

**UMTRI-95-10**

**EFFECTS OF INTENSITY, AREA, AND  
ASPECT RATIO ON REACTION TIME  
TO STOP LAMPS**

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**April 1995**

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Report No. UMTRI-95-10  
April 1995

1. Report No. UMTRI-95-10	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Effects of intensity, area, and aspect ratio on reaction time to stop lamps		5. Report Date April 1995	
		6. Performing Organization Code 302753	
7. Author(s) James R. Sayer, Michael J. Flannagan, and Michael Sivak		8. Performing Organization Report No. UMTRI-95-10	
9. Performing Organization Name and Address The University of Michigan Transportation Research Institute 2901 Baxter Rd, Ann Arbor, Michigan 48109-2150		10. Work Unit no. (TRAVIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address The University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety		13. Type of Report and Period Covered	
		14. Sponsoring Agency Code	
15. Supplementary Notes The Affiliation Program currently includes Adac Plastics, Bosch, Chrysler, Delphi Interior and Lighting Systems, Ford (Plastic and Trim Products Division), General Electric, GM NAO Safety Center, Hella, Ichikoh Industries, Koito Manufacturing, LESCOA, Libbey-Owens-Ford, Magneti Marelli, North American Lighting, Osram Sylvania, Philips Lighting, PPG Industries, Reflexite, Stanley Electric, TEXTRON Automotive, United Technologies Automotive Systems, Valeo, Wagner Lighting, and 3M.			
16. Abstract <p>The objective of this study was to investigate the influence of stop lamp intensity, area, and aspect ratio on reaction time. Recent trends in auto body styling have begun to incorporate center high-mounted stop lamps (CHMSLs) into spoilers and trunk lids. These developments, brought on in part by technical advances in automotive lighting, have resulted in questions about the efficacy of stop lamps whose effective luminous area is long and narrow.</p> <p>Subjects in this study were asked to perform a computer-based tracking task to control their eye fixations, and to provide the approximate cognitive loading associated with driving, while responding to the onset of stop lamps of varying characteristics. The results of this laboratory study indicate that aspect ratio and intensity of stop lamps, as well as their interaction, influence reaction time. Specifically, subject reaction times to the onset of simulated stop lamps were longer when the stimulus intensity was low and the aspect ratio was large.</p> <p>These results suggest that further empirical investigation that examines intensity, area, and aspect ratio of stop lamps in the context of the total rear-signaling system is required to determine whether regulation affecting the aspect ratio of stop lamps or CHMSLs is warranted.</p>			
17. Key Words Stop lamp, rear signal, CHMSL, intensity, area, aspect ratio, reaction time, FMVSS No. 108, brake signal, luminance		18. Distribution Statement Unlimited	
19. Security Classification (of this report) Unclassified	20. Security Classification (of this page) Unclassified	21. No. of Pages 11	22. Price

## ACKNOWLEDGMENTS

Appreciation is extended to the members of The University of Michigan Industry Affiliation Program for Human Factors in Transportation Safety for support of this research, and the Michigan Secretary of State for cooperation in obtaining subjects. The current members of the Affiliation Program are:

Adac Plastics  
Bosch  
Chrysler  
Delphi Interior and Lighting Systems  
Ford (Plastic and Trim Products Division)  
General Electric  
GM NAO Safety Center  
Hella  
Ichikoh Industries  
Koito Manufacturing  
LESCOA  
Libbey-Owens-Ford  
Magneti Marelli  
North American Lighting  
Osram Sylvania  
Philips Lighting  
PPG Industries  
Reflexite  
Stanley Electric  
TEXTRON Automotive  
United Technologies Automotive Systems  
Valeo  
Wagner Lighting  
3M

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## INTRODUCTION

This study investigated the influence of stop lamp intensity, area, and aspect ratio (the ratio of height to width) on reaction time. Currently, neither federal regulations (49 CFR, 1994) nor SAE standards (SAE, 1995) specify limitations on aspect ratio for either stop lamps or center high-mounted stop lamps (CHMSLs). Furthermore, only minimum effective luminous areas are specified without setting maximum allowances for area. Recent trends in automotive body styling that incorporate CHMSLs into motor vehicle spoilers and trunk lids, achievable in part by technical advances in automotive lighting, have resulted in questions related to the efficacy of stop lamps whose effective luminous area is long and narrow.

