Legibility of Prismatic and Non-Prismatic License Plates Study Report

Operator Performance Laboratory
University of Iowa
Iowa City, IA
https://hfdata.opl.uiowa.edu/opl/

Outline

- Project Overview
- Study Overview
- Static Study
- Dynamic Study
- Discussion of Results

Project Overview

- Study Objective:
  - Quantify the legibility benefits, if any, of next generation license plate sheeting, over the conventional beaded and non-reflective license plate sheeting that is widely used on today's vehicles.
- Operational Hypothesis:
  - Next generation sheeting provides higher levels of luminance under nighttime low-beam driving conditions, improving both the contrast between the letters and the background and the luminance of the background.

Study Overview

- The challenge put forth for this study was the need to design an experiment that could provide performance measures of the optics of the different materials used without legibility distance as a factor but yet simulating real world diving conditions.

- We determined the best approach was to design two separate experiments which, when the data was analyzed together, could produce, as close as possible, real world statistical data.

Study Overview

- The first experiment was a static study performed indoors in which the OPL researchers could control the legibility distance, weather, and lighting.

- The second experiment was a dynamic study which required the participant to determine visibility and legibility distances while driving a vehicle at idle speed.

Study Overview

- Three sheeting materials were evaluated
  - Non-reflective
  - Beaded
  - Microprismatic
- Two levels of degradation were evaluated
  - 0% degraded
  - 50% degraded

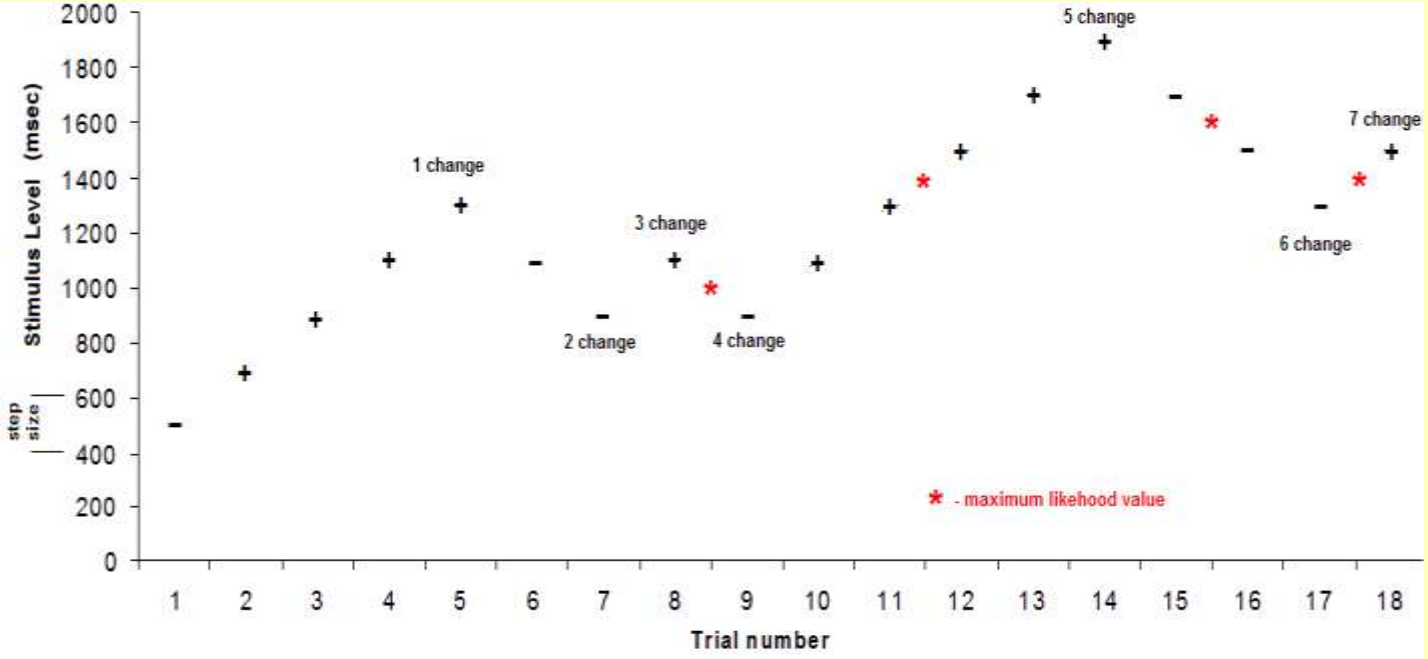
Static Study

- Operational Basis
  - A practical method for the investigation of the interrelationship between exposure time, information transfer accuracy, and license plate sheeting performance is to limit the exposure time
  - Determine the percent success level of information acquisition at varying reflectance levels (different optics)

