TLA 2006-02

A Transportation Lighting Alliance Report

The Influence of Dynamic Lighting Conditions on Visibility: A Pilot Study

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September 2006

Lighting Research Center

Rensselaer

Technical Report Documentation Page

Report number TLA2006-01

Report title/subtitle .... The Influence of Dynamic Lighting Conditions on Visibility: A Pilot Study

Report date .... September 2006

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Performing organization .... Lighting Research Center
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Transportation Lighting Alliance members .... Automotive Lighting, DaimlerChrysler, General Electric, Hella, Lighting Research Center, Philips, OSRAM SYLVANIA, Visteon

Notes .... (none)

Abstract

A pilot laboratory study to measure the effects of dynamic changes in light level on target detection performance was conducted. Subjects responded to peripheral targets following the presentation of a light level increase in one part of a visual display, or following no change in light level. Even when the target was located in a different part of the display than the location where the light level increase occurred, reaction times were shorter. There were few missed targets under all conditions tested in the study. While the results cannot be directly applied to vehicular lighting situations, they provide some indication that light level changes can affect target detection in ways unrelated to the change in visibility that the light level change induces.

Keywords: .... automotive, headlamp, lamp, intensity, HID, halogen, targets, peripheral, illumination, visibility, beam, target, field study

CONTENTS

ABSTRACT

A pilot laboratory study to measure the effects of dynamic changes in light level on target detection performance was conducted. Subjects responded to peripheral targets following the presentation of a light level increase in one part of a visual display, or following no change in light level. Even when the target was located in a different part of the display than the location where the light level increase occurred, reaction times were shorter. There were few missed targets under all conditions tested in the study. While the results cannot be directly applied to vehicular lighting situations, they provide some indication that light level changes can affect target detection in ways unrelated to the change in visibility that the light level change induces.

INTRODUCTION

The results of a laboratory study to investigate the influence of dynamic lighting conditions on peripheral visibility are reported. The advent of advanced forward-lighting systems (AFS) on vehicles for forward illumination will increase the use of lighting patterns and distributions that change in response to ambient driving conditions such as traffic volume, weather, or changes in roadway geometry. These changes have not been studied extensively, with most studies of AFS systems exploring novel beam distributions in a static delivery mode. The dynamic change in lighting distribution itself could be postulated to perform an alerting function, but it might also be seen as distracting, especially to objects not illuminated to a higher light level by the dynamic change in light distribution.

BACKGROUND

The advent of AFS for vehicular forward lighting is resulting in beam pattern distributions that can differ widely from conventional low and high beam distributions. Systems that provide swiveling of light sources or switching on and off of light sources will result in illumination that, hopefully, will provide the driver with additional visual information than typically provided by conventional configurations. At present, there are few standards or recommendations for the temporal aspects of AFS configurations. Most studies of these systems have explored the resulting final beam distribution on aspects such as visibility or glare but have not explicitly considered the actual transition time during swiveling or switching on/off of light sources.

Changes in light distribution might alert drivers to objects within the field of view, but such changes could also result in negative effects if they result in misadaptation of the visual system while driving. While the magnitude of visual misadaptation under such conditions would be far less than what might be experienced following the presentation of direct glare from a light source in the field of view (Van Derlofske et al., 2005), it is not well understood whether any negative effects on the visibility of objects would be significantly affected.

Because of the relative lack of data in this area, a pilot laboratory study was conducted to assess these effects (or lack thereof).

METHODS

Figure 1 shows a simple schematic diagram of the experimental apparatus. A simple tracking task consisting of a randomly, slowly-drifting needle display was located in the center of a vertical, black wall board. To the left and right of the tracking task were small (approximately 1 cm diameter) flip-dot components painted black on one side and white on the other. The flip-dots were set to normally display the black side, blending in with the black background. Upon receiving a signal from a computer controller, the flip-dots could flip to the white side (reflectance = 0.8) within 20 ms. The flip-dots were located so that from an observation distance of 2 m, they were located 5^{o}, 10^{o} and 15^{o} off-axis when the observer was fixated on the tracking task.

