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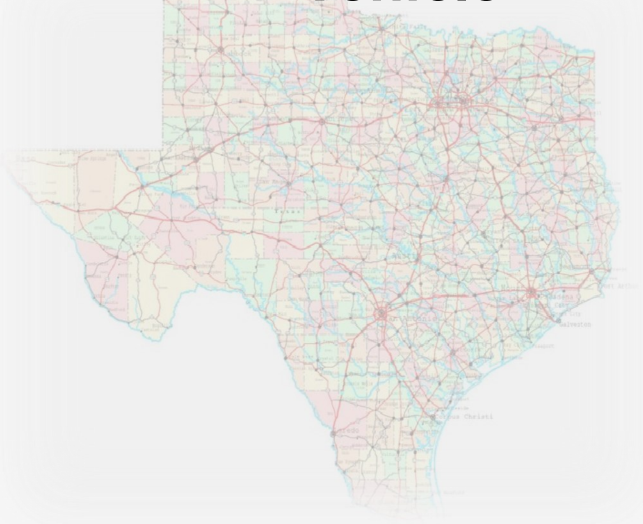
Impact of Alcohol on Lane Placement and Glance Patterns when Passing a Parked Active Law Enforcement Vehicle



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Impact of Alcohol on Lane Placement and Glance Patterns when Passing a Parked Active Law Enforcement Vehicle

Report: ATLAS-2013-02

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16. Abstract

For this project, researchers used an existing dataset from a previous research effort to investigate the moth effect theory, where it is believed that drivers drift toward bright lights. While the previous research study primarily focused on signs, on one segment of the closed-course participants drove past a law enforcement vehicle with its overhead flashing lights activated at two blood alcohol concentration (BAC) levels (0.00 and 0.12 g/dL). Researchers also utilized the existing dataset to investigate how alcohol affects pupil size and vehicle speed.

Within 300 ft of the law enforcement vehicle, all of the participants initially steered the vehicle away from the vehicle. However, about 250 ft upstream of the vehicle all of the participants began to drift back toward the vehicle and continued to drift toward the vehicle for approximately 200 ft, moving laterally 8 to 24 inches. Nonetheless, all participants kept the study vehicle well within in the lane lines. On average, participants drifted farther toward the law enforcement vehicle at a BAC level of 0.12 g/dL. However, the effect of BAC level on lane placement varied by participant.

Researchers confirmed that the pupil diameter for the majority of participants was larger at a BAC level of 0.12 g/dL than at a BAC level of 0.00 g/dL. Participants at a BAC level of 0.12 g/dL also tended to look directly at the law enforcement vehicle less.

Small differences in the vehicle speed between BAC levels were seen; however, the differences were practically negligible. Typically, the participants at the 0.00 g/dL BAC level appeared to drive more conservatively.

Overall, the vehicle lane placement findings upstream of the law enforcement vehicle support the moth effect theory. In addition, the pupil diameter findings confirmed expectations regarding bright light sources and alcohol-impaired driving.

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INTRODUCTION

In 2012, 36 percent of fatalities that occurred as a result of a crash involved alcohol-impaired driving (*1*). Many studies have examined the effects of alcohol at various blood alcohol concentration (BAC) levels on driving-related skills and crashes, with the majority of these studies reporting impairment of some skill by a BAC level of 0.05 g/dL (*2*). As part of a recent research project sponsored by the Texas Department of Transportation (TxDOT), Texas A&M Transportation Institute (TTI) researchers conducted a nighttime study in which 30 participants drove a state-owned vehicle along a closed-course at four BAC levels (i.e., 0.00, 0.04, 0.08, and 0.12 g/dL). The primary objectives of this study were to:

- Determine where alcohol-impaired drivers look in the forward driving scene.
- Provide insight into how alcohol-impaired drivers recognize and read signs.

While this study primarily focused on signs, on one segment of the closed-course participants drove past a law enforcement vehicle with its overhead flashing lights activated. Since researchers collected eye tracking, pupil size, lane placement, and speed data, there was an opportunity to investigate the moth effect theory, which hypothesizes that drivers drift toward bright lights. Researchers also utilized the existing dataset to investigate how alcohol affects pupil size and vehicle speed.

STUDY VEHICLES AND EQUIPMENT

The study used two instrumented state-owned vehicles, both 2005 Dodge Grand Caravans. As headlight performance can differ greatly between vehicles based on age, varied use, and maintenance, the headlight assemblies and HB4 bulbs were completely replaced and aimed in accordance with the manufacturer's instructions. Figure 1 depicts the in-vehicle equipment used. Researchers mounted a global position system (GPS) on the windshield and connected it to a laptop with data collection software. The GPS collected latitude, longitude, and speed data. Researchers also mounted an eye-tracking system on the dashboard. This system includes two cameras and an infrared pod used to track the driver's eyes and measure the diameter of his pupils. In addition, researchers used a forward driving scene camera. This camera uses the data from the eye-tracking system to visually document a point of gaze for the driver in the forward driving scene video. Prior to each driving task, researchers calibrated the eye-tracker equipment to each participant.

Figure 2 shows the video camera mounted on the outside of one vehicle that was used to determine lateral position within the lane. Each night researchers placed a large ruler with 2-inch markings perpendicular to the tire well under the camera and recorded its placement. The 2-inch markings allowed the researchers to create a calibrated polynomial fit trend line that converts vertical pixel location to lateral placement with sub-inch accuracy. Researchers synchronized all data collected by the various pieces of on-board equipment with the laptop clock time.

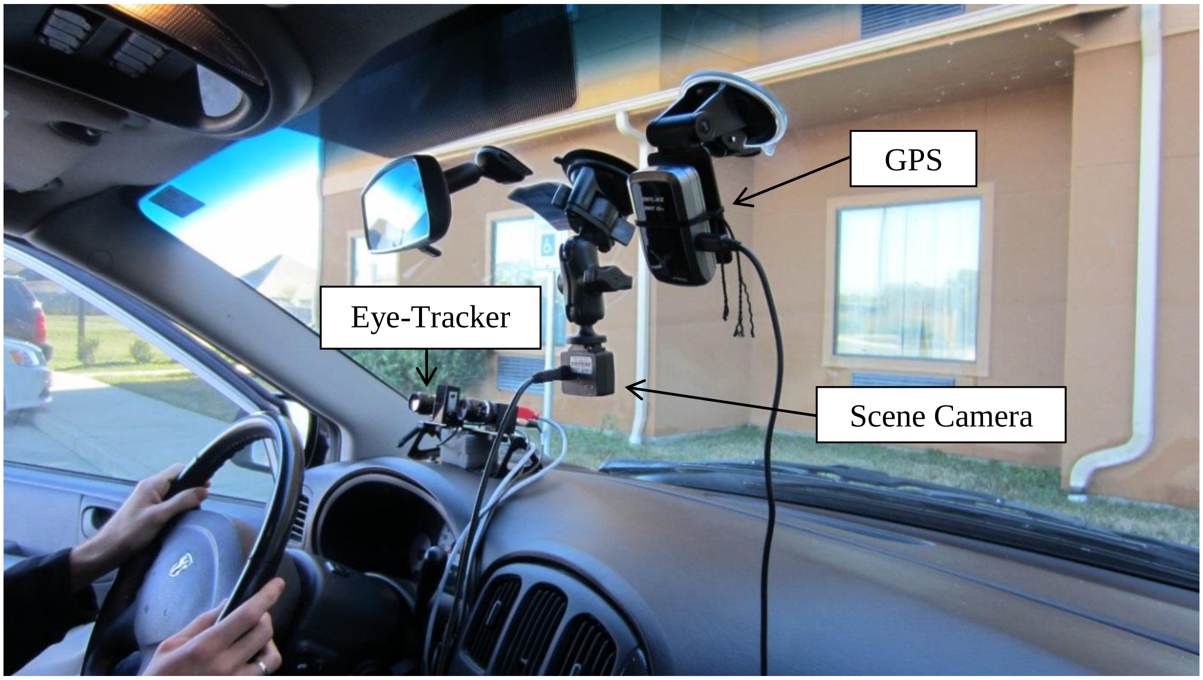


Figure 1. In–Vehicle Equipment.

Figure 2. Lateral Position Camera and Calibration Ruler.

STUDY PROCEDURE

Researchers recruited potential participants from the Bryan/College Station, Texas, area. Participants had to meet the following criteria:

- Have a current driver's license with no nighttime driving restrictions.
- Be a male.
- Be at least 21 years old.
- Weigh less than or equal to 250 pounds.
- Not be color blind.

All participants were required to have a valid driver's license with no nighttime restrictions because the participant would be driving the study vehicle at night. Only male participants were used since the study involved consuming alcohol and the budget did not provide funding for staff and the equipment needed to test female participants for possible pregnancy. Participants had to be at least 21 years old since that is the legal drinking age in Texas. Researchers set a maximum weight limit in an effort to minimize the time needed for alcohol consumption and to maintain a similar alcohol consumption period for all participants. Since the main study involved identifying sign colors, the participants could not be color blind.

Researchers conducted the study in three parts: pre-screening, part 1, and part 2. Each part was administered on a different date. The pre-screening portion took about an hour and was conducted during the day at the TTI State Headquarters and Research Building. Upon arrival participants read and signed an informed consent document. A researcher verified that each participant had a valid driver's license with no nighttime restrictions and that he was at least 21 years old. Each participant's weight was also measured using a standard scale. Researchers then asked participants their race and how many alcoholic beverages they typically drank in a day. Texas Department of Public Safety (DPS) staff used the answers to these questions, as well as the weight measurements, to determine the approximate number of drinks each participant needed to consume to reach the target BAC levels. Each participant underwent two eye tests (standard visual acuity test and color blindness) to ensure that he had at least the minimal levels of acceptable vision (i.e., 20/40 and not color blind). Each participant also completed two assessments that provided information about his typical alcohol consumption and behavior. Researchers used the answers to these assessments to identify naïve drinkers, individuals that may be at risk for alcohol dependence, and individuals that were alcohol dependent. At risk individuals were not allowed to participate. Participants that met all the pre-screening criteria and agreed to complete the remaining parts of the study were scheduled for part 1.