Static Study

- To assist in this determination an algorithm known as the "Up-Down-Transformed Rule" (UDTR).
  - Developed by Wetherill [1]
  - Provides a simple yet methodical investigation protocol for forced-choice psychophysical responses.
  - A method to converge on a desired level of performance by systematically increasing and decreasing an independent variable of interest based on the preceding responses.
  - Based on the assumption that the probabilities of occurrence of the "up"(correct) and "down"(incorrect) responses are equal.
  - Tends to converge on that stimulus level where the probability of a "down" response sequence equals the probability of an "up" response sequence.

Static Study



Example of a run using the UDTR

Static Study

- Independent Variables
  - License plate sheeting type
  - Level of degradation
- Dependent Variable
  - Convergence Time

	Plate Type			Degradation	
Run Number	Nonreflective	Beaded	Microprismatic	0%	50%
1	X				X
2	X			X	
3		X			X
4		X		X	
5			X		X
6			X	X	

Run Matrix

Static study

- Fixed Settings
  - 84th percentile UDTR accuracy
  - Low beam headlight illumination from be a Lexus LS 430.
  - License plate light illuminating the plates
  - Ambient illumination corresponding to nighttime suburban viewing conditions.
  - Legibility index: 22.5 ft/in
  - Central placement: target vehicle located directly centered in front of observer vehicle to simulate a “same lane” effect.

Static Study

- Participants
  - 13 males (65%)
  - 7 females (35%)
  - Between ages of 26 & 65
  - Required to have a minimum visual acuity range of 20/40 (with or without corrective lenses)

Apparatus

- Target Vehicle
  - Military HMMWV (AMG Model 997)
  - Located 61.875 feet from observer
- Plate presentation device
  - Fitted into back of HMMWV
  - Allow rapid plate changing
  - Illuminated plates with standard plate light

Apparatus

- Observation vehicle
  - Lexus LS 430
  - Outfitted with electrochromic shutter
- Shutter control
  - Controlled by user with push button
  - Integrated into data collection software

Static Study

- Location was in a light controlled barn which allowed for
  - Viewing at the proper distance
  - Simulation of suburban night time illumination
- Operational Order (Per plate type, with 20 plates per type)
  - Researcher tells participant that the system is ready
  - Participant pushes button on shutter controller (Screen becomes clear)
  - Participant attempts to read the current plate to the researcher
  - Screen reverts to transparent based upon exposure time given by the UDTR
  - Researcher records correct/incorrect answer
  - Researcher sets up next plate
  - Order is repeated until such time as the UDTR converges

Static Study Results

- In the presented analysis results, the plate sheeting material and degradation indications are given as in the table below