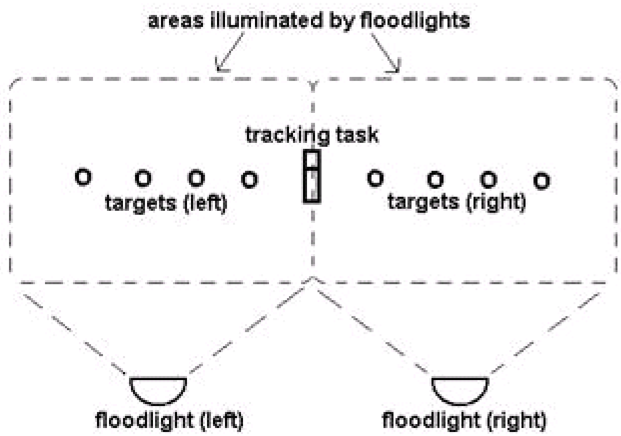

Figure 1. *Schematic diagram of the experimental apparatus.*

The vertical wall surface was illuminated by two white light emitting diode (LED) floodlight luminaires designed for this study. The floodlight luminaires each illuminated a side (left or right) of the vertical wall surface to a luminance of 0.03 cd/m² (this is equivalent to a horizontal illuminance of 1 lx on asphalt pavement with a reflectance of 0.07). Through computer control of the LED current, their output could be increased so that the luminance of the vertical surface increased to 0.3 cd/m². At no time was the direct view of the LED sources in the floodlight luminaires possible from the subjects' viewing location.

Figure 2 shows a photograph of the experimental apparatus from the approximate location of the subject, and Figure 3 shows the same view with the floodlight luminaire on the right-hand side increased in light output.