Part 1 was conducted at night at the Texas A&M University Riverside Campus and took about two hours. Participants did not consume any alcohol. Upon arrival participants read and signed the informed consent document again. Before driving, each participant had his BAC level determined by standard DPS breath sample equipment to ensure that his BAC level was 0.00 g/dL. Participants then drove an instrumented state-owned vehicle at about 30 mph along a simulated two-lane, two-way roadway on a closed-course (shaded area in Figure 3). While driving, two persons accompanied the participants: a study administrator who sat in the front passenger seat and provided verbal directions, and an equipment operator who sat in the back seat. Along the pre-determined route, participants encountered a law enforcement vehicle twice and multiple sign treatments. For each sign, participants verbally indicated the background color and sign legend (i.e., text). Researchers marked the participants' responses on standard forms and within the in-vehicle equipment software program. In addition, researchers recorded all of the participants' comments as they traveled through the course for later review.

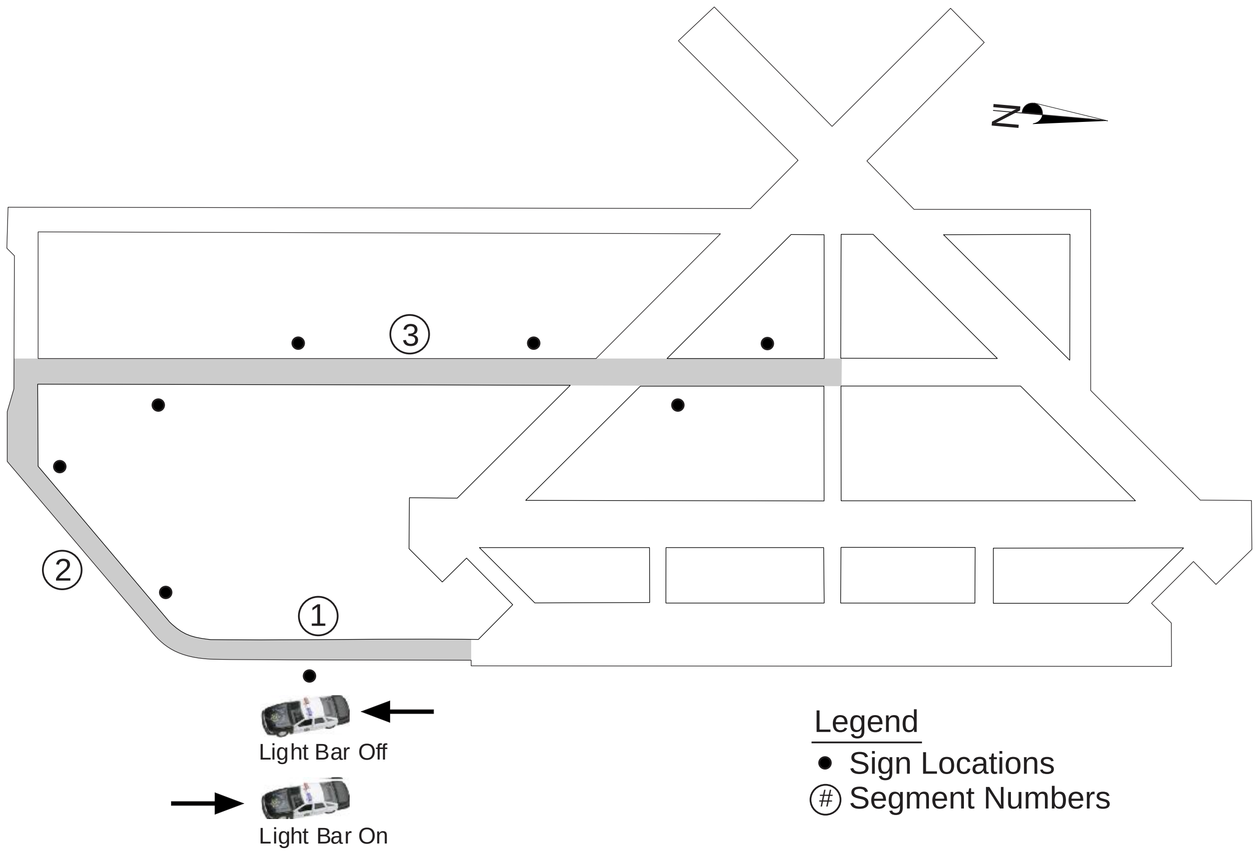


Figure 3. Driving Route and Treatment Locations on Closed-Course.

At the end of the driving task, participants returned to the study check-in building where they completed a short survey and three standard police field sobriety tests (i.e., following a stimulus with your eyes, walking in a line using heel to toe steps, and balancing on one leg). Upon completion of part 1 of the study, researchers scheduled participants for part 2.

Part 2 was conducted at night at the Texas A&M University Riverside Campus and took approximately 10 hours. Participants were required to consume alcoholic beverages (either regular beer or 80-proof spirit mixed drinks). Upon arrival at the Riverside Campus participants reviewed and signed the informed consent document. Before consuming any alcohol, each participant had his BAC level determined by standard DPS breath sample equipment. Participants then consumed alcoholic beverages over approximately a two hour period until they reached a BAC level of 0.12 g/dL. Researchers used the same standard DPS breath sample equipment to monitor each participant's BAC level. At a minimum, each participant's BAC level was measured immediately prior to and after each driving task.

When each participant reached a BAC level of 0.12 g/dL, he drove an instrumented state-owned vehicle at approximately 30 mph along a simulated two-lane, two-way roadway on a closed-course. The state-owned vehicle and driving task were the same as in part 1. At the end of the 0.12 g/dL BAC driving task, each participant completed the short survey and three standard police field sobriety tests (the same as in part 1). Participants then returned to the study check-in building conference room where they had a comfortable place to sit, food, and non-alcoholic drinks. When each participant reached a BAC level of 0.08 g/dL and 0.04 g/dL, he repeated the driving task and the three standard police field sobriety tests. In addition, upon reaching a BAC level of 0.10 g/dL and 0.06 g/dL, each participant repeated the three standard police field sobriety tests. All participants had to remain on-site until their BAC level was less than 0.04 g/dL, at which time researchers drove them home.

TREATMENTS

As mentioned previously, the primary focus of the TxDOT study was signs. However, in one segment of the course, a law enforcement vehicle was located 20 ft from the edge of the simulated two-lane, two-way roadway (see Figure 3 and Figure 4). The vehicle was stationary and faced south. Each participant drove past the law enforcement vehicle twice, first in the southbound direction and second in the northbound direction. The light bar on top of the cab was not activated when participants drove by in the southbound direction, but it was activated when participants drove by in the northbound direction. The vehicle's headlights were always on. Figure 5 shows the law enforcement vehicle from the northbound direction, and Figure 6 shows a close-up of the overhead light bar.

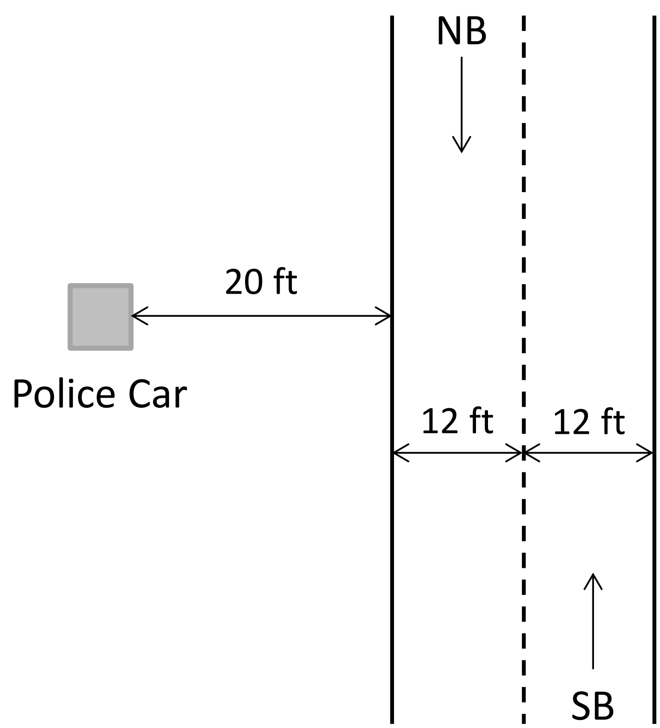


Figure 4. Location of Law Enforcement Vehicle Relative to Simulated Two-Lane Road.

Figure 5. Law Enforcement Vehicle from Northbound Direction.

Figure 6. Overhead Light Bar.

PARTICIPANTS

The TxDOT study included 30 male participants that completed part 1 and part 2 of the study; however, only a portion of the original 30 could be used for the analysis documented herein. Since lateral position was not a measure of effectiveness of interest in the TxDOT study, researchers only mounted a video camera on the outside of one of the study vehicles. Therefore researchers only collected lane placement data for 16 participants. In addition, vehicle and equipment malfunctions further reduced the number of participants for which researchers had lane placement data to 10. Even though the number of participants in the final dataset was smaller than initially planned, the sample sizes for the analyses were still fairly large since all data were collected at 10 to 30 frames per second (equipment dependent) and the participants drove at approximately 44 ft per second, yielding over 500 data points per participant per BAC level.

The average age of the 10 participants was 28 and ranged from 21 to 42. The average visual acuity was 20/16 and the average weight was 203 pounds.

