible value of visual demarcation between a spherical convex zone and an aspheric zone (a solid line or dotted line, etc.)
- The proportion of spherical convex and aspheric zones
- The radius of the spherical section and the radius range for the aspheric section
- The best transition between spherical and aspheric sections

6. Investigate the history and rationale for mirror practices outside the U.S., where convex and aspheric mirrors have been used extensively in the exterior, driver-side position.

7. Attempt to identify a nonverbal way of marking convex mirrors that would convey the same message as the current U.S. verbal warning "Objects in mirror are closer than they appear," but without the language specificity inherent in a verbal label, and perhaps with less visual clutter.

8. Study the possible benefits of nonplanar interior mirrors, including the possibility that combining rearward views in one display location simplifies the driver's task by eliminating the need to perceptually integrate information across displays.

In what ways, and to what extent, do previously inexperienced drivers adapt to nonplanar mirrors?

1. Investigate whether drivers adapt to the difference in image sizes for the two eyes that are presented by aspheric mirrors.

2. Investigate the extent to which drivers adapt to the reduction in the blind zone provided by nonplanar mirrors. Do drivers develop confidence that if there is a vehicle present they will see it in the mirror, so that they can be confident that when they do not see a vehicle, none is present?

3. Investigate how well drivers could switch between vehicles with planar and nonplanar driver-side mirrors in a mixed fleet.

4. Investigate possible effects of nonplanar mirrors on drivers' general driving strategies (e.g., do they change lanes more often or maneuver through traffic more aggressively).

5. Investigate the experiences of U.S. drivers with nonplanar driver-side mirrors in Europe, possibly through rental companies.

6. Investigate drivers' adaptation to reaiming of planar exterior mirrors (Platzer, 1995) as an alternative to nonplanar mirrors for remedying problems with the blind zone. It may take time for drivers to become accustomed to the reaiming method, partly because people seem to want to see part of their own vehicle in the exterior mirrors, possibly as an orientation cue. The issues that should be researched include: characteristics of devices to help drivers aim mirrors reliably, methods for training drivers to use the reaiming method, and characteristics of drivers (such as driving experience and age) that might affect the relative ease with which they could adapt to the reamed mirrors.

What human factors evaluation measures and methodologies are meaningful? Does the NHTSA-sponsored protocol (developed by Scientex Inc.) produce safety-relevant data? How can it be improved? How do other evaluation methodologies compare to this one?

1. Continue to use, and further develop, divided-attention tasks as part of an evaluation protocol. There was a general consensus that the use of secondary tasks in the NHTSA protocol, in addition to a primary task that involved use of the rearview mirrors, was important for the validity of the protocol.

2. Consider the possibility that multiple evaluation methods, ideally with complementary strengths and weaknesses, might allow better assessment of rearview mirror systems than even the most valid single protocol. A single protocol offers significant advantages in that it can be well defined and standardized, but all standard test protocols are subject to the criticism that they may systematically bias results because they represent only a subset of real world conditions. For example, in the area of vehicle crashworthiness, it has been argued that full-width and offset barrier crash tests provide complementary information.

What more can be learned about the safety effects of different mirror designs from current accident data in Europe or elsewhere?

1. Consult with representatives of organizations such as the Association of International Automobile Manufacturers (AIAM) and the American Automobile Manufacturers Association (AAMA) in an attempt to identify countries and accident databases that might be useful in extending the UMTRI accident studies (Luoma, Sivak, & Flannagan, 1995; Schumann, Sivak, & Flannagan, 1996).

2. Follow up on the UMTRI studies of lane-change accidents by looking at other types of accidents that might be affected by driver-side mirror type. For example, mirror type might affect the amount of time that drivers must look away from the straight ahead to look directly into the blind zone, and that might affect their tendency to strike vehicles in front of them.

What important research issues have not been identified in previous discussions?