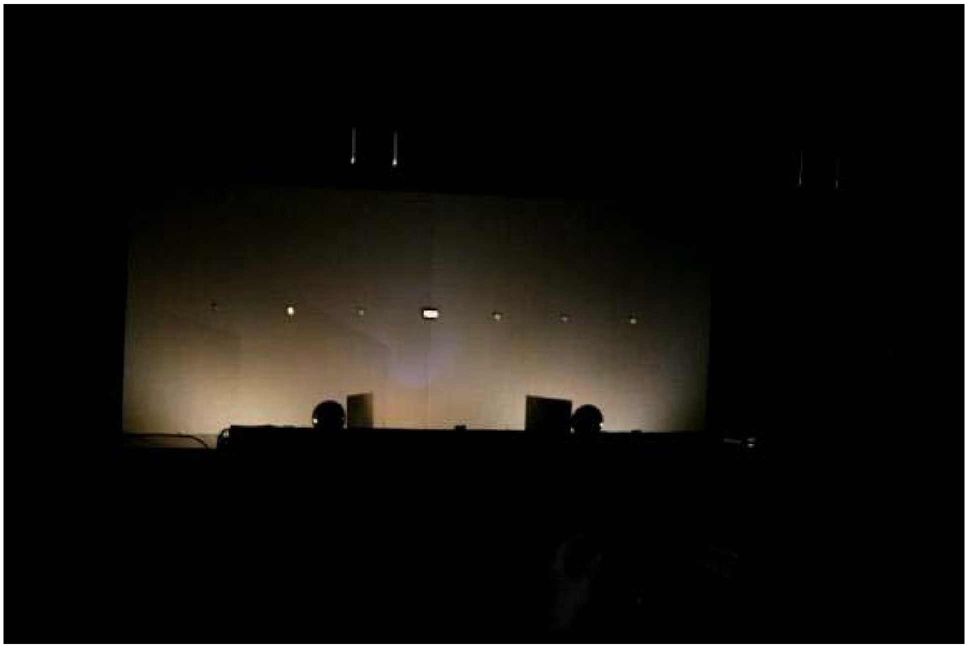

Figure 2. *Photograph of the experimental apparatus.*

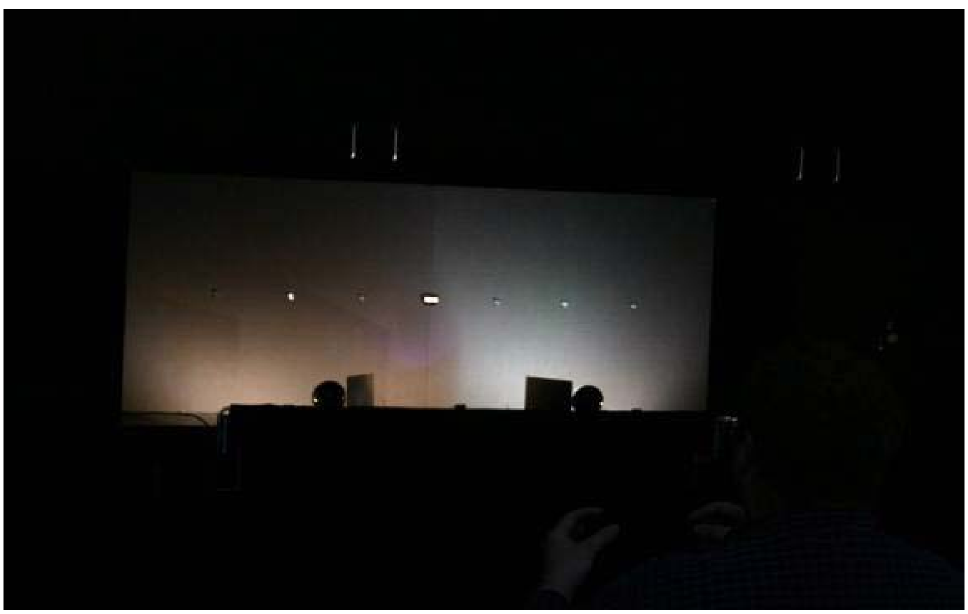

Figure 3. *Photograph of the experimental apparatus with the floodlight luminaire on the right-hand side increased in light output.*

Six subjects (aged 21 to 44 years) participated in the pilot study. After signing an informed consent form and adapting to the low light level in the experimental laboratory, subjects practiced the tracking task, which was performed using a knob on a small box held by the subjects. The box also contained a rocker switch that subjects were asked to hold down and release only when they detected the onset of one of the targets on either side of the tracking task, and then to re-press the switch.

The procedure of the experiment was as follows: While subjects performed the tracking task, a target in a randomly selected location would flip after random intervals from 3 to 5 seconds. Just before this target presentation, either 100 +/- 50 ms or 350 +/- 100 ms, one of the floodlights might increase in light level. One third of the time, the light level increase occurred on the same side of the display as the target presentation, one third of the time, the light level increase occurred on the opposite side of the display, and one third of the time, there was no light level increase on either side before the target presentation.

In addition, several "false positive" conditions were set up so that for 25% of the trials, one of the floodlight luminaires would increase in light output, but there would be no target presentation following this. This was done to help ensure that subjects were responding to actual target presentations and not simply releasing the switch following the light level increase. Subjects were instructed to release the switch only when they were certain that they had seen a target presentation, and that sometimes, the light level might increase without a target being present.

The order of all presentations was randomized to minimize any learning effects on the results, except for the delay between light level increases and target presentations. Half of the subjects ran trials with the delay between the light level increase first at 100 ms and then at 350 ms, while the other half ran trials in the opposite order.

RESULTS

Figure 4 shows the mean reaction times to the target presentations, plotted as a function of the target location. Figure 5 shows the percentage of missed targets (any target not detected within 1000 ms was considered missed) as a function of target location. Generally, it is seen that there were relatively few missed targets and that reaction times tended to increase for the targets furthest from the line of sight. This is consistent with field study results from previously reported studies (Van Derlofske et al., 2001, 2002).

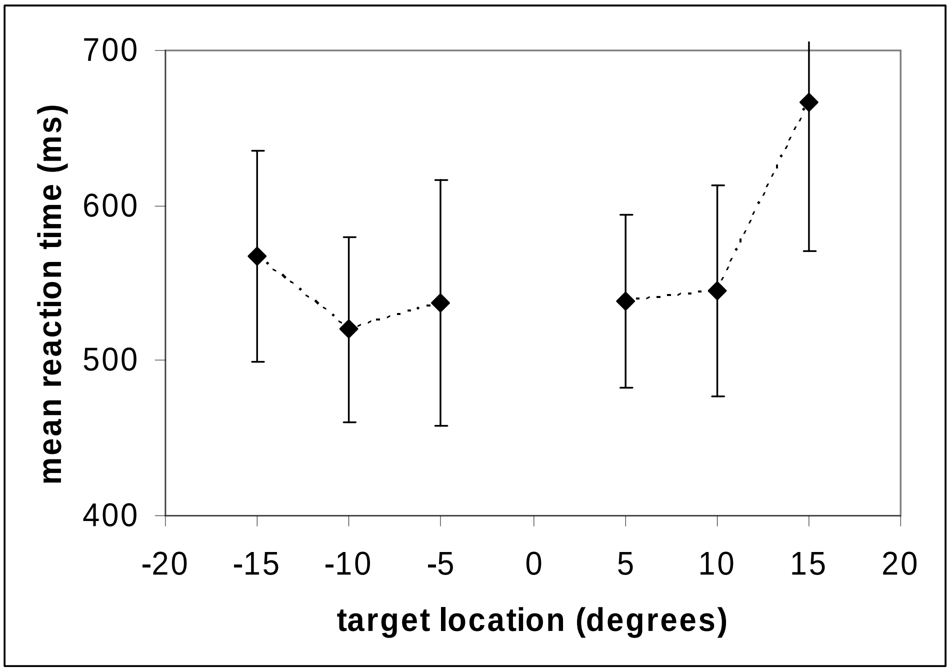

Figure 4. *Mean reaction times for each target location, collapsed across all other conditions.*