DATA REDUCTION

Following data collection, researchers screened and reduced each participant's raw data into a fully formatted dataset to obtain the necessary information for analysis. During the data screening process, researchers eliminated any anomalous data (e.g., misidentifications and malfunctioning treatment/equipment).

Next, researchers reviewed the BAC level data measured immediately before and after each driving task. Researchers computed the average BAC level for each participant for each driving task by averaging the two before and two after BAC level measurements. Figure 7 shows the average BAC level for the 10 participants for the three target BAC levels (i.e., 0.12, 0.08, and 0.04 g/dL), and Table 1 contains the overall BAC level descriptive statistics.

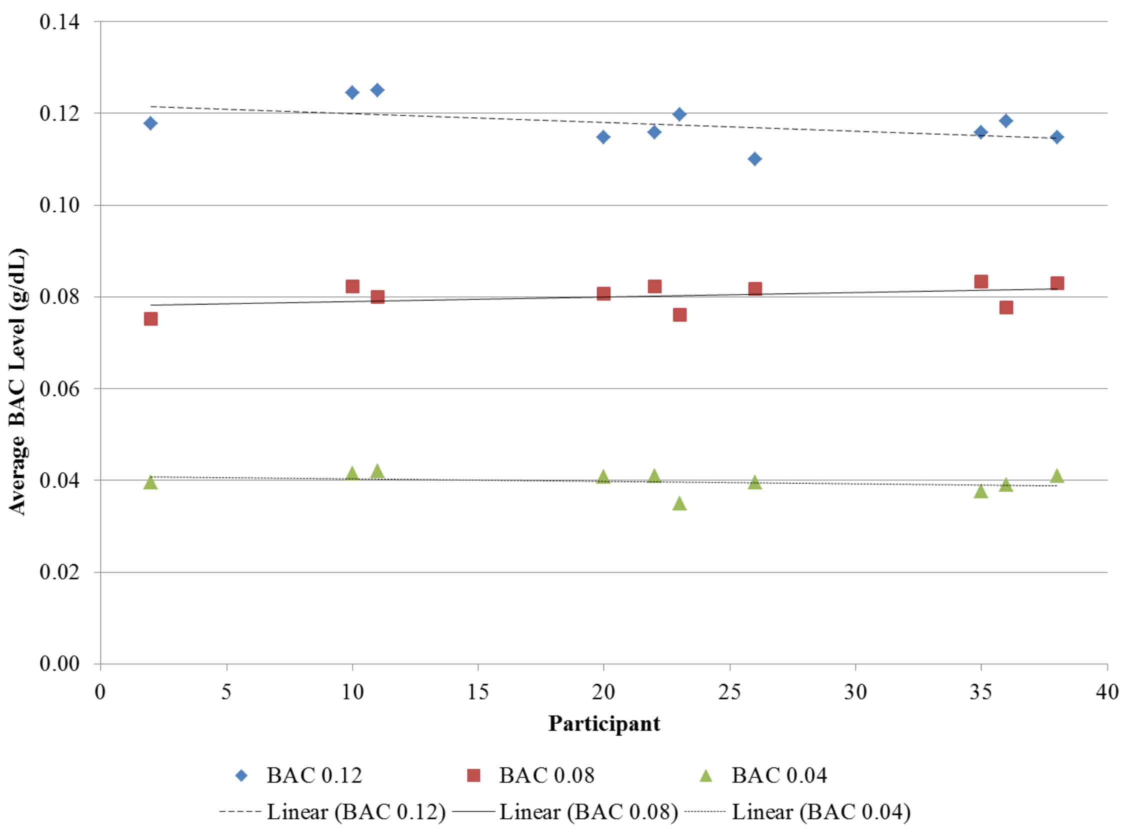


Figure 7. Participants' Average BAC Levels (g/dL).

Table 1. Overall BAC Level Descriptive Statistics (g/dL).

Target Level	Average	Standard Deviation	Minimum	Maximum
0.000	0.000	0.000	0.000	0.000
0.120	0.118	0.005	0.110	0.125
0.080	0.080	0.003	0.075	0.083
0.040	0.040	0.002	0.035	0.042

For the investigation into the moth effect theory, researchers reduced and analyzed lane placement and eye-tracker glance data collected in segment one (Figure 3) in the northbound direction at two BAC levels (0.00 and 0.12 g/dL). The lateral position data were reduced using a newly developed process within TTI that applies image processing and analysis techniques from the OpenCV Python library to find the pavement marking line's associated vertical pixel. The pixel value is then converted to inches through polynomial trend-line regression. Through a semi-automated algorithm, the program follows the edge of the pavement marking with little to no guidance from user interaction. As this was a new method, a sample of the data was compared to manually coded data from a human observer, and it was found that the new method was equally reliable and provided improved precision.

Researchers manually reviewed the eye-tracker scene camera video for each participant at the two BAC levels to determine the beginning and end of each law enforcement vehicle glance. As Figure 8 shows, the forward driving scene video denoted the point of gaze for the driver via a green circle. From these data, researchers computed the total number of direct glances at the law enforcement vehicle for each participant and linked the glance data with the lane placement data.

Figure 8. Example of a Participant Looking at the Law Enforcement Vehicle.

Researchers also reduced the pupil diameter data from the eye-tracker files and the vehicle speed data from the GPS files for the northbound direction of segment one (Figure 3) at two BAC levels (0.00 and 0.12 g/dL). According to the eye-tracking system used, in order to obtain an accurate reading of the pupil diameter the gaze quality parameter must be a three. Thus, researchers removed all data that had a gaze quality less than three from the dataset. Also, the average pupil diameter of the human eye typically ranges from 2 mm to 8 mm (*3*); hence researchers also eliminated all data that had a diameter less than 2 mm or greater than 8 mm from the dataset. For the remaining data, researchers averaged the right and left eye pupil diameter data (measured separately by the eye-tracking system) to yield an average pupil diameter for each observation period.

RESULTS

The following subsections contain the results of the analyses regarding the moth effect theory, pupil diameter, and vehicle speed. When appropriate, researchers used the predicted values (least squares means) for each response variable to compare different treatments. When there are multiple factors in the model, it is not fair to make comparisons between raw cell means in data because raw cell means do not compensate for other factors in the model. The least squares means are the predicted values of the response variable for each level of a factor that has been adjusted for the other factors in the model. A 5 percent significance level ($\alpha = 0.05$) was used for all statistical analyses.

Moth Effect Theory

For this analysis, researchers were primarily interested in determining whether or not the participants drifted toward the law enforcement vehicle as they drove toward the vehicle with its overhead light bar activated. Therefore, researchers analyzed the vehicle's lane placement (i.e., lateral distance from the edgeline to the right back tire) based on the approach distance, BAC level, and whether or not the participant was directly looking at the vehicle. Researchers initially fit a model for the lateral distance variable with the main effects shown below, their two-way interaction effects, and distance traveled toward the vehicle as a covariate:

- BAC level (0.00 and 0.12 g/dL).
- Looking at law enforcement vehicle (yes or no).
- Participant (2, 10, 11, 20, 22, 23, 26, 35, 36, and 38).

This dataset included 16,462 observations. This statistical analysis found that the distance traveled ($p = 0.000$) and the two-way interaction between BAC level and participant ($p = 0.010$) were statistically significant (α=0.05). Figures 9–18 contain graphs of the lateral distance from the edgeline by the distance traveled toward the law enforcement for each participant at each BAC level, noting when the participant was looking at the law enforcement vehicle (i.e., solid lines). The law enforcement vehicle was located at approximately 1150 ft. Table 2 contains descriptive statistics for lateral distance by participant and BAC level, and Table 3 shows the number of direct glances at the law enforcement vehicle by participant and BAC level. From these figures and tables, researchers observed the following:

- Nine out of 10 participants drove closer to the edgeline when they entered the course segment at a BAC level of 0.12 g/dL than at a BAC level of 0.00 g/dL. Since the participants were exiting a horizontal curve at this point, researchers believe that the participants at a BAC level of 0.12 g/dL had less control over the study vehicle and thus allowed it to swing more toward the outside of the curve.

- Within the first 100 ft of the segment, all of the participants began to steer the study vehicle back toward the centerline (i.e., typical maneuver after exiting a horizontal curve). Over the next 700 ft, some participants continued to drift toward the centerline (e.g., Participant 11), while others drove fairly straight (e.g., Participant 22). Even with these different driving styles, most participants drove such that the study vehicle was positioned near the center of the lane (i.e., lateral distance of 36 inches) or slightly toward the centerline (i.e., lateral distance greater than 36 inches).
- Reviewing the vehicle's lane placement data between 100 at 800 ft shows the variability in driving styles by participant. Only three participants consistently drove closer to the edgeline at a BAC level of 0.12 g/dL (i.e., Participants 2, 11, and 22). In contrast, two participants drove closer to the centerline at a BAC level of 0.12 g/dL (i.e., Participants 36 and 38). One participant exhibited similar lane placement trends at the both BAC levels (i.e., Participant 35). The other four participants' lane placement was so varied that consistent trends could not be identified.
- On average, the participants looked at the law enforcement vehicle more at a BAC level of 0.00 g/dL. However, there was slightly more variation in the number of glances at a BAC level of 0.12 g/dL. Researchers believe that at 0.12 g/dL participants may have avoided looking at the overhead light bar because alcohol had restricted the ability of their pupils to contract and slowed their pupils' reaction time, increasing their sensitivity to glare (*4*).
- Typically, the last glance sequence at the law enforcement vehicle occurred within 350 ft of the vehicle. In this portion of the segment, all of the participants exhibited a similar driving pattern, independent of the number of direct glances at the law enforcement vehicle. At both BAC levels, the participants began to steer the vehicle toward the centerline (i.e., away from the law enforcement vehicle) around 850 ft. However, around 900 ft they began to drift back toward the law enforcement vehicle and continued to drift toward the law enforcement vehicle for approximately 200 ft. The data in Table 4 and Table 5 support these trends. Table 4 shows that at a BAC level of 0.00 g/dL, participants, on average, drifted 14.6 inches toward the law enforcement vehicle (from 52.5 inches to 37.9 inches). In addition, for nine out of 10 participants the vehicle lane placement at the end of the drift maneuver (around 1100 ft) was closer to the edgeline than the vehicle lane placement before the participant began to steer the vehicle toward the centerline (around 850 ft). Thus, these participants did not just steer the vehicle back toward the edgeline to correct for the initial drift toward the centerline. Similarly, Table 5 shows that at a BAC level of 0.12 g/dL participants, on average, drifted 15.7 inches toward the law enforcement vehicle (from 54.8 inches to 39.1 inches). For the BAC level of 0.12 g/dL, five out of 10 participants positioned the vehicle such that it was closer to the edgeline at the end of the drift than before the participant began to steer the vehicle toward the centerline. While all of the participants at both BAC levels drifted toward the law enforcement vehicle in the area approximately 200 ft upstream of the vehicle, the vehicle was still well within in the lane lines. In addition, the effect of BAC level among the participants was varied. Nevertheless, these data show that within 200 ft of the law enforcement vehicle participants did drift toward the vehicle.