Material Type	Optics Designation
Non-reflective	NR
Beaded	BD
Microprismatic	MP

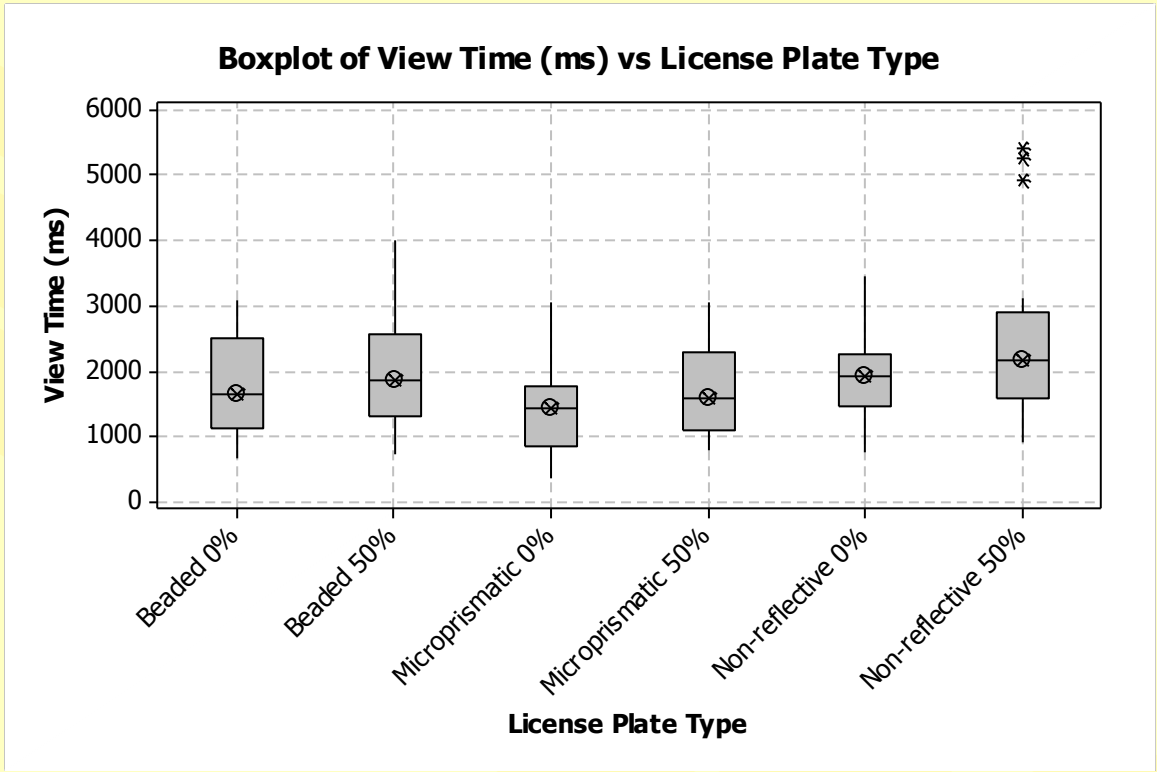
Static Study Results

- As would be expected, non-degraded plates resulted in faster acquisition times than degraded
- Microprismatic sheeting material resulted in faster acquisition times than the other materials

Optics	Wear Percent	Mean Time(ms)
1	0	1922.5
2	0	1751.25
3	0	1492.5
1	50	2466.25
2	50	1957.5
3	50	1650

Mean Acquisition Times

Static Study Results



Static Study Results

- To determine if the mean acquisition times represented a statistically significant difference between plate types an ANOVA analysis was perfumed
  - Pairwise comparison of Optics with Wear Interactions
  - Pairwise comparison of Optics without Wear Interactions

Static Study Results

- Pairwise comparison of Optics with Wear Interactions

Optics		NR	BD	MP	NR	BD	MP
	Wear Percent	0	0	0	50	50	50
NR	0						
BD	0	-171.25					
MP	0	-430.00	-258.75				
NR	50	543.75	715.00	973.75			
BD	50	35.00	206.25	465.00	-508.75		
MP	50	-272.50	-101.25	157.50	-816.25	-307.50	

Differences in Mean Acquisition Times

Optics		NR	BD	MP	NR	BD	MP
	Wear Percent	0	0	0	50	50	50
NR	0						
BD	0	0.7031					
MP	0	0.0063	0.2594				
NR	50	0.0002	<0.0001	<0.0001			
BD	50	0.9997	0.5135	0.0024	0.0006		
MP	50	0.2084	0.9569	0.7712	<0.0001	0.1113	

P-Values

Static Study Results

- The Pair wise comparison of Optics with Wear Interactions between the plate types and degradation levels indicated
  - A statistically significant difference between the non-reflective material and all other materials
  - There was not a statistically significant difference between beaded and microprismatic materials when wear interactions were included

