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REPRESENTATIVE ILLUMINATION LEVELS OF AUTOMOBILE INSTRUMENT CLUSTERS

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TECHNICAL REPORT

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16. Abstract

Ambient illumination levels of automobile instrument panel clusters were measured on a sunny day, an overcast day, and an overcast night. This study was done as part of a comprehensive, four-part project to determine the factors affecting the legibility of instrument panel clusters. The amount of light falling on the cluster was measured at eight locations around Ann Arbor, Michigan in mid-January in each of three automobiles. The mean illumination levels were 902 fc (foot-candles) (9700 lux) for the sunny condition, 365 fc (3927 lux) for the overcast day, and .112 fc (1.21 lux) for the nighttime. The range of readings was from .002 to 5570 fc (.022 to 59,933 lux). There were no significant differences between the three vehicles measured, but there were differences between the locations.

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Human factors, ergonomics, human engineering, displays, legibility instrument panels, automobiles, cars, engineering psychology	

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PREFACE

This report is part of the second task in a four-task project entitled "Recognition and Comprehension of Electronic Display Graphics." This research was funded by the Chrysler Corporation through the Chrysler Challenge Fund. The purpose of the Fund is to establish closer ties between the Chrysler Corporation and leading American universities, and to promote direct access to the advanced technologies being developed in universities. It also aims to increase interaction between the Chrysler engineering staff and university research personnel, and to increase undergraduate and graduate student awareness of the engineering opportunities available at the Chrysler Corporation.

This project is intended to provide information that designers and engineers can use to develop automotive displays that will be both legible and understandable. This particular report describes a brief evaluation of representative illumination levels falling on instrument panel clusters.

Other reports sponsored by this project include reviews of the literature on display legibility (task 1, 3 reports), several experiments concerned with alternative methods for evaluating legibility (task 2, 2 reports including this one), an experiment on the legibility of seven-segment numeric displays (task 3, 1 report), and a review of the research on human factors/ergonomics and the design of gauges (task 4, 1 report).

We would like to thank Cathy Colosimo of the Chrysler Corporation for serving as the liaison for this project. Her patience and understanding were greatly appreciated. We would also like to thank Tom Dunn for his insight. Finally, and most importantly, we would like to thank Jim Geschke who was the initial contact person in 1984 when we approached Chrysler about this research. He was instrumental in having this project included in the Challenge Fund Program.

The authors would like to thank Dr. Paul Green of the University of Michigan Transportation Research Institute (UMTRI), who guided this experiment and reviewed the results, and John Boreczky, also of UMTRI, who volunteered the use of his car and helped collect the measurements.

INTRODUCTION

The legibility of an instrument panel depends on several factors, including the size, color, and luminance of labels, digits, and their background. These factors and others are being examined as part of a major study of instrument panel legibility being conducted at the University of Michigan Transportation Research Institute (UMTRI). To select appropriate test conditions for this study, it was necessary to identify real world lighting conditions.

Mourant and Langolf (1982) studied the threshold luminance required for older people (over age 45) to read instrument panel accurately (90% accuracy). As preparation for that experiment, they measured the illumination at a subject's eyes on a dark night while driving in a 1973 Buick LeSabre with low-beam headlights and no artificial street lighting. They found that .005 foot-candles (fc) (.053 lux) represented a worst case nighttime illumination level for car instrument panels. However, their study gave no data on daylight levels.

Yamaguchi, Kishino, and Dorris (1982) studied the minimum brightness levels of vacuum fluorescent displays under various sunlighting conditions. As preparation to their experiment, they measured illumination levels due to sunlight on various surfaces of an unspecified car. From their figure, it is assumed the car was a sedan without a hatchback or sunroof. They found that sunlight incidental through the windshield can illuminate the instrument panel surface with 139 fc (1500 lux), while sunlight coming through the rear window can give a direct instrument panel illumination of 1859 fc (20,000 lux). The weakness of both these studies is that they were not rigorous and did not attempt to approximate the range of illumination levels present during the day and night.