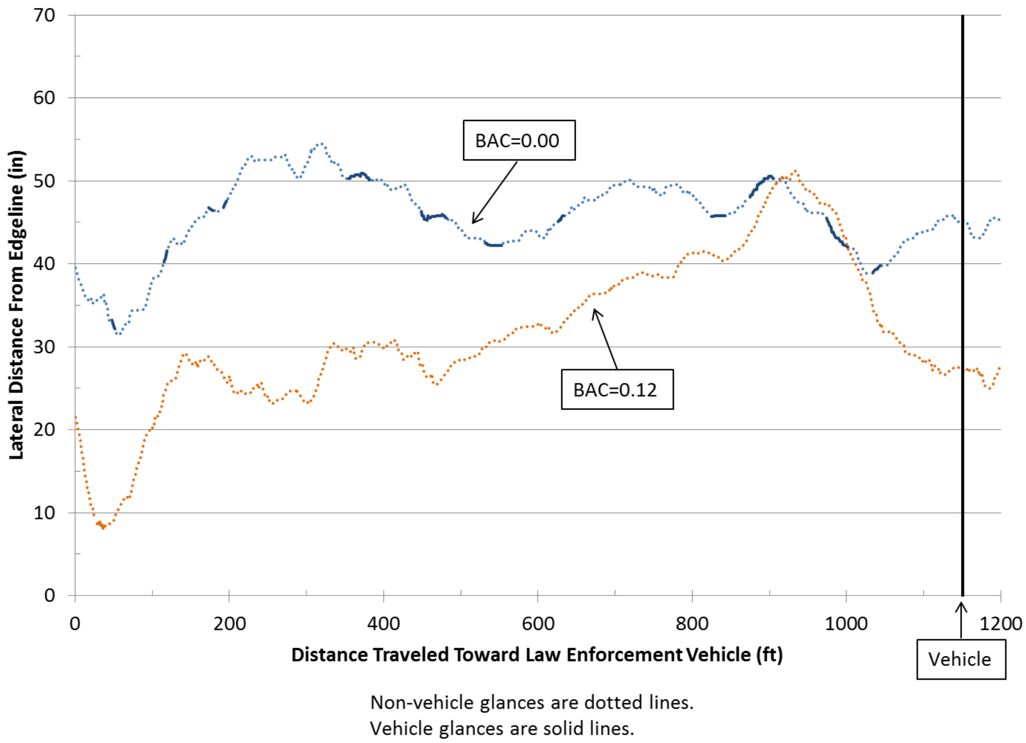


Figure 9. Participant 2 Lane Placement by Distance Traveled and BAC Level.

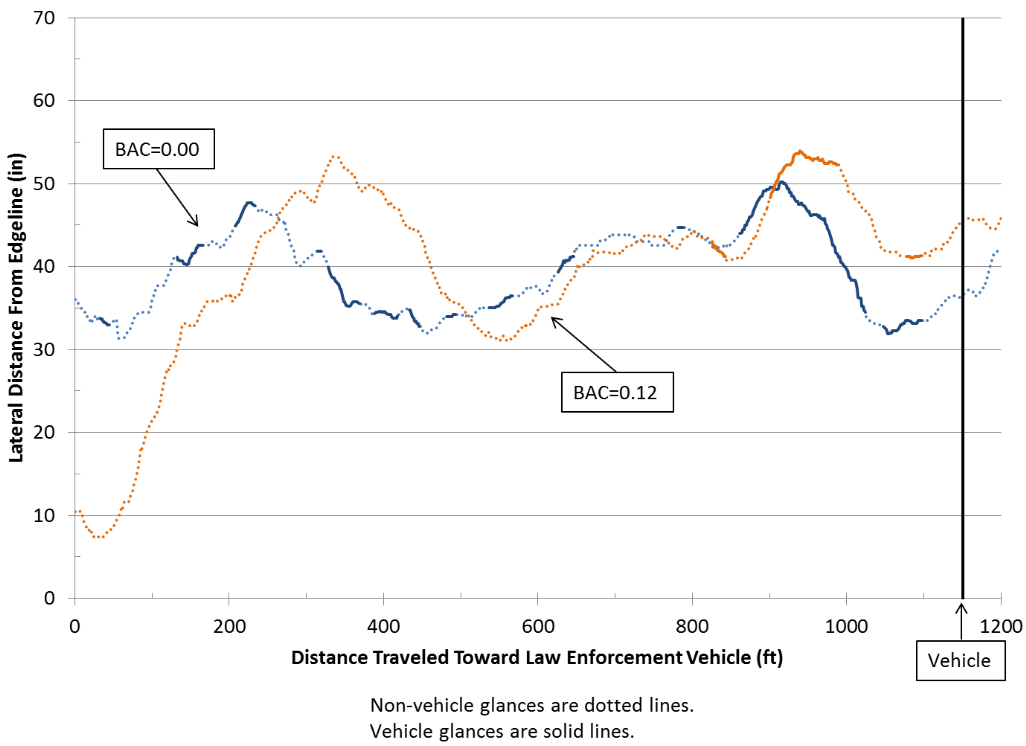


Figure 10. Participant 10 Lane Placement by Distance Traveled and BAC Level.

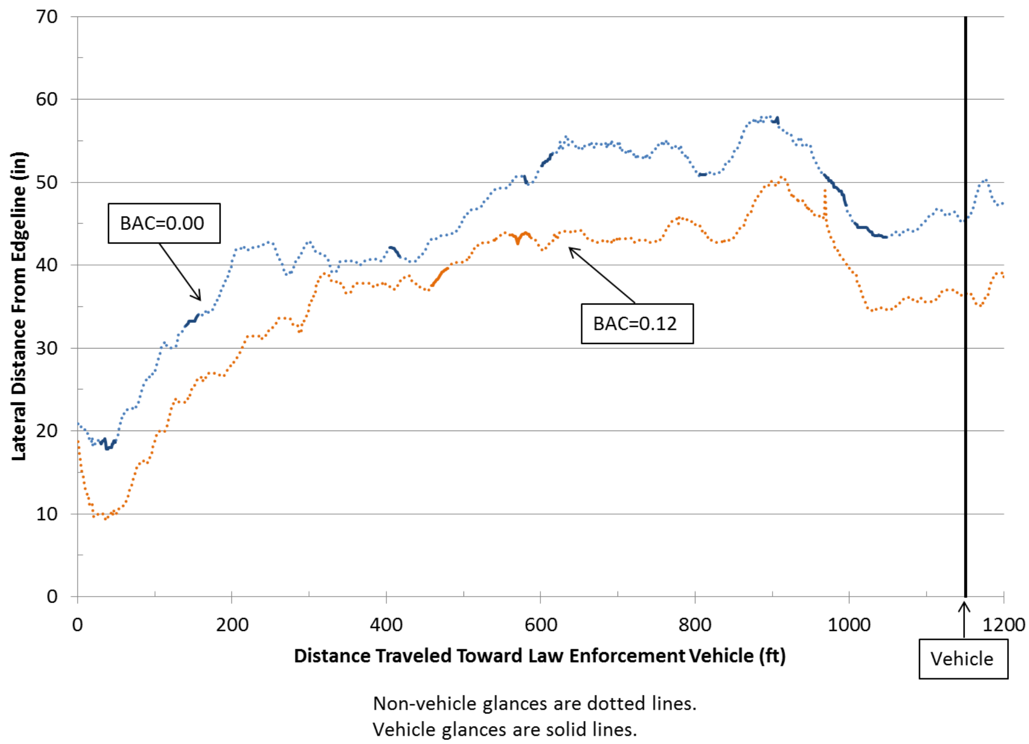


Figure 11. Participant 11 Lane Placement by Distance Traveled and BAC Level.