Current U.S. regulations concerning the minimum effective luminous area for stop lamps (non-CHMSL) on motor vehicles less than 80 inches in width require an area not less than 50 cm<sup>2</sup> (49 CFR, 1994). This requirement is independent of the number of compartments included in the stop lamp. However, individual compartments can be no less than 22 cm<sup>2</sup>. Intensity requirements for non-CHMSL stop lamps permit a range of 80 to 420 cd on the H-V axis, dependent upon the number of lamp compartments.

U.S. regulations for CHMSLs require a minimum effective projected luminous area of not less than 4.5 square inches (29 cm<sup>2</sup>) for motor vehicles under 80 inches in width (49 CFR, 1994). A combination of two high-mounted stop lamps can be used in certain circumstances, but each lamp is required to be no less than 2.25 square inches (14.5 cm<sup>2</sup>). Intensity requirements for CHMSLs permit a range of 25 to 160 cd on the H-V axis.

## METHOD

### Tasks

Subjects performed two concurrent tasks. The primary task was to detect the illumination of a simulated stop lamp, and to respond to the illuminated lamp as quickly as possible by depressing a button. The secondary task was a continuous tracking task designed to be the focus of a subject's attention between stop lamp presentations. The tracking task was similar to steering a car down a winding road, and was presented directly in front of the subjects. The tracking task was relatively simple for subjects to perform. The task did not contain obstacles or traffic, and tracking speed remained constant.

## **Subjects**

Twelve individuals participated in the experiment. All subjects were licensed drivers solicited while visiting a local motor vehicle licensing bureau. The list of potential subjects was stratified by age into two groups, younger and older. Individuals were called at random from the list until six persons, an equal number of males and females, were identified for each age group. The age of subjects in the younger group ranged from 21 to 27 (mean = 23.5) and in the older group from 64 to 75 (mean = 67.2). Each subject was paid \$20 for the 1.5 hours spent in the laboratory. All subjects wore the same eyewear, if any, that they would normally wear when driving, with the exception that sunglasses were not permitted.

## **Apparatus**

A diagram of the experimental set up as seen by subjects is shown in Figure 1. A computer was used to display the simulated roadway for the secondary tracking task. The computer's monitor was located directly in front of subjects at a distance of 2.2 meters (7.1 feet). A constant viewing location was maintained across subjects through the use of a chin and forehead rest. Subjects controlled the tracking task using a joystick with their dominant hand, and responded to the stop lamps by pushing a button held in the opposite hand. A second computer was used to collect reaction time data and to control the presentation of the stop lamp stimuli.

The light sources for the simulated stop lamps were two 35mm slide projectors. The lenses of the projectors were equipped with electro-mechanical shutters. The opening and closing of these shutters was controlled by a computer program. Light from the projectors was passed through neutral density and red filters, as well as an array of diverging cylindrical lenses (4 cylinders per inch), to obtain a stimulus with approximately uniform luminance. The chromaticity coordinates of the red stimuli were  $x = 0.67$  and  $y = 0.32$ . The area and aspect ratio of the simulated stop lamps were varied by using a series of masks that could be easily changed between blocks of trials. A neutral density filter was used to modify the intensity of the source to present two levels of stop lamp intensity. A 0.5 neutral density filter was used with larger area stimuli to make their intensities approximately equal to the intensities of corresponding smaller area stimuli.