This experiment was conducted to compare and determine typical ambient illumination levels found during both nighttime and daytime driving. Furthermore, these measurements will provide some indication of the difference in lighting levels due to cloud cover, urban versus suburban driving, as well as the compass direction of the vehicle.

- *INTRODUCTION* -

TEST PLAN

Test Equipment

A Minolta T-1 hand-held illumination meter was used to record illumination levels within all the vehicles. This hand-held device used an automatic calibration system and recorded the light levels in foot-candles (fc) at an accuracy of three significant digits.

Three different vehicles were used during the testing. A 1987 Chevrolet Cavalier RS, a 1986 Mazda 323 DXi, and a 1987 Chevrolet Cavalier Z-24. All of these vehicles had dark-colored interiors and their drivers wore dark clothing. The Cavalier RS and the 323 had analog displays while the Z-24 had a digital instrument panel. Both Chevrolets had a glass dot-matrix sunroof and all cars had lightly tinted glass.

Data Collection Procedure

Three research assistants from the University of Michigan Transportation Research Institute served as experimenters for this study. One person drove the test car, another operated the illumination meter, and the third recorded the data. To record illumination levels, the meter was placed parallel to the face of the speedometer cluster. Both the Mazda 323 and Chevrolet Cavalier RS had glare shields extending out from the cluster face at a 45 degree angle. This required the meter to be held at another angle of 45 degrees to assure that the illumination meter remained parallel to the speedometer face. Except for location 1, all readings were taken while the car was moving (20 to 55 mph), leading to some variability among the precise location at which the measurements were taken.

Illumination readings were recorded for three weather conditions: a cloudy night, a cloudy day, and a clear sunny day. Each car completed the loop two times per daylight weather condition and three times for the nighttime condition. Data was recorded at approximately the same spot at each of the eight locations. (See Figure 1.) The daytime readings were all taken with the sun near its azimuth position, 1000 hours through 1300 hours. The panel brightness for the night driving conditions was set by the driver to a comfortable level.