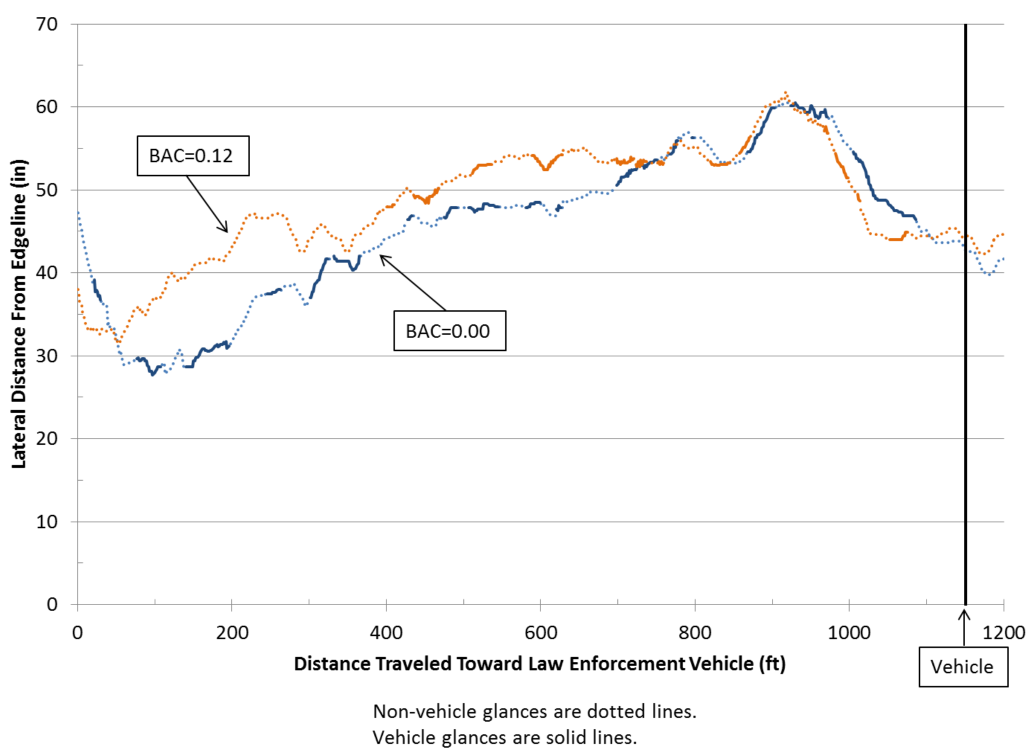


Figure 12. Participant 20 Lane Placement by Distance Traveled and BAC Level.

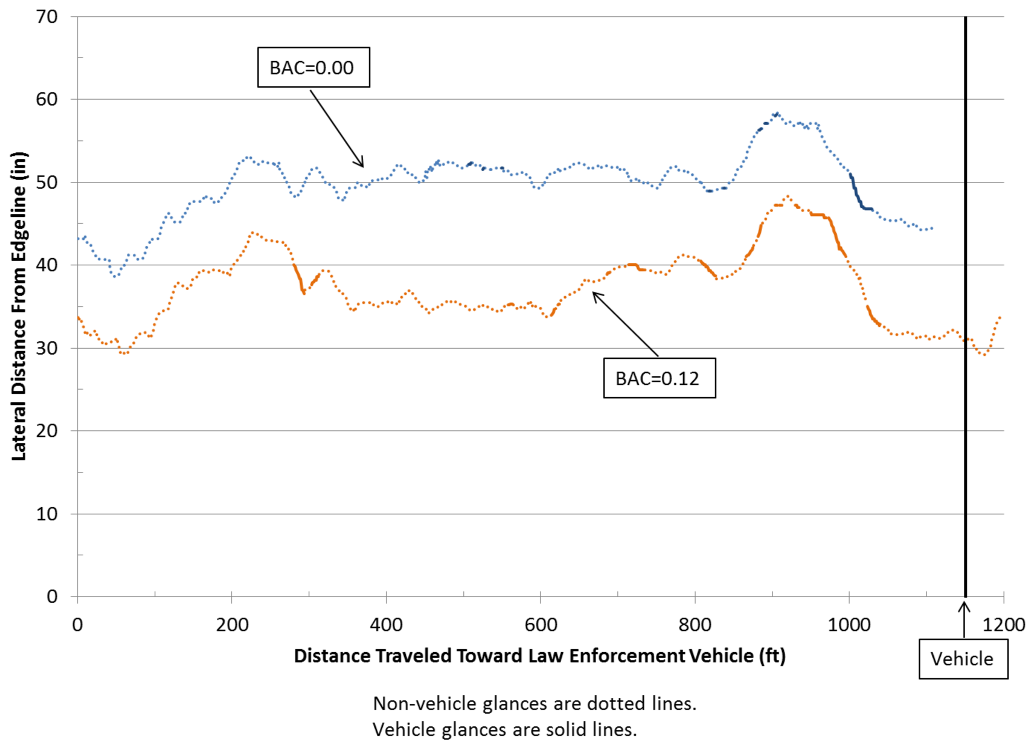


Figure 13. Participant 22 Lane Placement by Distance Traveled and BAC Level.

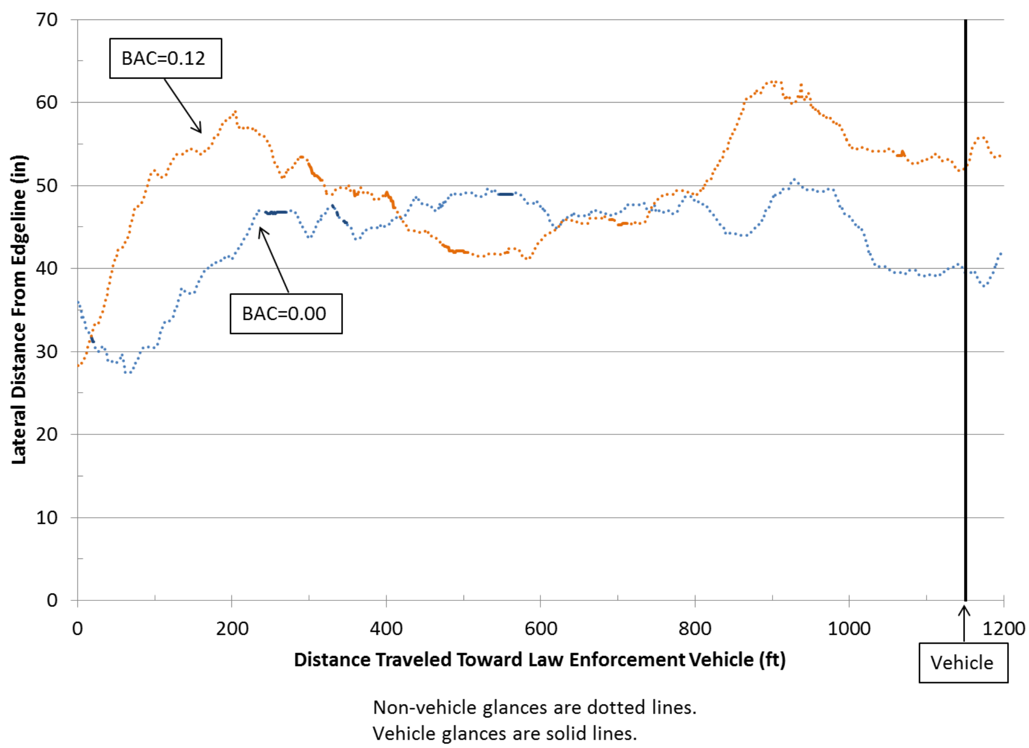


Figure 14. Participant 23 Lane Placement by Distance Traveled and BAC Level.

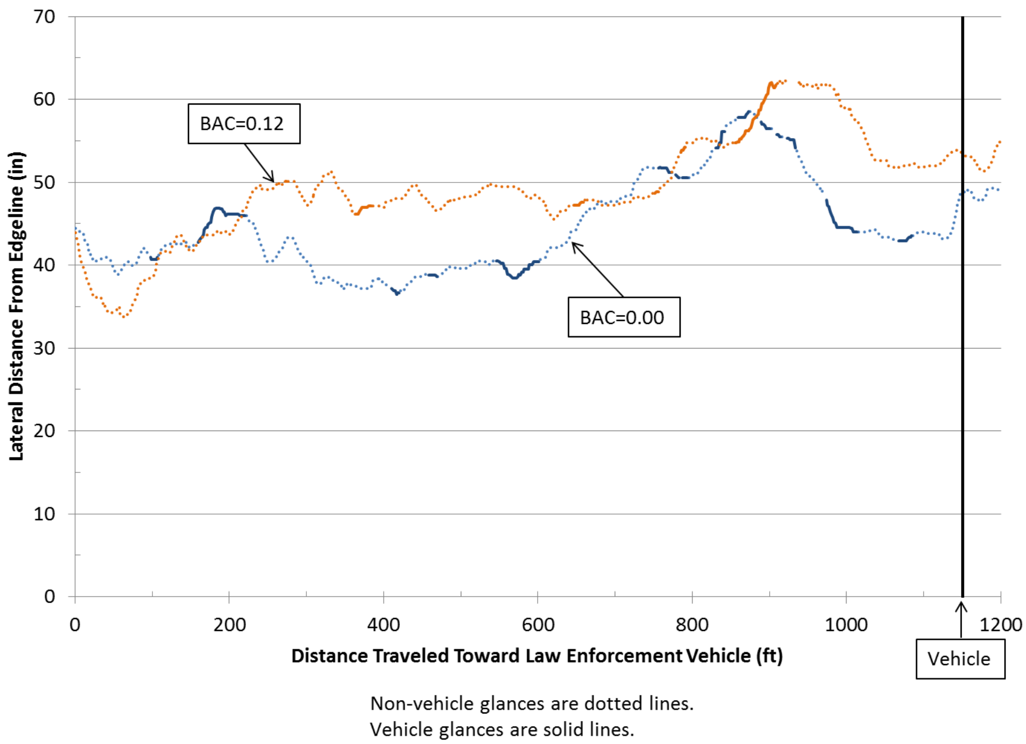


Figure 15. Participant 26 Lane Placement by Distance Traveled and BAC Level.