## **Stimuli**

The stop lamp stimuli were presented in one of two locations, either to the left or right of the tracking task (Figure 1). The centers of the stimuli were located  $8.5^\circ$  (33 cm) from the center

of the tracking task, on either side. The stimulus background ( $35^\circ$  by  $29^\circ$ ) was a uniform white and illuminated in the area immediately surrounding the stimuli to  $3400 \text{ cd/m}^2$  in order to simulate daylight viewing conditions. The laboratory stimuli were constructed to simulate lamps on a vehicle viewed from  $14.3 \text{ m}$  ( $47 \text{ ft}$ ). This distance is approximately equal to a 1-second headway when traveling at  $50 \text{ km/h}$  ( $30 \text{ m/h}$ ). The actual viewing distance in the laboratory was  $2.2 \text{ m}$  ( $7.1 \text{ ft}$ ). Stimuli were presented approximately at subjects' eye height. Stimulus size and intensity were scaled appropriately to account for differences in the simulated distance and the viewing distance in the laboratory.

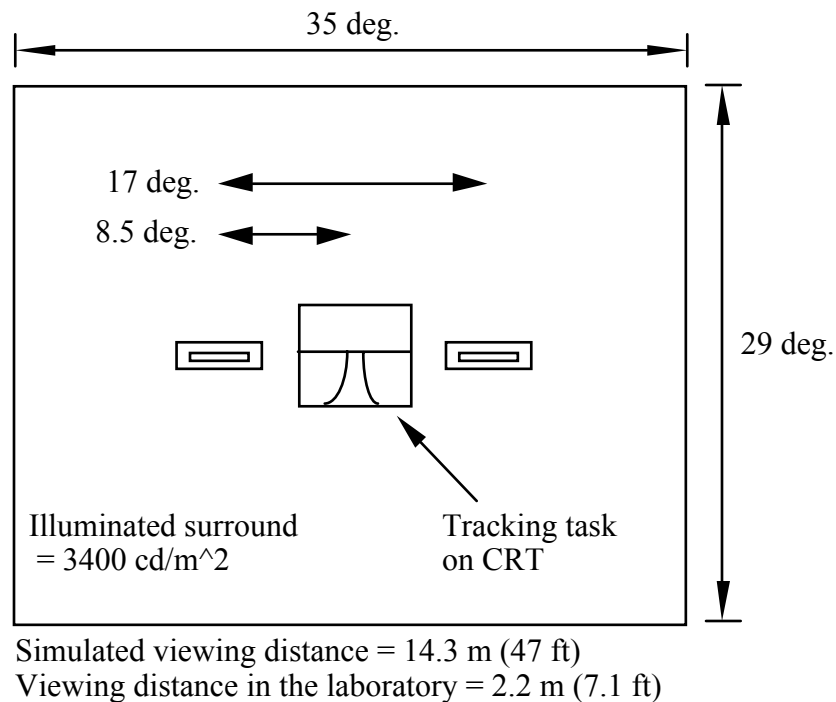


Figure 1. A diagram of the experimental stimulus arrangement as seen by subjects.

*Intensity.* Two levels of stop lamp intensity were simulated, a low level (approximately  $35 \text{ cd}$ , or  $1.54 \text{ log cd}$ ) and a high level (approximately  $150 \text{ cd}$ , or  $2.18 \text{ log cd}$ ). The low level of intensity is representative of the lower end of the permissible luminous intensity range for CHMSLs. The high level of intensity represented a typical luminous intensity value for stop lamps. The intensities observed in simulating the two target stop lamp intensities are provided in Table 1.

*Area.* Two levels of stop lamp area were simulated. The first area,  $50 \text{ cm}^2$ , was selected as a typical area for CHMSLs. The second area,  $150 \text{ cm}^2$ , was selected as a reasonable



maximum for CHMSLs based upon vehicle width, and a typical area for stop lamps based upon an informal sample. Actual stimulus area values are provided in Table 2.

*Aspect Ratio.* Three levels of aspect ratio, the ratio of height to width, were examined; 1:1, 1:6, and 1:67. The 1:6 aspect ratio was chosen because it was representative of a range of CHMSLs informally sampled. The largest aspect ratio, 1:67, was selected as a realistic maximum based on vehicle width. The sizes of the stimuli, in subtended visual angle, are provided in Table 3.