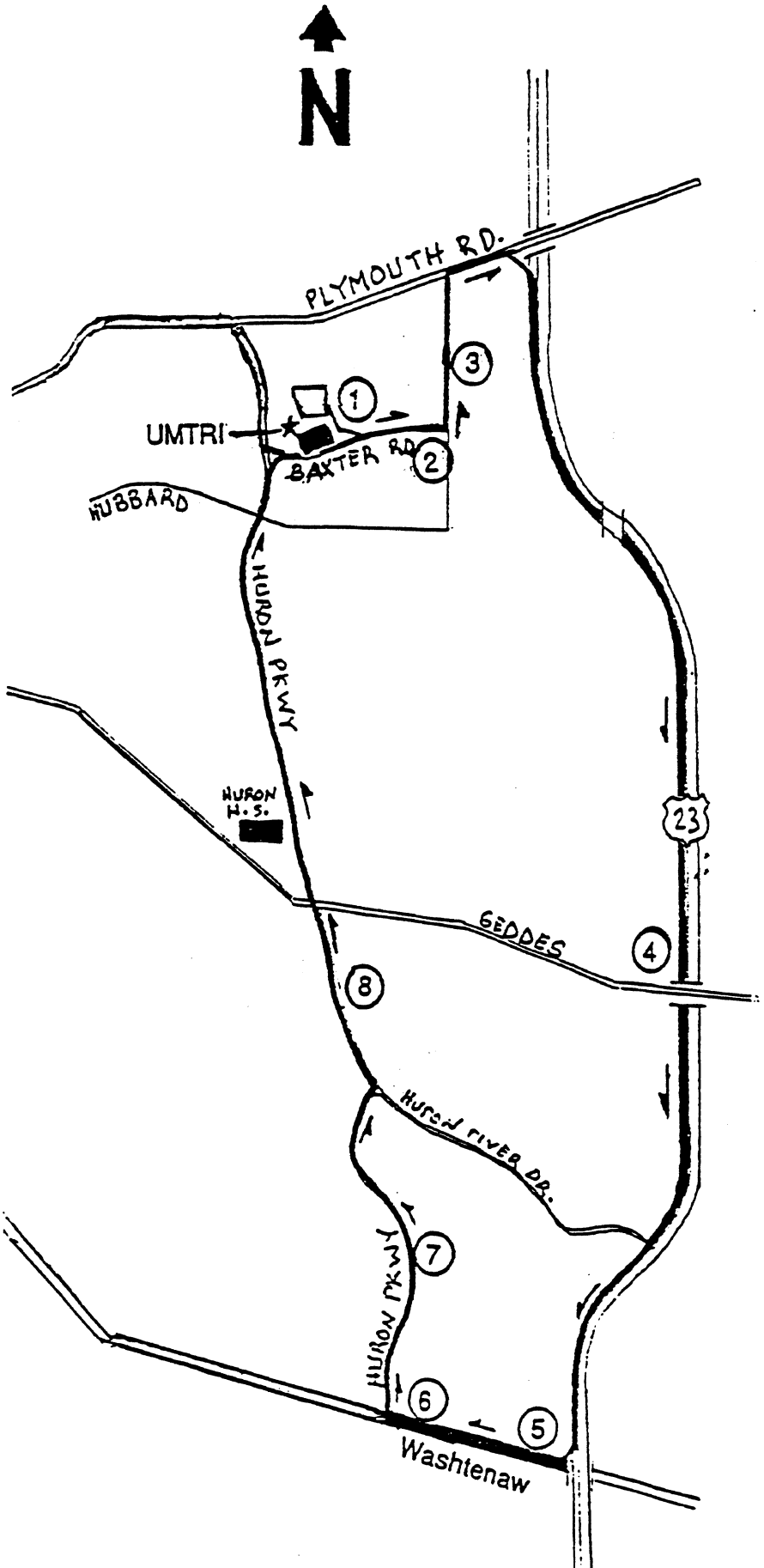

Figure 1 - Map of the Illumination Recording Locations

- *TEST PLAN* -

Measurements were recorded at 8 locations on January 12 and 13, 1988 along an 8.9 mile loop in Ann Arbor, Michigan (latitude 43, longitude 25). (See Figure 1.) Light levels were recorded in an empty parking lot behind UMTRI (location #1), along an unlighted road (#2), at a busy intersection near a shopping mall (#3), on an expressway (#4), along a well-lighted main street in a shopping district (#5 and #6), on an unlighted but well traveled parkway (#7), and a well-lighted bridge (#8). The experimenters switched cars when they returned to the parking lot and repeated the loop. The sequence of locations did not change from loop to loop.

The vehicles faced a variety of compass directions at the various locations. No attempt was made to block the background illumination caused by the headlights of following cars, overhead streetlights, or reflected light off of other vehicles or snow.

RESULTS

Table 1 shows the analysis of variance (ANOVA) of the illumination readings. The main effects were weather condition (sunny and overcast day, and overcast night), car type, and station location. All effects were considered to be random. The three-way term (LCW) was used as the error term for computing the F ratio. Appendix A contains the raw means by weather condition, car type, and station location.

Table 1 - ANOVA of the Illumination Readings

Factor	D.F.$_n$	S.S.	Mean Square	F	p
Location	7	8.591E+6	1.227E+6	4.473	.0022*
Car	2	2.105E+6	1.052E+6	3.835	.0328
Weather	2	9.868E+6	4.934E+6	17.980	.0001*
LC	14	4.151E+6	2.965E+5	1.081	.4138
LW	14	1.429E+7	1.021E+6	3.720	.0018*
CW	4	2.725E+6	6.814E+5	2.483	.0658
LCW	28	7.683E+6	2.744E+5		

* Statistically significant effect.

As expected, the weather conditions proved to be significantly different ($p<.01$). Table 2 compares the mean illumination levels for the three conditions. These means ranged from .112 fc (overcast night) to 901.5 fc (sunny day).