Because the discussions and research suggestions for previous questions had already been rather wide ranging, this item was not covered. The time that had been allocated to it was in effect reassigned to the two questions concerning safety effects that would result from use of nonplanar driver-side mirrors in the U.S., because those questions were of great interest to many participants.

What are the relative priorities for future research issues?

The workshop elicited a large number of suggestions for research, 67 items in the edited form presented in this report. Although no formal attempt was made to set priorities among these items, as a preliminary exercise toward that end the workshop participants were each asked to select three items that they considered to be the most significant. For a number of reasons, it is important not to overinterpret the results of this informal exercise. The participants generated their lists without being able to review a comprehensive summary of the discussions that took place during the workshop. They described their selected items in their own words, making it difficult to compare responses across individuals without ambiguity. And, perhaps most importantly, not all participants responded. Of the 38 participants who were not UMTRI staff members, 16 responded with suggested research priorities. Keeping all of these limitations in mind, a summary of their responses may still be a useful starting point for more formal consideration of research priorities.

We resolved the ambiguities of wording across individual responses in terms of slightly more general classes of research proposals. Four of these general classes were mentioned by at least two participants:

1. Conduct studies to evaluate the expected effect on safety of permitting nonplanar rearview mirrors on the driver side in the U.S.

2. Investigate the possibility of international harmonization of rearview mirror requirements.

3. Determine whether convex mirrors with relatively large radius of curvature would yield perceptions of distance and speed that are practically indistinguishable from "unit magnification" mirrors.

4. Investigate drivers' evaluations of a strategy of reaiming the fields of view of conventional planar exterior mirrors at a slightly greater angle to the vehicle midline to eliminate blind zones large enough to conceal vehicles.

Conclusion

The workshop accomplished the organizers' goal, which was to promote lively discussions of rearview mirror research needs. The suggestions for research that arose during those discussions are documented in this report in a relatively straightforward way, with little comment or evaluation.

No formal attempt was made to set priorities or organize an explicit research plan, and this report should not be interpreted as an endorsement of any particular course of action. However, keeping that qualification in mind, it is worth highlighting two major aspects of the workshop discussions that may not be obvious from the bare lists of proposals on the preceding pages. First, during the discussions on the second day of the workshop it became clear that there was a great deal of interest in the possibility of using nonplanar mirrors in the exterior, driver-side position to address the problem of the blind zone on that side. Because of that interest, there was much discussion of what research might be necessary to reexamine the current restriction to "unit magnification" mirrors on the driver side in the U.S. Second, there were few substantive comments about the NHTSA rearview mirror evaluation protocol. This was probably partly because most participants were not familiar with that protocol prior to the meeting.

Many of the proposals made at the workshop deserve further consideration. We hope that the documentation presented here will facilitate discussion of what research should be undertaken.

Appendix A: Meeting Agenda

Workshop on Rearview Mirror Human Factors Research Needs

The University of Michigan
Matthaei Botanical Gardens
Ann Arbor, Michigan
May 8-9, 1996

The purpose of this workshop is to identify future human factors research needed for determining mirror performance and design requirements that will insure that drivers can use rearview mirrors safely and effectively. The workshop will bring together experts on mirror issues from the research community, regulatory area, and mirror and vehicle manufacturing sectors. The scope of the workshop will include commercial vehicles as well as passenger vehicles.

The meeting will begin on Wednesday with background presentations intended to summarize the current state of our knowledge about driver performance with rearview mirrors. These will be followed on Thursday by group discussions of several key questions about possible future research. All participants will be encouraged to participate in these discussions.

Although, as indicated by the following agenda, the scope of the workshop is intended to be broad, one of the major current motivations for reviewing mirror research needs comes from recent studies that have highlighted the possible benefits of nonplanar driver-side mirrors in passenger vehicles.

The workshop activities will be documented in a written report.