Table 1. Intensity values of the stimuli (cd), directed toward the subject’s eye.

Simulated Area	Aspect Ratio	Simulated Intensity	
		High Level	Low Level
50 cm <sup>2</sup>	1:1	187	43
	1:6	208	49
	1:67	122	29
150 cm <sup>2</sup>	1:1	107	26
	1:6	164	37
	1:67	104	24

Table 2. Simulated versus the laboratory stimulus area.

Simulated Area	Aspect Ratio	Area in Lab
50 cm <sup>2</sup>	1:1	1.17 cm <sup>2</sup>
50 cm <sup>2</sup>	1:6	1.16 cm <sup>2</sup>
50 cm <sup>2</sup>	1:67	1.15 cm <sup>2</sup>
150 cm <sup>2</sup>	1:1	3.46 cm <sup>2</sup>
150 cm <sup>2</sup>	1:6	3.47 cm <sup>2</sup>
150 cm <sup>2</sup>	1:67	3.50 cm <sup>2</sup>

Table 3. Subtended visual angles of the stimuli.

Simulated Area	Aspect Ratio	Height	Width
50 cm <sup>2</sup>	1:1	0.28°	0.28°
50 cm <sup>2</sup>	1:6	0.11°	0.73°
50 cm <sup>2</sup>	1:67	0.03°	2.30°
150 cm <sup>2</sup>	1:1	0.49°	0.49°
150 cm <sup>2</sup>	1:6	0.20°	1.20°
150 cm <sup>2</sup>	1:67	0.06°	4.00°

## **Experimental Design**

The main independent variables in this experiment were stop lamp intensity (2 levels), area (2 levels), aspect ratio (3 levels), and subject age (2 levels).

Each of the twelve combinations of two levels of intensity, two levels of area, and three levels of aspect ratio was presented ten times per subject. These ten trials were presented in blocks, in which an equal number of stimuli were presented on each side of the tracking task. The order of presentation of the twelve stimulus combinations was randomized, as was location of the stimulus within a block of trials (left or right side). The dependent measure was reaction time to the onset of the simulated stop lamp. The interstimulus interval was random, with an even distribution from 15s to 25s.

## **Procedure**

The experimenter read the instructions to subjects. They were instructed to perform a tracking task by keeping a simulated roadway centrally located on a monitor, and to respond to the presence of stop lamps by pressing the response button. Subjects were allowed to practice the tracking task for several minutes. They were also shown examples of the stop lamp stimuli, and practiced using the button to respond to these stimuli. Once subjects felt comfortable with both tasks, the data collection began. Breaks between blocks of trials permitted the experimenter to change stimuli.

## **RESULTS**

### **Derived Reaction Time**

For each of the twelve stimulus intensity, area, and aspect-ratio combinations best fitting linear equations were derived independently for each subject by regressing reaction times on log intensity values. The resulting linear equations were then used to derive reaction times to the simulated target intensity values (1.54 and 2.18 log cd). It was necessary to derive measures of reaction time because of variations in simulated intensity values observed across levels of area and aspect ratio. The resulting derived reaction times were then used as the dependent measure in the remaining analyses.

## Analysis of Variance

An analysis of variance was performed on the derived reaction times. The variables included were stimulus intensity, area, aspect ratio, and subject age. The Greenhouse-Geisser correction factor was applied to the variable aspect ratio as it was the only repeated measure independent variable with more than two levels. The reported  $p$  value for aspect ratio is based upon the Greenhouse-Geisser correction. A significance level of  $p = 0.05$  was adopted for the purpose of reporting all analyses.