Static Study Results

- Pairwise comparison of Optics without Wear Interactions

Optics	NR	BD	MP
NR			
BD	-340.00		
MP	-623.13	-283.13	

Differences between mean acquisition times

Optic	Mean Time(ms)
NR	2194.38
BD	1854.38
MP	1571.25

Mean acquisition times

Optics	NR	BD	MP
NR			
BD	-4.041		
MP	-7.406	-3.365	

ANOVA P-Values

Static Study Results

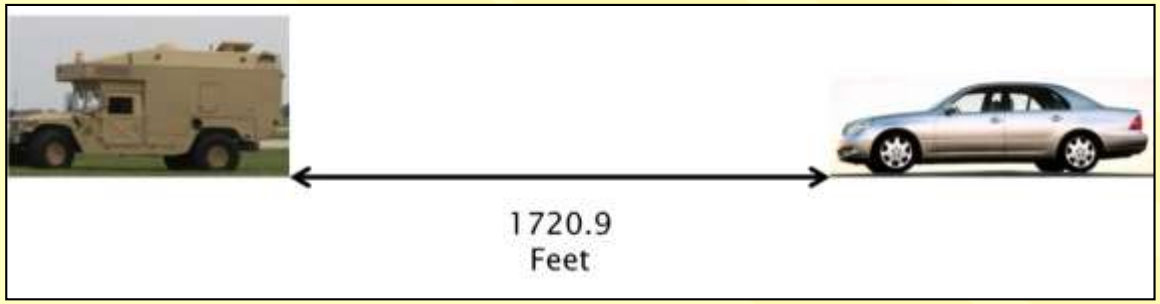
- The Pair wise comparison of Optics without Wear Interactions between the plate types and degradation levels indicated
  - A statistically significant difference between the non-reflective material and all other materials
  - There was a statistically significant difference between beaded and microprismatic materials when wear interactions were excluded

Dynamic Study

- Focused on the detection and legibility of license plates while the driver approached the target vehicle.
- The hypothesis used in this study was that microprismatic license plates provide longer detection distances under low beam illumination conditions at various levels of sheeting material deterioration.

Dynamic Study

- A simple field detection distance experiment was conducted in which we approached three types of license plates (non-reflective, beaded, and microprismatic) at night under low beam illumination conditions (Lexus LS 430) under two levels of deterioration (0%, 50%).
- The license plates were fixed on the back of a HMMWV (target vehicle).
- The target vehicle was then approached under low beam illumination conditions from a “long distance” (1720.9 feet) on an abandoned airport runway.



Dynamic Study

- Using a distance measuring instrument (DMI), stopping distances were marked during the approach at the first indication that the participant could clearly identify the visual target as a license plate (first view distance).
- The distance was recorded and the participant was asked to move forward again and stop when they felt they could accurately read the license plate sequence (legibility distance).

Dynamic Study

- Three plates from each sheeting material were randomly selected, resulting in 18 plates in total.
- All 18 plates were randomly presented to eliminate any potential biased expectation in stopping distances.
- However, the same 18 plates were used throughout this study and were not changed between participants even though the presentation order of the plates was changed.

Dynamic Study

- The following independent variables were used in the design of this experiment:
  - License plate sheeting type: non-reflective, beaded, microprismatic
  - Level of degradation: 0%, 50%

- The following were the dependent variables in the design of this experiment:
  - Distance between the observer vehicle and target vehicle at the first view of a license plate
  - Distance between the observer vehicle and target vehicle at the legibility distance of a license plate

Dynamic Study

- The following fixed settings were used:
  - Low beam headlight illumination from be a Lexus LS 430.
  - License plate light turned off on the target vehicle
  - Starting distance of 1720.9 feet.
  - Lateral placement: observer vehicle approached the target vehicle in the left lane while the target vehicle was stationary and in the right lane of a simulated highway to give an “out of lane” approach to the target vehicle

Dynamic Study

- A total of fifteen participants were used for this study
  - 9 males (60%)
  - 6 females (40%)
  - Between the ages of 26 and 65
  - Had a minimum visual acuity of 20/40
- The apparatus was the same as the static study with the exception of
  - The use of a DMI
  - The electrochomic shutter was removed