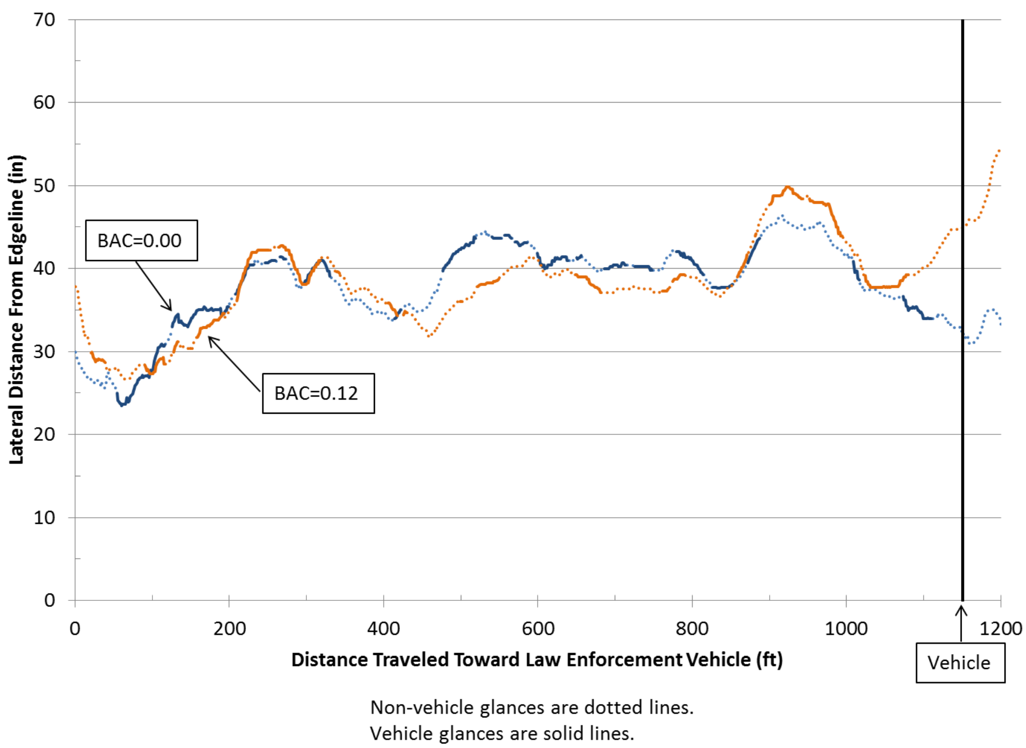
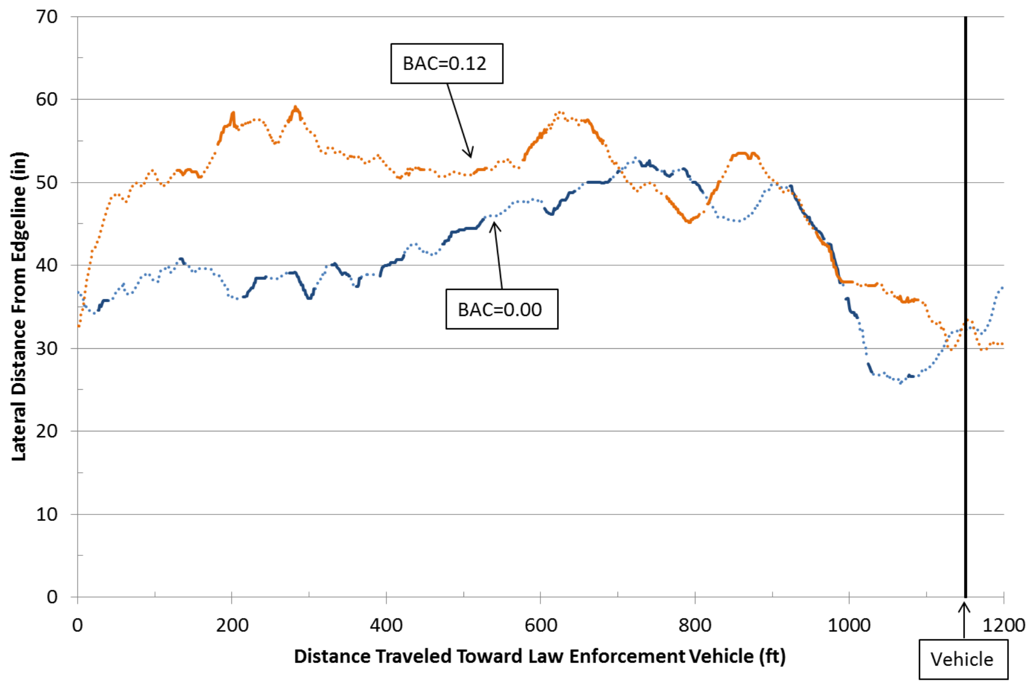
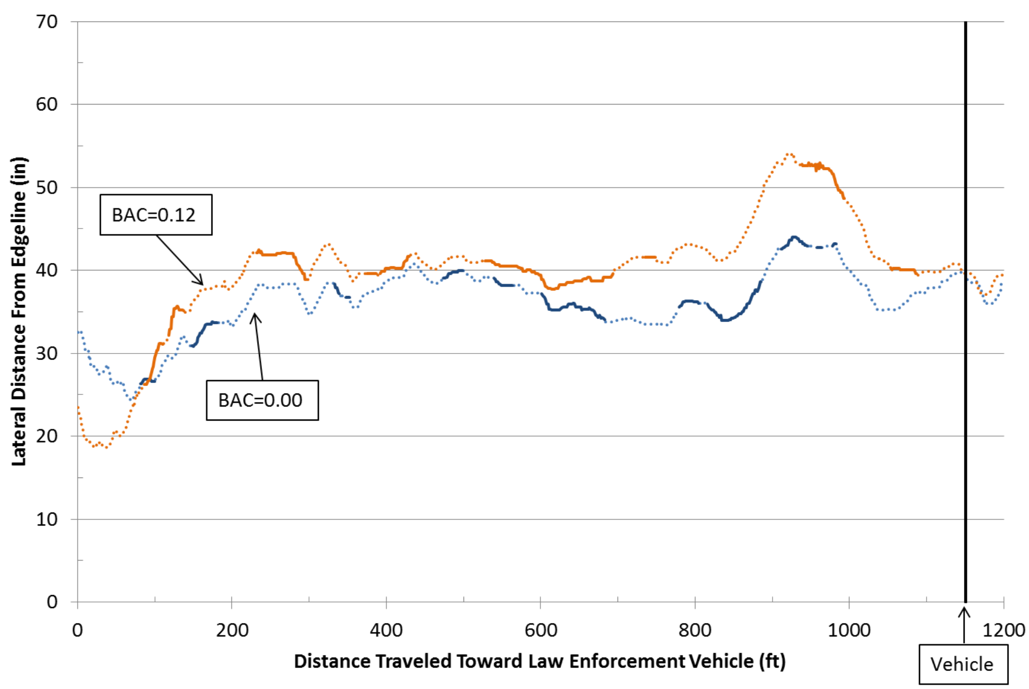


Figure 16. Participant 35 Lane Placement by Distance Traveled and BAC Level.



Non-vehicle glances are dotted lines.
Vehicle glances are solid lines.

Figure 17. Participant 36 Lane Placement by Distance Traveled and BAC Level.



Non-vehicle glances are dotted lines.
Vehicle glances are solid lines.

Figure 18. Participant 38 Lane Placement by Distance Traveled and BAC Level.

Table 2. Lateral Distance Descriptive Statistics.

Participant	Target BAC Level (g/dL)	Sample Size (n)	Mean (in)	Standard Deviation (in)	Minimum (in)	Maximum (in)
2	0.00	830	45.5	4.9	31.5	54.5
	0.12	792	31.0	9.3	8.2	51.2
10	0.00	843	39.3	5.0	31.4	20.2
	0.12	830	39.4	11.1	7.2	54.0
11	0.00	923	44.0	10.0	17.9	58.0
	0.12	802	35.8	10.1	9.3	50.7
20	0.00	834	45.3	8.9	27.7	60.5
	0.12	778	48.0	7.1	31.5	61.8
22	0.00	838	49.7	4.1	38.6	58.5
	0.12	861	37.1	4.5	29.2	48.4
23	0.00	856	43.7	5.6	27.4	50.7
	0.12	808	50.0	6.7	28.3	62.5
26	0.00	726	44.6	5.5	36.5	58.5
	0.12	759	49.2	6.2	33.7	62.4
35	0.00	875	37.6	5.3	23.5	46.5
	0.12	814	38.4	5.6	26.7	54.2
36	0.00	888	41.1	6.9	25.5	53.0
	0.12	840	48.4	7.7	29.9	59.1
38	0.00	801	36.0	4.2	24.3	44.0
	0.12	764	39.7	7.1	18.7	54.1
Overall	0.00	8414	42.6	7.5	17.9	60.5
	0.12	8048	41.7	10.0	7.2	62.5

Table 3. Number of Direct Glances by Participant and BAC Level.

Participant	Target BAC Level (g/dL)	
	0.00	**0.12**
2	12	1
10	13	3
11	9	3
20	17	15
22	9	14
23	6	9
26	15	6
35	20	20
36	20	13
38	20	13
Mean	14.1	9.7
Standard Deviation	5.1	6.3
Minimum	6	1
Maximum	20	20

Table 4. Lateral Position and Distance Traveled while Drifting toward Law Enforcement Vehicle by Participant at BAC Level 0.00 g/dL.