Table 2 - Mean Illumination Levels by Weather Condition

WEATHER CONDITION	Overall Mean	Standard Deviation
Sunny Day	901.5	1305.0
Overcast Day	365.0	127.8
Overcast Night	0.112	0.187

A few of the readings for the sunny day condition were much larger than the rest (about 3000-5000 fc), raising the question of whether these values are spurious. (See Table A-1 in Appendix A.) Boyd (1954) showed that a value of 11,250 fc was obtainable in the Ann Arbor area as direct illumination. Since our readings were obtained while traveling in a northwest direction with the sun directly on the instrument panel, the obtained readings appear to be reasonable.

Another significant main effect was the station location ($p<.01$). Table 3 shows the mean illumination levels by location and direction. Compass directions are relative to 0 degrees north. The highest ambient illumination levels occurred when the car was heading roughly northwest (W-NW, NW), while the lowest levels occurred when the car was heading towards the south (S-SW, E-SE, S-SE).

Table 3 - Mean Illumination by Station and Direction

LOCATION	Direction		Mean
#1 Parking Lot	S-SW	205°	194.2
#2 Baxter Road	E-SE	105°	193.1
#3 Green Road	N-NE	15°	305.0
#4 US 23	S-SE	160°	177.7
#5 Washtenaw East	W-NW	285°	822.2
#6 Washtenaw West	NW	305°	1170.1
#7 Huron Parkway	NE	35°	218.4
#8 Huron Bridge	N	0°	297.2

Notes:

Angular directions are specified assuming 0° is north and continuing clockwise. Compass directions are broken into 16 directions (N, N-NE, NE, E-NE, E, E-SE, SE, S-SE, S, S-SW, SW, W-SW, W, W-NW, NW, N-NW).

Table 4 shows the mean illumination levels at each location for the sunny day condition. They are consistent with the results of Table 3. The highest illumination level occurred while traveling towards the northwest (W-NW, NW) and the least occurred while traveling towards the south (S-SW, E-SE, S-SE). These readings are easily explained by the position of the sun. Since the readings were taken during the winter while the sun was near its azimuth, the instrument panel would get the most direct sunlight while traveling north and the least while traveling south. Furthermore, traveling northwest allows the sun to enter the driver-side window and fall more directly on the instrument cluster.

Table 4 - Mean Illumination by Station for Sunny Day

LOCATION	Direction		Mean
#1 Parking Lot	S-SW	205°	299.3
#2 Baxter Road	E-SE	105°	302.7
#3 Green Road	N-NE	15°	462.7
#4 US 23	S-SE	160°	266.8
#5 Washtenaw East	W-NW	285°	2032.5
#6 Washtenaw West	NW	305°	3019.3
#7 Huron Parkway	NE	35°	319.5
#8 Huron Bridge	N	0°	509.3
Overall Mean			901.5

Table 5 shows the mean illumination level at each location for the overcast day condition. Like the sunny day condition, the most illumination occurred while traveling roughly northwest (W-NW, NW) and the least occurred while traveling approximately south (S-SW, E-SE, S-SE). However, traveling northwest did not create as much of an increase in illumination as before since the sun was obscured by clouds.

Table 5 - Mean Illumination by Station for Overcast Day

LOCATION	Direction		Mean
#1 Parking Lot	S-SW	205°	283.2
#2 Baxter Road	E-SE	105°	276.5
#3 Green Road	N-NE	15°	452.0
#4 US 23	S-SE	160°	266.3
#5 Washtenaw East	W-NW	285°	434.0
#6 Washtenaw West	NW	305°	490.5
#7 Huron Parkway	NE	35°	335.7
#8 Huron Bridge	N	0°	382.0
Overall Mean			365.0

Table 6 shows the mean illumination level at each location for the overcast night condition. At night, the direction had less of an effect on illumination. The highest readings (stations 3, 5, 6, and 8) occurred on roads that were lit by streetlights. These brighter readings varied considerably. The lower readings, which occurred in unlit areas, were much more consistent.