The main effect of stimulus intensity was statistically significant,  $F(1,10) = 17.7$ ,  $p = .0018$ . Reaction time was longer for the low-intensity stimuli (mean = 502 msec) than for the high-intensity stimuli (mean = 475 msec). The main effect of stimulus aspect ratio was also statistically significant,  $F(2,20) = 3.8$ ,  $p = 0.045$ . Reaction time was longest for the largest aspect ratio (1:1 mean = 474 msec; 1:6 mean = 491 msec; 1:67 mean = 500 msec). The remaining main effects of stimulus area and subject age were not statistically significant.

The only interaction to be statistically significant was between stimulus intensity and aspect ratio,  $F(2,20) = 4.4$ ,  $p = 0.043$ . Figure 2 shows that reaction times to stimuli with large aspect ratios are longer when stimuli are also of a low intensity, whereas high-intensity stimuli with large aspect ratios produce reaction times comparable to stimuli with smaller aspect ratios.

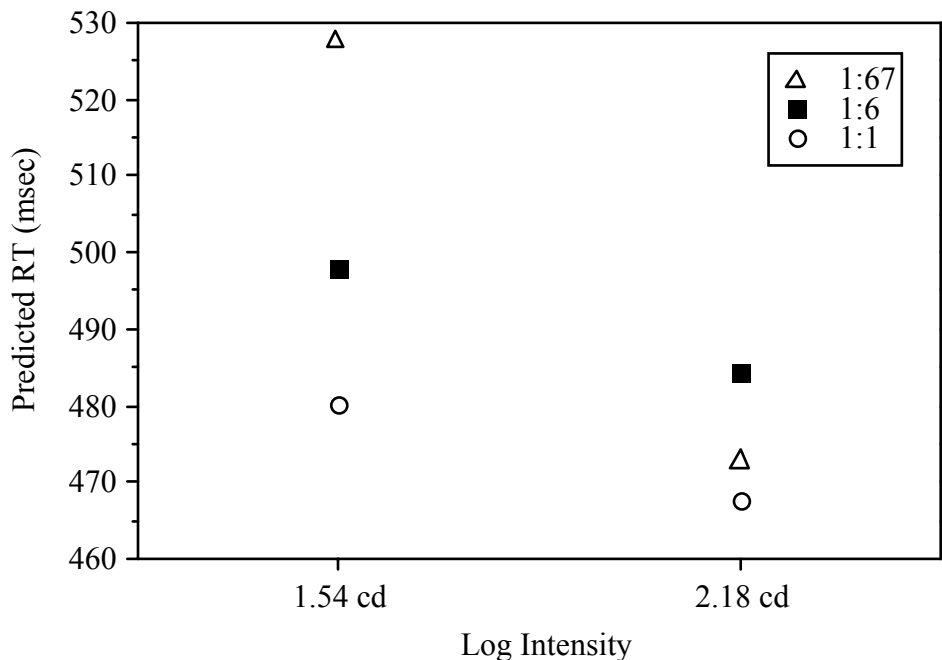


Figure 2. Reaction times by aspect ratio and log intensity.

## DISCUSSION AND CONCLUSIONS

The results of this study suggest that intensity and aspect ratio, as well as their interaction, are significant factors in driver reaction time to stop lamps. Because no current regulations or standards exist to specify limitations on the aspect ratio for stop lamps, and because this study is itself a preliminary investigation, further investigations are required. Specifically, additional research could be performed to examine changes in reaction time to stop lamps having aspect ratios between 1:6 and 1:67. Furthermore, additional efforts to produce stimuli that are more readily controllable in luminous intensity would improve future research. The ability to more readily control the luminous intensity of stimuli would eliminate the need to derive reaction times based on an assumed linear relationship between reaction time and log stimulus intensity, as was done in this study.

Although the results of this study do not indicate that subject age or stop lamp area were significant influences on reaction time, this should not preclude these issues from further research. Future investigations should further examine stop lamp variations in the context of a complete rear-signaling system (two stop lamps and one CHMSL), rather than individual lamp characteristics. The effects of intensity and aspect ratio on reaction time observed in this experiment may differ in the context of a complete rear-signaling system.

## REFERENCES

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