Participant	Lateral Position (in)			Distance Traveled (ft)		
	Beginning	Ending	Difference	Beginning	Ending	Difference
2	50.1	39.5	−10.6	920.1	1041.0	120.8
10	50.2	31.9	−18.3	917.1	1054.5	137.4
11	58.0	43.7	−14.3	898.0	1068.4	170.4
20	60.5	42.6	−17.9	929.7	1150.6	220.9
22	58.5	44.3	−14.2	907.9	1091.2	183.3
23	50.7	39.4	−11.4	929.8	1068.1	138.3
26	58.5	44.0	−14.5	878.4	1008.9	130.5
35	45.7	32.6	−13.1	909.4	1200.6	291.3
36	49.7	25.5	−24.2	909.4	1066.2	156.8
38	42.9	35.2	−7.7	956.0	1036.9	80.9
Mean	52.5	37.9	−14.6	915.6	1078.6	163.1
Standard Deviation	6.0	6.4	4.7	20.8	57.0	58.8

Table 5. Lateral Position and Distance Traveled while Drifting toward Law Enforcement Vehicle by Participant at BAC Level 0.12 g/dL.

Participant	Lateral Position (in)			Distance Traveled (ft)		
	Beginning	Ending	Difference	Beginning	Ending	Difference
2	51.2	27.1	−24.0	935.7	1150.7	215.0
10	53.1	41.1	−12.1	962.9	1085.9	123.0
11	50.7	34.6	−16.1	911.0	1053.8	142.8
20	61.8	44.0	−17.8	917.4	1052.3	134.9
22	48.4	31.1	−17.3	923.1	1087.7	164.6
23	62.5	53.9	−8.5	911.4	1199.6	288.2
26	62.4	51.8	−10.6	919.5	1058.4	138.9
35	49.9	37.7	−12.2	925.1	1031.1	106.0
36	53.6	29.9	−23.7	876.8	1129.1	252.3
38	54.1	40.1	−14.1	920.7	1054.6	134.0
Mean	54.8	39.1	−15.6	920.4	1090.3	170.0
Standard Deviation	5.5	9.0	5.2	21.5	53.4	60.9

Pupil Diameter

Table 6 contains the descriptive statistics for the average pupil diameter by participant and BAC level. Researchers initially fit a model for the average pupil diameter variable with the main effects shown below, their two-way interaction effects, and distance traveled toward the law enforcement vehicle as a covariate:

- BAC level (0.00 and 0.12 g/dL).
- Looking at law enforcement vehicle (yes or no).
- Participant (2, 10, 11, 20, 22, 23, 26, 35, 36, and 38).

This dataset included 11,797 observations. This statistical analysis found that the distance traveled ($p = 0.000$), looking at the law enforcement vehicle ($p = 0.021$), and the two-way interaction between BAC level and participant ($p = 0.000$) were statistically significant (α=0.05). Researchers expected the distance traveled variable to be significant since at the beginning of the segment it was fairly dark compared to the area closer to the law enforcement vehicle. Thus, while distance traveled was included in the model for completeness, researchers focused more on the influence of the other variables and their interactions.

Table 6. Average Pupil Diameter Descriptive Statistics.

Participant	Target BAC Level (g/dL)	Sample Size (n)	Mean (mm)	Standard Deviation (mm)	Minimum (mm)	Maximum (mm)
2	0.00	641	4.01	0.40	2.87	5.44
	0.12	617	4.43	0.46	3.12	5.63
10	0.00	–	–	–	–	–
	0.12	–	–	–	–	–
11	0.00	872	3.78	0.38	2.85	4.55
	0.12	734	3.91	0.27	3.21	4.55
20	0.00	697	3.48	0.29	2.68	4.30
	0.12	441	3.74	0.47	2.58	5.66
22	0.00	547	3.51	0.31	2.66	5.11
	0.12	627	3.62	0.31	2.81	4.31
23	0.00	670	4.20	0.32	3.08	4.98
	0.12	737	4.72	0.35	3.41	3.41
26	0.00	672	4.62	0.45	3.14	5.74
	0.12	556	4.20	0.25	3.68	5.01
35	0.00	620	3.84	0.30	2.85	4.80
	0.12	607	3.21	0.24	2.76	4.15
36	0.00	695	3.51	0.40	2.67	4.48
	0.12	619	4.28	0.62	3.05	5.55
38	0.00	740	4.37	0.28	3.57	5.32
	0.12	705	4.97	0.55	3.69	6.25
Overall	0.00	6154	3.93	0.52	2.66	5.74
	0.12	5643	4.15	0.67	2.58	6.25

– denotes no data.

Figure 19 contains a graph of the predicted means for the average pupil diameter by gaze point (i.e., whether or not the participant was looking at the law enforcement vehicle). This figure shows that when participants directly looked at the law enforcement vehicle the predicted mean pupil diameter was smaller (3.92 mm) than when participants were not directly looking at the law enforcement vehicle (4.05 mm). Researchers expected that this would be the case, since the human pupil is designed to constrict when a brighter light source is introduced.

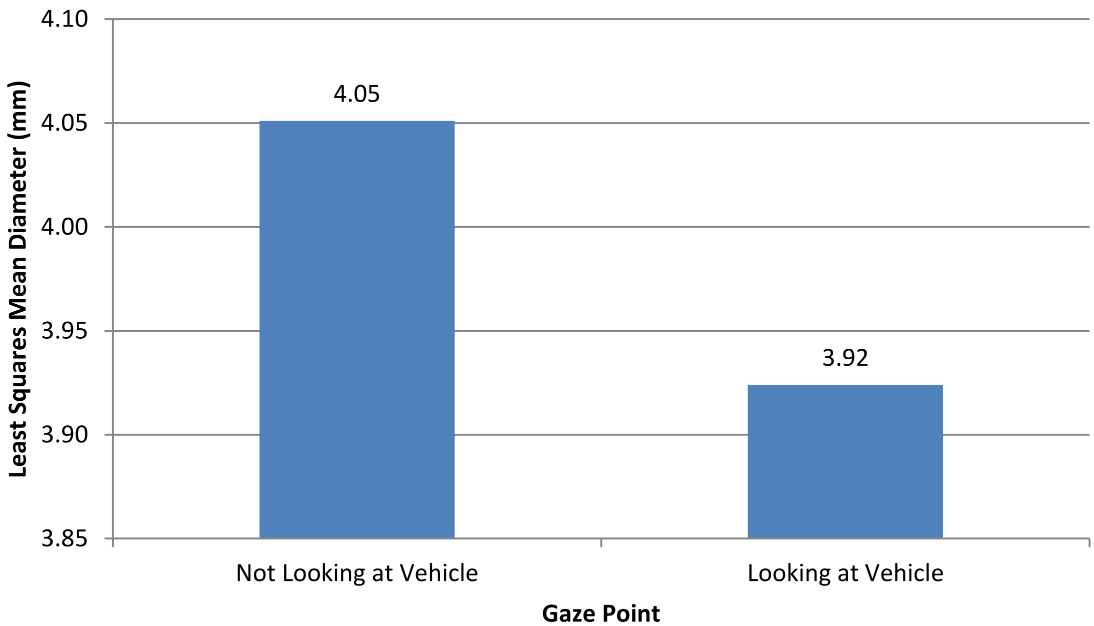


Figure 19. Average Pupil Diameter by Gaze Point.

Figure 20 shows a graph of the predicted means for the average pupil diameter by participant and BAC level. For the majority of participants, the predicted mean pupil diameter at a BAC level of 0.12 g/dL was larger than the predicted mean pupil diameter at a BAC level of 0.00 g/dL. Researchers also expected this finding since alcohol generally causes the pupil to expand or dilate. In addition, as discussed previously, participants at a BAC level of 0.12 g/dL looked at the law enforcement vehicle less. However, two of the participants' actual and predicted average pupil diameters were larger at a BAC level of 0.00 g/dL (i.e., Participants 26 and 35). Researchers hypothesized that the number of direct glances at the law enforcement vehicle may have affected these participants. However, upon further review Participant 26 looked at the law enforcement vehicle fewer times at a 0.12 g/dL BAC level than at a 0.00 g/dL BAC level, so one would think the pupil diameter would be larger at a BAC level of 0.12 g/dL. Participant 35 looked at the law enforcement vehicle the same number of times at both BAC levels, but the duration of the glances, especially those within 350 ft of the law enforcement vehicle, was longer at a 0.12 g/dL. Looking at the law enforcement vehicle for longer periods of time would decrease the pupil diameter. Overall, these data show the interdependence of multiple factors, several of which are participant dependent.

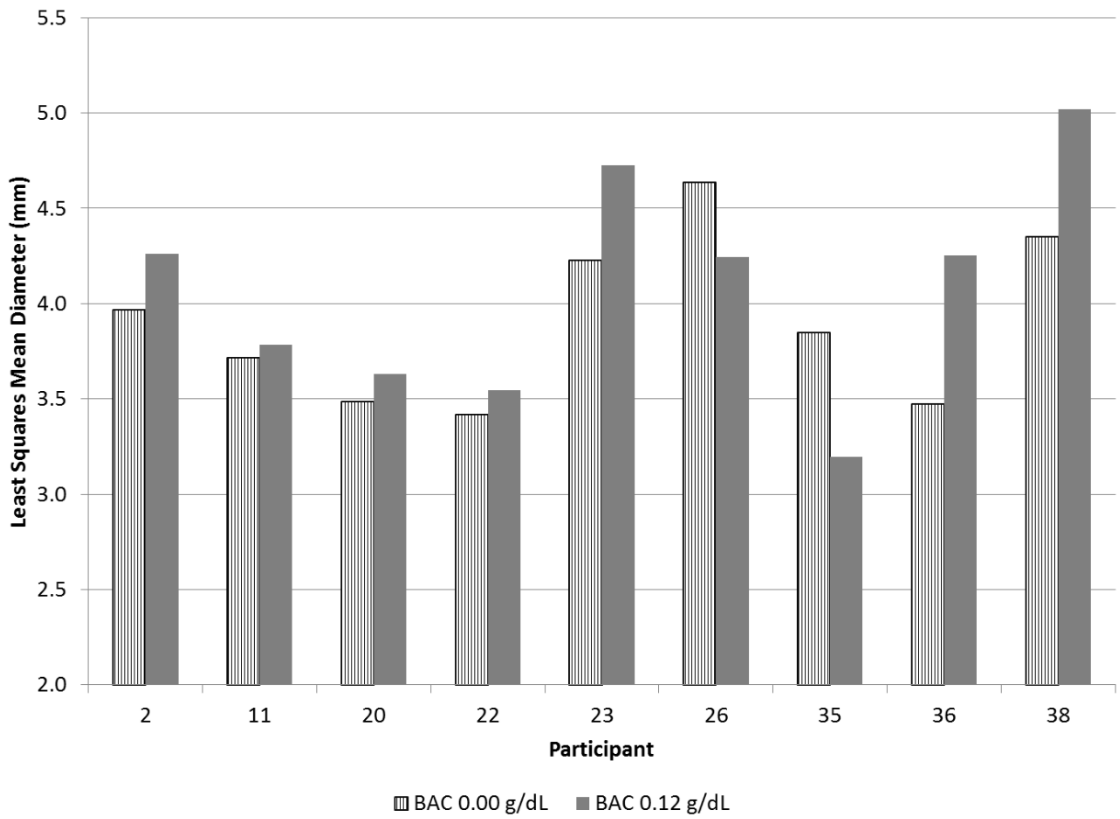


Figure 20. Average Pupil Diameter by Participant and BAC Level.