Table 6 - Mean Illumination by Station for Overcast Night

STATION LOCATION	Direction		Mean
#1 Parking Lot	S-SW	205°	0.007
#2 Baxter Road	E-SE	105°	0.008
#3 Green Road	N-NE	15°	0.049
#4 US 23	S-SE	160°	0.002
#5 Washtenaw East	W-NW	285°	0.127
#6 Washtenaw West	NW	305°	0.547
#7 Huron Parkway	NE	35°	0.006
#8 Huron Bridge	N	0°	0.149
Overall Mean			0.112

CONCLUSIONS

It is concluded that a level around .112 fc should be used to simulate the panel illumination levels of a vehicle for a night driving situation. In addition, a level between 360 fc and 900 fc should be used to simulate daytime illumination. (On a bright day, a maximum illumination of 5485 fc was recorded.) This range should adequately represent the mean levels from an overcast day to a bright sunny one.

These results must be applied with care. It is important to note that they describe only the panel illumination. They do not address such issues as panel luminance or reflectance as other previous studies have (Olson & Bender, 1986). A serious oversight of this experiment was that exterior illumination was not measured with every interior measurement. This would have allowed these results to be compared more readily with other studies done under different conditions and at different longitudes and latitudes.

- *CONCLUSIONS* -

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- REFERENCES -

APPENDIX A - MEANS FOR EACH CONDITION

Table A-1 - Panel Illumination Levels - **Sunny Day**

LOCATION	VEHICLE		
	Chevy Cavalier	Mazda 323	Chevy Z-24
#1 Parking lot	307.0	357.5	233.5
#2 Baxter Rd.	237.5	437.0	233.5
#3 Green Rd.	647.5	369.5	371.0
#4 US 23	287.5	330.5	182.5
#5 Washtenaw East	1589.0	3945.0	563.5
#6 Washtenaw West	2545.0	5485.0	1028.0
#7 Huron Pkwy.	267.0	415.5	276.0
#8 Huron Bridge	692.0	472.5	363.5
Car Mean	822.0	1476.5	403.0
Overall Mean = 900.5 fc Standard Deviation = 1040.8 fc			

Table A-2 - Panel Illumination Levels - **Overcast Day**

LOCATION	VEHICLE		
	Chevy Cavalier	Mazda 323	Chevy Z-24
#1 Parking Lot	205.5	422.5	221.5
#2 Baxter Rd.	224.0	410.5	194.5
#3 Green Rd.	320.0	512.5	523.5
#4 US 23	208.0	394.0	197.0
#5 Washtenaw East	314.5	623.5	364.0
#6 Washtenaw West	446.5	621.5	403.5
#7 Huron Pkwy.	239.5	417.0	350.5
#8 Huron,Bridge	324.5	459.5	362.0
Car Mean	280.0	482.6	327.0
Overall Mean = 363.2 fc Standard Deviation = 84.7 fc			

Table A-3 - Panel Illumination Levels - **Overcast Night**

LOCATION	**VEHICLE**		
	Chevy Cavalier	Mazda 323	Chevy Z-24
#1 Parking Lot	.005	.011	.006
#2 Baxter Rd.	.010	.004	.010
#3 Green Rd.	.018	.014	.114
#4 US 23	.002	.002	.003
#5 Washtenaw East	.133	.068	.179
#6 Washtenaw West	.525	.662	.453
#7 Huron Pkwy.	.005	.006	.007
#8 Huron Bridge	.069	.047	.332
Car Mean	.096	.114	.138
Overall Mean = .116 fc Standard Deviation = .188 fc			

APPENDIX B - DATA COLLECTION FORM

Illuminance Level Testing of Vehicle Interiors

Date:_____ Data Recorder:_____

Car (Make):_____ Equipment:_____

Test Conditions:_____

_____

****

Station #1 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #2 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #3 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #4 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #5 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #6 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #7 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____

Station #8 (Please describe):_____

Data Measurements (Ft/candles)

1._____
2._____
3._____
4._____
5._____