Agenda

Wednesday, May 8
1:00 PM - 5:00 PM
Background presentations

1:00 Introduction (M. Flannagan)

1:10 The nature of current safety issues, and a preliminary research agenda (M. Perel)

1:45 Convex passenger-side mirrors in the United States (M. Flannagan)

2:00 Multiradius driver-side mirrors in Europe (S. Pilhall)

2:30 Alternatives for aiming of planar mirrors (G. Platzer)

3:00 Break

3:15 Accident experience in Europe with nonplanar mirrors (J. Schumann)

3:45 Research on evaluation methods for driver performance (L. Staplin)

4:30 Adaptation to nonplanar mirrors (M. Flannagan)

5:00 Adjournment

Thursday, May 9
9:00 AM - 5:00 PM
Discussion of questions regarding needs for future research

9:00 What are the extent and nature of safety problems with current rearview mirrors?

9:30 What are the needs of special populations of drivers, such as the elderly?

10:00 What optical alternatives to standard mirrors exist for providing indirect vision?

10:15 How complete, accurate, and user-friendly are existing procedures, standards, and techniques for measuring, quantifying, and displaying fields of view?

11:00 What are the most important current issues concerning rearview mirrors on commercial vehicles?

11:30 How can rearview mirrors be optimized for use in backing commercial vehicles?

12:00 Lunch

1:00 What does existing research tell us about the safety effects that would result from use of nonplanar driver-side mirrors in the U.S.?

1:30 What issues should be addressed by future research to assess the safety effects that would result from use of nonplanar driver-side mirrors in the U.S.?

2:00 In what ways, and to what extent, do previously inexperienced drivers adapt to nonplanar mirrors?

2:45 What human factors evaluation measures and methodologies are meaningful? Does the NHTSA-sponsored protocol (developed by Scientex Inc.) produce safety-relevant data? How can it be improved? How do other evaluation methodologies compare to this one?

3:15 Break

3:30 What more can be learned about the safety effects of different mirror designs from current accident data in Europe or elsewhere?

4:00 What important research issues have not been identified in previous discussions?

4:30 What are the relative priorities for future research issues?

5:00 End of meeting

Lunch will provided at the meeting site on Thursday.

Appendix B: Attendees

Richard Berg (de Montfort)
Vivek Bhise (Ford)
Renae Bowers-Carnahan (SAE Truck & Bus Visibility Subcommittee)
Sara Bowker (Nissan)
Patrick Boyd (NHTSA)
Carl Buttermore (Ford)
George Dalby (Multivex)
Florian Dutke (GM)
Michael Flannagan (UMTRI)
Jeffrey Gahr (Honda)
Kenneth Gish (Scientex)
Arthur Hess (United Technologies Automotive Systems)
David Houston (Ford)
Toshiko Ito (Nissan)
Hans Jartoft (Saab)
Rick Karbowski (Ford)
Kenji Kurohoshi (Ichikoh)
Raymond Labrecque (Chrysler)
Steve Logan (Chrysler)
Terry Manion (Muth-Hirtz)
Robert McCord (Multivex)
Allan McIntyre (Sprague Devices)
Robert McFarland (Adac Plastics)
Jere Medlin (NHTSA)
Mary Lynn Mefford (UMTRI)
Tsuyoshi Miki (Ichikoh)
Kathleen Parlow (SAE Truck & Bus Visibility Subcommittee)
Michael Perel (NHTSA)
Stig Pilhall (Volvo)
George Platzer (Consultant)
Michael Plotzke (GM)
John Roberts (Gentex)
Gary Rupp (SAE Driver Vision Standards Committee)
Thomas Ryan (Britax Rainsfords)
James Sayer (UMTRI)
Josef Schumann (UMTRI)
Debra Senytka (GM)
Noel Simpson (UMTRI)
Michael Sivak (UMTRI)
Larry Smythe (Toyota)
Loren Staplin (Scientex)
Paul Terrano (SAE Truck & Bus Visibility Subcommittee)
Eric Traube (UMTRI)
Roger Veldman (Donnelly)
Alex Vincent (Transport Canada)

References

Ball, K., Owsley, C., & Beard, B. (1990). Clinical visual perimetry underestimates peripheral field problems in older adults. *Clinical Vision Sciences*, *5*, 113-125.