Dynamic Study Results

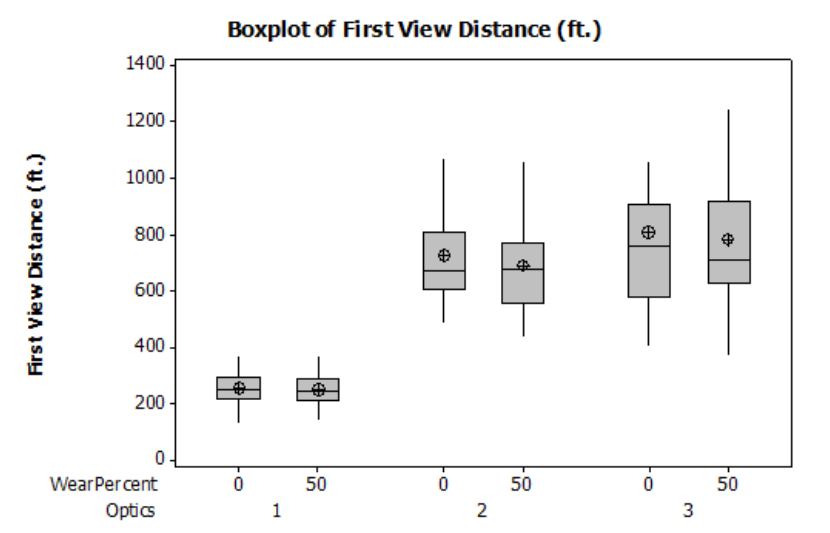
- The mean first view distance and legibility distances are given in the tables below

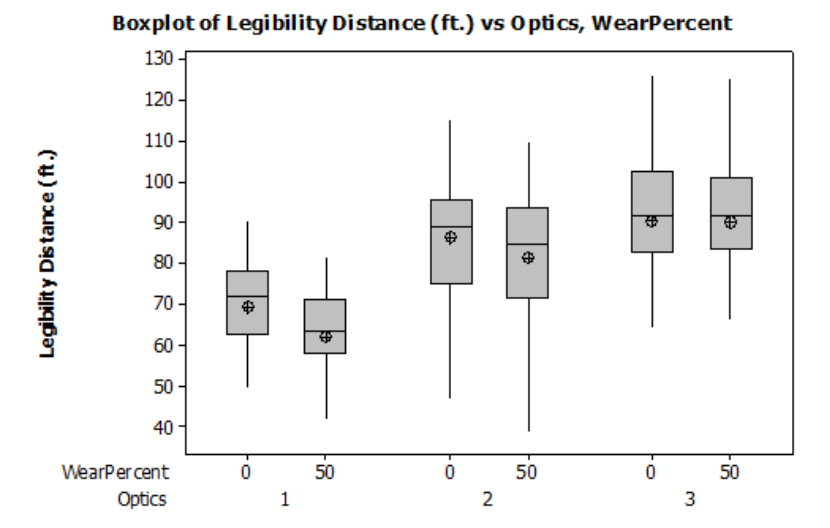
Optics	Wear Percent	View Distance (ft.)
NR	0	253.8
BD	0	727.3
MP	0	808.3
NR	50	250.0
BD	50	689.6
MP	50	781.4

Optics	Wear Percent	Legibility Distance (ft)
NR	0	69.4
BD	0	86.1
MP	0	90.6
NR	50	61.8
BD	50	81.3
MP	50	90.2

Dynamic Study Results

- As can be seen below, the microprismatic material performed better than the other materials





Dynamic Study Results

- A pair wise ANOVA analysis was performed to determine if the differences between the performance of the various sheeting materials represents a statistically significant difference.
  - Pair wise comparison of Optics with Wear Interactions between sheeting types
  - Pair wise comparison of Optics without Wear Interactions between sheeting types

Dynamic Study Results

- Pairwise comparison of Optics with Wear Interactions for First View Distances

Optics		NR	BD	MP	NR	BD	MP
	Wear Percent	0	0	0	50	50	50
NR	0						
BD	0	473.5					
MP	0	554.6	81.1				
NR	50	-3.8	-477.3	-558.3			
BD	50	435.9	-37.6	-118.7	439.6		
MP	50	527.6	54.1	-27	531.4	91.7	