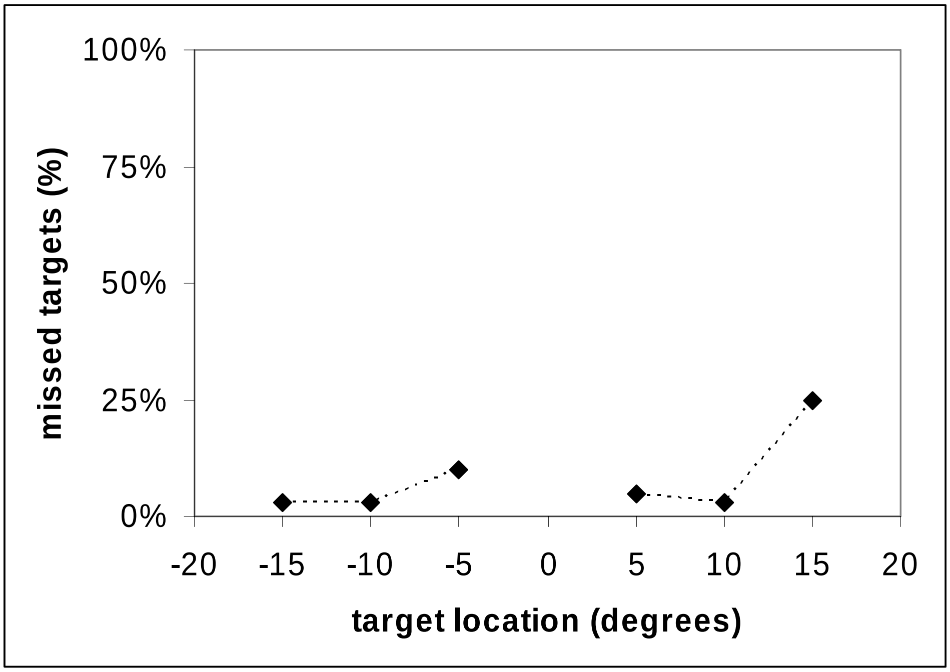

Figure 5. *Missed targets for each target location, collapsed across all other conditions.*

Figures 6 and 7, respectively, show the mean reaction times and missed targets for the conditions corresponding to the light level increase occurring on the same side as the target, the different side, or on no side at all.

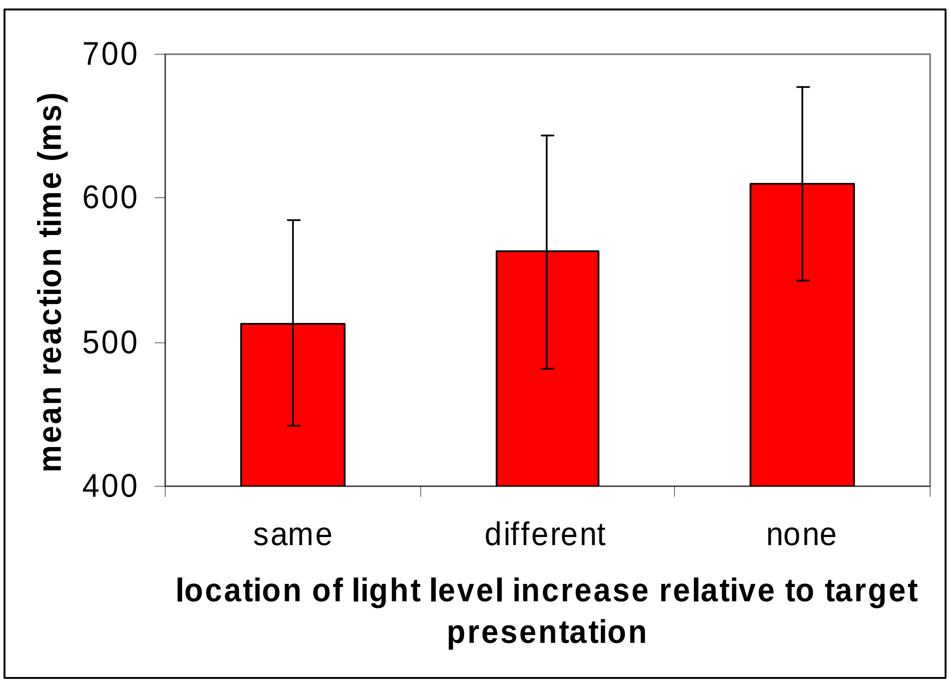

Figure 6. *Mean reaction times for light level increases occurring on the same and different side as the target, and when no light level increase occurred.*