Burger, W., Mulholland, M., Smith, R., & Bardales, M. (1980). *Measurement of blind areas on the right front of heavy trucks* (DOT HS 805 636). Washington, D.C.: Department of Transportation, National Highway Traffic Safety Administration.

Flannagan, M. (1988). *Human performance aspects of rearview mirrors: An applied-literature review* (Report No. UMTRI 88-20). Ann Arbor: The University of Michigan Transportation Research Institute.

Flannagan, M. J., Sivak, M., & Traube, E. C. (1996). Driver perceptual adaptation to nonplanar rearview mirrors. In C. Serafin & G. Zobel (Eds.), *Automotive design advancements in human factors: Improving drivers' comfort and performance, SP-1155* (pp. 213-220). Warrendale, Pennsylvania: Society of Automotive Engineers.

Helmers, G., Flannagan, M. J., Sivak, M., Owens, D. A., Battle, D. A., & Sato, T. (1992). *Response times using flat, convex, and multiradius rearview mirrors* (Report No. UMTRI-92-20). Ann Arbor: The University of Michigan Transportation Research Institute.

Henderson, R. L., Smith, R. L., Burger, W. J., & Stern, S. D. (1983). Visibility from motor vehicles. In *Crash avoidance, SP-544* (pp. 95-119). Warrendale, Pennsylvania: Society of Automotive Engineers.

Kelley, C., R., & Prosin, D. J. (1969). *Motor vehicle rear vision.* Santa Monica, California: Dunlap and Associates. (NTIS No. PB 186228).

Luoma, J., Sivak, M., & Flannagan, M. J. (1995). Effects of driver-side mirror type on lane-change accidents. *Ergonomics*, *38*, 1973-1978.

Mortimer, R. G. (1971). *The effects of convex exterior mirrors on lane-changing and passing performance of drivers* (SAE Technical Paper Series No. 710543). New York: Society of Automotive Engineers.

Pilhall, S. (1981). *Improved rearward view* (SAE Technical Paper Series No. 810759). Warrendale, Pennsylvania: Society of Automotive Engineers.

Platzer, G. E. (1995). *The geometry of automotive rearview mirrors: Why blind zones exist and strategies to overcome them* (SAE Technical Paper Series No. 950601). Warrendale, Pennsylvania: Society of Automotive Engineers.

Seeser, J. (1974). *Automotive convex mirrors: Optical properties* (Technical Report 201). Holland, Michigan: Donnelly Mirrors.

Society of Automotive Engineers. (1994). *Recommended practice SAE J941 JUN92: Motor vehicle drivers' eye locations* (rev. June 1992). Warrendale, Pennsylvania: Author.

Society of Automotive Engineers. (1994). *Recommended practice SAE J1050 AUG94: Describing and measuring the driver's field of view* (rev. August 1994). Warrendale, Pennsylvania: Author.

Schumann, J., Sivak, M., & Flannagan, M. J. (1996). *Are driver-side convex mirrors helpful or harmful?* (Report No. UMTRI-96-7). Ann Arbor: The University of Michigan Transportation Research Institute.

Tijerina, L., Hendricks, D., Pierowicz, J., Everson, J., & Kigel, S. (1993). *Examination of backing crashes and potential IVHS countermeasures* (DOT HS 808 016). Washington, D.C.: National Highway Traffic Safety Administration.

Wang, J.-S., & Knipling, R. R. (1994). *Backing crashes: Problem size assessment and statistical description* (DOT HS 808 074). Washington, D.C.: National Highway Traffic Safety Administration.