Vehicle Speed

Table 7 contains the descriptive statistics for the vehicle speeds extracted from the GPS data by participant and BAC level. While researchers closely monitored and verbally corrected the vehicle speed as the participant drove through the closed-course, researchers believed that the alcohol-impaired state might require more monitoring and have greater variability. Thus, researchers fit a model for the vehicle speed variable with the main effects shown below and their two-way interaction effects:

- BAC level (0.00 g/dL and 0.12 g/dL).
- Looking at law enforcement vehicle (yes or no).
- Participant (2, 10, 11, 20, 22, 23, 26, 35, 36, and 38).

This dataset included 16,471 observations. This statistical analysis found that the BAC level ($p = 0.031$), participant ($p = 0.0\ 20$), and the two-way interaction between BAC level and participant ($p = 0.003$) were statistically significant (α=0.05). Since the two main effects were found to interact, researchers could not look at these factors separately.

Figure 21 shows a graph of the predicted mean vehicle speed by participant and BAC level. For the majority of participants, the predicted mean vehicle speed at a BAC level of 0.00 g/dL was 1 to 4 mph less than the predicted mean vehicle speeds at a BAC level of 0.12 g/dL. As a result of this trend, the predicted mean vehicle speeds at a BAC level of 0.12 g/dL were typically closer to the target speed (i.e., 30 mph) than the predicted mean vehicle speeds at a BAC level of

0.00 g/dL. However, it does appear that researchers might have been more closely monitoring and correcting vehicle speeds at a BAC level of 0.12 g/dL since overall there was less variation in speeds at that BAC level (2.0 mph versus 2.5 mph). In addition, while researchers found that BAC level was a statistically significant factor, the difference in the mean vehicle speeds between the two BAC levels for each participant and overall were typically less than 2 mph and thus are not practically different.

Table 7. Vehicle Speed Descriptive Statistics.

Participant	Target BAC Level (g/dL)	Sample Size (n)	Mean (mph)	Standard Deviation (mph)	Minimum (mph)	Maximum (mph)
2	0.00	829	29.6	1.4	24.5	31.3
	0.12	791	31.0	2.1	24.9	33.4
10	0.00	842	29.1	2.2	22.8	31.2
	0.12	829	29.6	1.4	26.0	31.4
11	0.00	922	26.6	1.7	21.3	28.5
	0.12	801	30.7	2.8	23.5	33.6
20	0.00	833	29.5	1.4	24.5	31.4
	0.12	777	31.4	1.4	27.6	33.0
22	0.00	837	27.2	0.8	24.2	28.2
	0.12	860	28.5	1.0	24.6	29.7
23	0.00	855	28.7	0.7	26.2	30.2
	0.12	807	30.4	1.0	27.2	32.6
26	0.00	725	33.9	1.5	28.0	35.5
	0.12	767	32.0	0.9	28.0	33.6
35	0.00	874	28.1	2.0	22.4	30.6
	0.12	813	30.2	1.7	24.3	32.0
36	0.00	887	27.7	1.6	21.3	29.4
	0.12	839	29.3	1.9	23.7	31.1
38	0.00	800	30.7	2.6	23.0	33.5
	0.12	763	32.2	1.2	28.0	33.9
Overall	0.00	8414	29.0	2.5	21.3	35.5
	0.12	8057	30.5	2.0	23.5	33.9

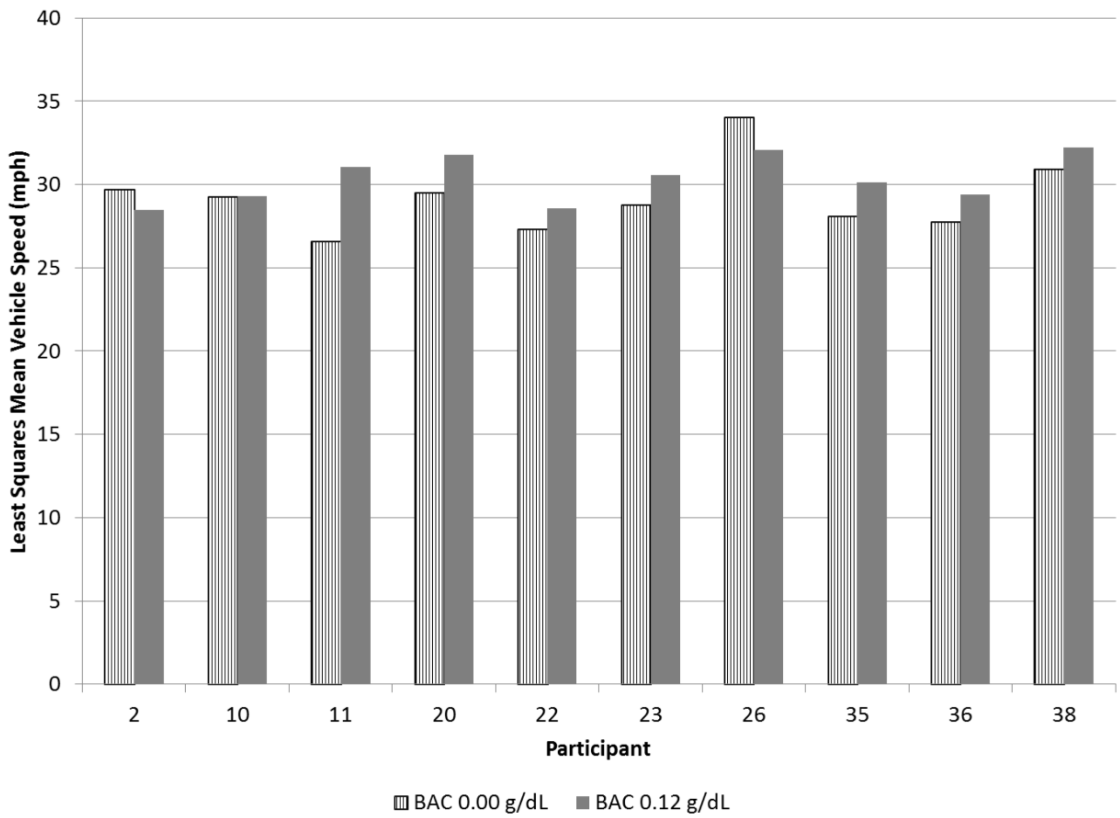


Figure 21. Mean Vehicle Speed by Participant and BAC Level.

SUMMARY AND CONCLUSIONS

For this project, TTI researchers used an existing dataset from a previous research effort to investigate the moth effect theory, where it is believed that drivers drift toward bright lights. Researchers also utilized the existing dataset to investigate how alcohol affects pupil size and vehicle speed.

Within 300 ft of the law enforcement vehicle, all of the participants initially steered the vehicle away from the vehicle. However, about 250 ft upstream of the vehicle all of the participants began to drift back toward the vehicle and continued to drift toward the vehicle for approximately 200 ft, moving laterally 8 to 24 inches. For the majority of the participants, at the end of the drift maneuver the vehicle was closer to the edgeline than before the participant began to steer the vehicle toward the centerline. This implies that these participants did not just steer the vehicle back toward the edgeline to correct for the initial drift toward the centerline. On average, participants drifted farther toward the law enforcement vehicle at a BAC level of 0.12 g/dL. However, the effect of BAC level on lane placement varied by participant. Nonetheless, all participants kept the study vehicle well within in the lane lines.

Researchers confirmed that when participants directly looked at the law enforcement vehicle their pupil diameter was statistically less than when they were not directly looking at the law enforcement vehicle. While the effect of BAC level on the pupil diameter was dependent upon the participant, the pupil diameter for the majority of participants was larger at a BAC level of

0.12 g/dL than at a BAC level of 0.00 g/dL. Participants at a BAC level of 0.12 g/dL also tended to look directly at the law enforcement vehicle less.

While researchers closely monitored the speeds of the participants, it was believed that the alcohol-impaired state might require more monitoring and have greater variability. Small differences in the vehicle speed between BAC levels (typically less than 2 mph) were seen; however, the differences were practically negligible. Typically, the participants at the 0.00 g/dL BAC level appeared to drive more conservatively.

Overall, the analysis documented herein was a small exploratory effort of a dataset from a larger research project whose primary focus was on signs. Nevertheless, the vehicle lane placement findings upstream of the law enforcement vehicle support the moth effect theory. In addition, the pupil diameter findings confirmed expectations regarding bright light sources and alcohol-impaired driving.

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