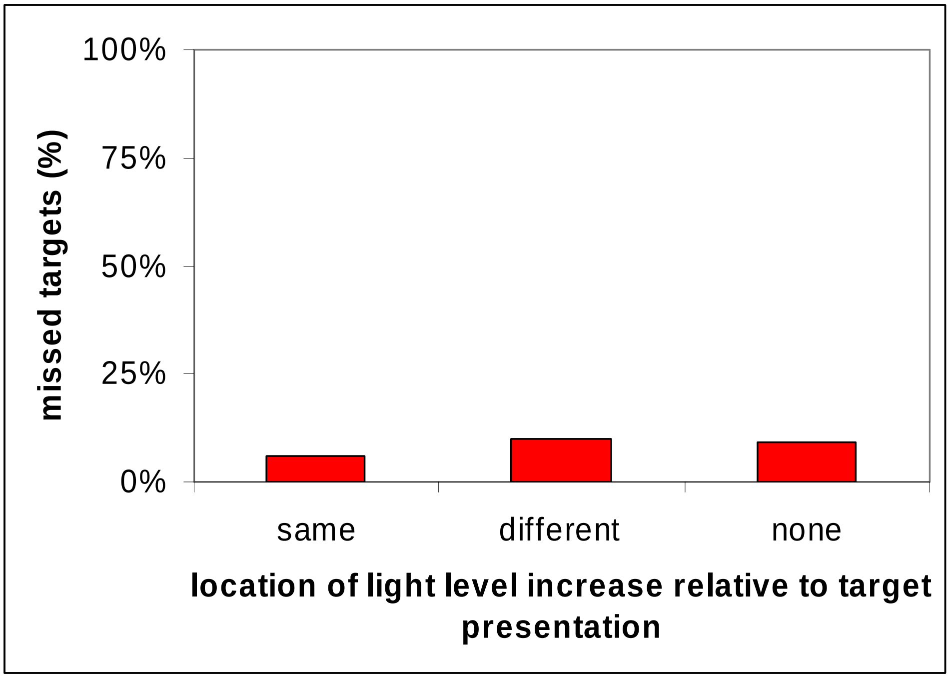

Figure 7. *Missed targets for light level increases occurring on the same and different side as the target, and when no light level increase occurred.*

A within-subjects, repeated-measures analysis of variance (ANOVA) revealed statistically significant ($p<0.05$) main effects of target location and of the location of the light level increase relative to the target side on reaction times. There was no statistically significant effect of the different delay times (100 or 350 ms) on reaction times, nor were there any statistically significant two-way interactions between any of these factors.

Regarding the missed target data, a repeated-measures ANOVA revealed no statistically significant effects of target location, location of the light level increase or the delay time on missed targets. Again, because there were relatively few missed targets altogether (usually less than 10%), this response measure seemed to be less sensitive to lighting related changes in the visual display.