Differences in Mean Acquisition Times

P-Values

Optics		NR	BD	MP	NR	BD	MP
	Wear Percent	0	0	0	50	50	50
NR	0						
BD	0	<0.0001					
MP	0	<0.0001	0.355				
NR	50	1	<0.0001	<0.0001			
BD	50	<0.0001	0.9421	0.0439	<0.0001		
MP	50	<0.0001	0.7742	0.9864	<0.0001	0.2205	

Dynamic Study Results

- Pairwise comparison of Optics with Wear Interactions for Legibility Distances

Optics		NR	BD	MP	NR	BD	MP
	Wear Percent	0	0	0	50	50	50
NR	0						
BD	0	16.7					
MP	0	21.2	4.5				
NR	50	-7.5	-24.3	-28.7			
BD	50	11.9	-4.8	-9.3	19.5		
MP	50	20.8	4.1	-0.3	28.4	8.9	

Differences in Mean Acquisition Times

P-Values

Optics		NR	BD	MP	NR	BD	MP
	Wear Percent	0	0	0	50	50	50
NR	0						
BD	0	<0.0001					
MP	0	<0.0001	0.7797				
NR	50	0.2335	<0.0001	<0.0001			
BD	50	0.0064	0.7269	0.0732	<0.0001		
MP	50	<0.0001	0.8323	1.000	<0.0001	0.0947	

Dynamic Study Results

- The Pair wise comparison of Optics with Wear Interactions between the plate types and degradation levels indicated
  - A statistically significant difference between the non-reflective material and all other materials
  - There was not a statistically significant difference between beaded and microprismatic materials when wear interactions were included

Dynamic Study Results

- Pairwise comparison of Optics without Wear Interactions

Optics	NR	BD	MP
NR			
BD	456.5		
MP	542.9	86.4	

Differences between mean first view distances

Optic	Distance (ft.)
NR	251.9
BD	708.4
MP	794.8

Mean First View Distances

Optics	NR	BD	MP
NR			
BD	<0.0001		
MP	<0.0001	0.0081	

ANOVA P-Values

Dynamic Study Results

- Pairwise comparison of Optics without Wear Interactions

Optics	NR	BD	MP
NR			
BD	18.1		
MP	24.8	6.7	

Differences between mean Legibility distances

Optic	Distance (ft.)
NR	65.6
BD	83.7
MP	90.4

Mean Legibility Distances

Optics	NR	BD	MP
NR			
BD	<0.0001		
MP	<0.0001	0.0155	

ANOVA P-Values

Dynamic Study Results

- The Pair wise comparison of Optics without Wear Interactions between the plate types and degradation levels indicated
  - A statistically significant difference between the non-reflective material and all other materials
  - There was a statistically significant difference between beaded and microprismatic materials when wear interactions were excluded

Discussion of Results

- This analysis conducted in this project indicated a number of facts about the plate sheeting materials.
  1. Non-reflective sheeting material resulted in consistently lower performance.
  2. When wear interactions are included in the analysis, no statistically significant differences exist between the beaded and microprismatic sheeting types.
  3. When wear interactions are excluded from the analysis, a statistically significant difference exists between the performance of the beaded and microprismatic types.

Discussion of Results
MP Compared to BD

- With the microprismatic material type, participants, on average, experienced:
  - A decrease in acquisition time of 283 milliseconds over beaded
  - An increase in first view distances of 86.4 feet over beaded
  - An increase in legibility distances of 6.7 feet over beaded
- These figures indicate that the microprismatic material performed
  - 15% better than beaded for acquisition time
  - 12% better than beaded for first view distance
  - 8% better than beaded for legibility distance

Discussion of Results
MP Compared to NR

- With the microprismatic material type, participants, on average, experienced:
  - A decrease in acquisition time of 623milliseconds over non-reflective
  - An increase in first view distances of 542.9 feet over non-reflective
  - An increase in legibility distances of 24.8 feet over non-reflective
- These figures indicate that the microprismatic material performed
  - 28% better than non-reflective for acquisition time
  - 215.5% better than non-reflective for first view distance
  - 37.8% better than non-reflective for legibility distance

References

1. WETHERILL G.., C.H., VASUDEVA R.B., *Sequential estimation of quantal response curves: A new method of estimation.* Biometrika, 1966. **53**(3-4): p. 14