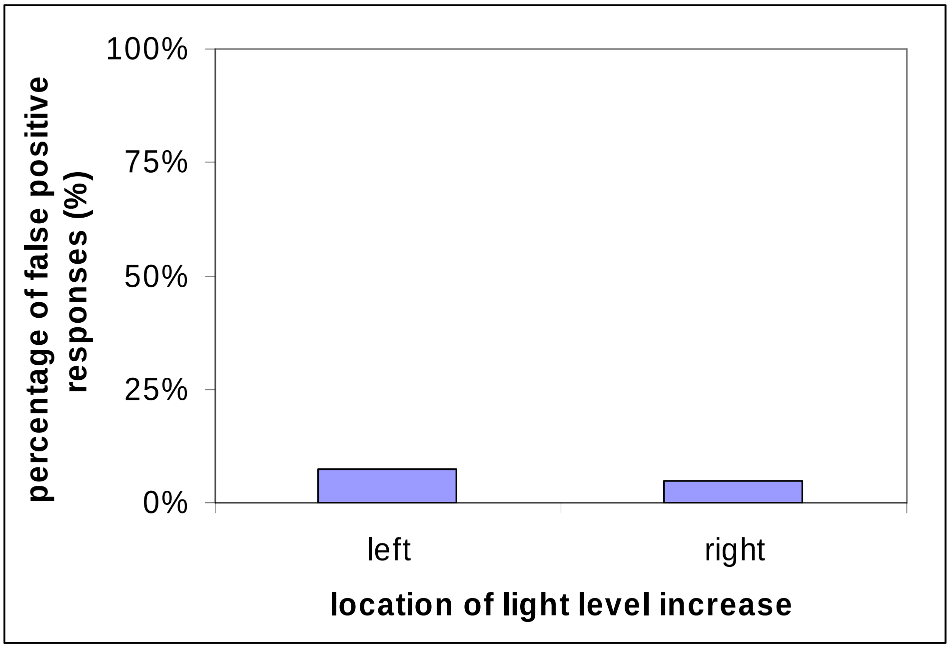

Figure 8. *Percentage of "false positive" responses for light level increases occurring on the left and right side of the display.*

Finally, regarding the "false positive" trials, when no target was displayed following a light level increase, Figure 8 shows that there were very few (less than 10%) false positive responses (releasing the switch following the introduction of a light level increase, with no actual target being displayed). This seems to help confirm that subjects were responding to actual target presentations and not to the onset of the light level increase.

DISCUSSION

The present results are from a modest pilot study and thus, it is difficult to interpret the significance of these data for driving contexts using AFS. However, they do illustrate that light level increases on the order of a ten-times increase (from 0.03 to 0.3 cd/m^2) did not reduce the ability of subjects to detect targets, even when those targets were located on the opposite side of the display from the light level increase. In fact, any increase in light level, regardless of the side on which it occurred, resulted in shorter reaction times (Figure 6), so there was clearly some alerting effect from the increase that, at least, was more than enough to compensate for any potential misadaptation of the visual system. This may indicate that abrupt light level changes, could *possibly* serve a beneficial effect on object detection, particularly if AFS functionality in the future will incorporate the ability to respond in real time to the roadway environment (e.g., the presence of pedestrians).

CONCLUSIONS

The present pilot study was conducted to determine whether there might be any possible positive or negative consequences of dynamic light level changes on peripheral target detection, and the results indicate that there can be benefits in terms of alerting subjects to the possible onset of a target. Unexpectedly, these benefits were found even when the targets were presented on a different side of the display than the side with the light level increase. If the increased light levels resulted in visual misadaptation of the observers in the present study, the alerting effects of the light level increase was able to overcome this effect, at least under the conditions used in this study.

Undoubtedly, AFS functions in the real world will likely operate in many ways that are very different from the conditions explored in the present pilot study. Light level changes are likely to be less abrupt, and perhaps will not be as large in magnitude. Future study under more realistic conditions will be needed before results such as those in this report can be applied to vehicular lighting situations.

ACKNOWLEDGMENTS

The members of the Transportation Lighting Alliance: Automotive Lighting, DaimlerChrysler, General Electric, Hella, the Lighting Research Center, Philips Automotive Lighting, OSRAM SYLVANIA, and Visteon, are acknowledged for their support of this research. The contributions of Yukio Akashi, Dennis Guyon, Chieko Ishikura and Chenlu Zhang to this report are also gratefully acknowledged.

REFERENCES

Van Derlofske, J., J. D. Bullough and C. M. Hunter. 2001. Evaluation of high-intensity discharge automotive forward lighting (SAE paper 2001-01-0298). Society of Automotive Engineers 2001 World Congress, Detroit, MI, March 5-8. In Lighting Technology Developments for Automobiles, SP-1595 (pp. 1-7). Warrendale, PA: Society of Automotive Engineers.

Van Derlofske, J., J. D. Bullough and C. M. Hunter. 2002. Visual benefits of high-intensity discharge forward lighting (SAE paper 2002-01-0259). Society of Automotive Engineers 2002 World Congress, Detroit, MI, March 4-7. In Advanced Lighting Technology for Vehicles, SP-1668 (pp. 51-56). Warrendale, PA: Society of Automotive Engineers.

Van Derlofske, J., J. Chen, J. D. Bullough and Y. Akashi. 2005. Headlight glare exposure and recovery (SAE paper 2005-01-1573). Society of Automotive Engineers 2005 World Congress, Detroit, MI, April 11-14. In Lighting Technology and Human Factors (pp. 235-242), SP-1932. Warrendale, PA: Society of Automotive Engineers.