Studying the Tailgating Issues and Exploring Potential Treatment

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A human factors study consisting of a vehicle headway analysis and a questionnaire survey was conducted in Rhode Island (RI) to investigate tailgating issues and possible means for tailgating treatment. Vehicle headways were collected from highway surveillance videos and serious tailgating issues were identified on RI highways. The results of the questionnaire survey further confirmed the observations made in the vehicle headway analysis that most RI drivers maintained insufficient vehicle headways on highways. Among a few tailgating treatments presented in the survey, most subjects preferred a system consisting of equally spaced, white horizontal bars marked on pavement and overhead graphic-aided dynamic message signs.

INTRODUCTION

This paper presents a human factors study that investigated the tailgating issues and possible means for tailgating treatment. "Tailgating" is defined as following a vehicle with insufficient vehicle headway where vehicle headway is the time interval that the two consecutive vehicles passed the same reference point. Following with a vehicle headway less than two seconds is considered insufficient and unsafe (Hutchinson 2008). Tailgating is one of the most dangerous and aggressive driving behaviors, and is a major cause of rear-end crashes which resulted in 1.8 million incidents in the United States in 2006 (National Highway Traffic Safety Administration 2008). To help reduce crashes caused by tailgating, effective tailgating treatments need to be found to advise drivers about maintaining proper vehicle headways.

In this study, a vehicle headway analysis was first conducted to assess the tailgating situation on Rhode Island highways. It next surveyed drivers' opinions regarding the causes and effects of tailgating, their experiences and perceptions on tailgating behavior, and their preferences for possible tailgating treatments consisting of advisory signs and road markings. Findings from the vehicle headway analysis and the survey lead into the next phase of the project where a driving simulation experiment is developed to allow a real-time test on drivers' responses to different tailgating treatments. It is expected, upon completion of the project, that an effective tailgating treatment system would be recommended to Rhode Island and other states. The findings of this project might interest practitioners in this field and possibly contribute to the development of a standard tailgating treatment systems to be included in the Manual on Uniform Traffic Control Devices (MUTCD). Ultimately, it could help ease the tailgating issues and facilitate safer driving on U.S. highways.

BACKGROUND

Reviews of literature and past studies involving tailgating issues and tailgating treatments are provided below.

Tailgating Issues

Tailgating is generally considered a form of aggressive driving (Teigen 2007). The National Highway Traffic Safety Administration (NHTSA 2008) defines "aggressive driving" as "an individual committing a combination of moving traffic offenses so as to endanger other persons or property."

While many driving patterns are considered aggressive, tailgating is among the most dangerous ones and is a major cause of rear-end crashes.

Out of about 5.9 million police-reported automobile accidents in the United States during the year 2006, rear-end collisions ranked the highest, with more than 1.8 million cases (30.4%), and resulted in more than 2,100 fatalities and approximately 500,000 injuries (National Highway Traffic Safety Administration 2008). Data from athe Federal Highway Administration (FHWA) indicate that each year, approximately 2.2% of total licensed drivers in the United States are involved in rear-end crashes (Singh 2003). Two factors are primarily responsible for rear-end crashes: inattention and tailgating (Dingus et al. 1997), while the latter is the major contributing cause with a deadly consequence (Carter et al. 1995).

Some past researchers showed that a wide range of factors such as drivers' behavior, traffic condition, road condition, roadway design, state law and regulation, and even personality had effects on vehicle headway (Ayres et al. 2001; Aycin and Benekohal 1998; Brackstone and McDonald 1999; Hogema 1999; Brackstone 2003; Rajalin, Hassel, and Summala 1997). Based on these factors, various car following models were developed to describe the interaction between individual vehicles or the whole traffic dynamic. However, none of them compared these factors and identified factors that have major effects on vehicle headway.

While driving on highways, a driver's reaction time varies from 0.5 second for simple situations to 4 seconds for complex situations and the reaction time in braking is about 2.5 seconds (American Association of State Highway Officials [AASHO] 1973). Green (2000) and Summala (2000) reported that simple reaction time was often less than one second while decision reaction time could take much longer. According to this, quantified safe following distance has been written into rules of the road. It varies from state to state, but is mostly in the form of a "two-second rule." Drivers are advised to keep a vehicle headway of at least two seconds from the vehicle ahead driving in the same direction. Rear-end crash risk increases as vehicle headway decreases. When vehicle headway reduces to zero, a rear-end crash occurs.

Tailgating Treatments

Hutchinson (2008) conducted an in-depth investigation in Australia of rear-end crashes, tailgating, and the correlation between them. Calculations about how tailgating could lead to rear-end crashes were presented in his study and the results proved that a safe vehicle headway should be at least two seconds. Although he mentioned that inattention in various forms is a more frequent cause than tailgating as shown from some rear-end crash investigations, inattention could naturally lead to tailgating. Measures to counter tailgating such as advisory signs, pavement markings, and enforcement by the police could help reduce rear-end crashes and were recommended in his study.

Rama and Kulmala (2000) conducted a field study in Finland and investigated the effects of two variable message signs (VMS) on drivers' car-following behavior. The signs warned of slippery road conditions and to keep a minimum following distance. It was performed as a before-and-after experiment at three test sites. Results showed that the slippery road conditions sign reduced the mean speed by one-two km/hour in addition to the decrease caused by the adverse road conditions. The minimum following distance sign reduced the proportion of cars with following distance of less than 1.5 seconds, in addition to a speed reduction of one km/hour.

To help drivers gauge their following distances, research was conducted to assess the effects of regularly-spaced markings on highway pavement. Lertworawanich (2006, 2009) conducted a study to estimate safe car-following distance according to speed limit, and developed the "dot" treatment pavement markings. Headways in term of distance were examined before and after the implementation of "dot" markings. He found that headways were increased after the marking implementation at a given flow rate and the likelihood of rear-end collisions was reduced at the study site. Arrows spaced 131 feet apart, implying a gap of about three seconds at 60 miles per hour, were painted on a U.K. motorway in a study by Helliar-Symons, Webster, and Skinner (1995). They found that, because of the markings, crashes were reduced by 56% at the study site.

A few tailgating treatment programs were pilot-tested in several states such as Pennsylvania, Minnesota, and Maryland. PENNDOT's Tailgating Treatment Program (Safety Improvements) was considered the most successful and was honored in 2001 with the National Highway Safety Award. On a portion of US Route 11 that previously experienced high rates of tailgating, aggressive driving and tailgating has dropped a significant 60% after equipping with reflective dots on the roadway, pavement markings, and signs that help motorists gauge their distance behind moving vehicles (Roadway Safety Foundation 2001). Before the implementation, there were 135 crashes a year costing approximately $1.9 million. After the implementation, yearly crashes decreased to 60 at a reduced cost of $1.3 million. The cost of implementation in the first year is estimated at just over $11,000, including enforcement. After eight to nine months, statistics indicated that crash reductions remained fairly constant, pointing to the success of the program.

Given the successes, relatively low implementation cost, and the measurable benefits of the PENNDOT program, Minnesota DOT and Public Safety piloted a similar project in 2006. The project was viewed as a tool to educate motorists on how to identify and maintain a minimum safe following distance, and to ultimately reduce rear-end crashes. Minnesota used similar engineering elements from the Pennsylvania program: elliptical pavement dots, informational signs, and a strong public information campaign. A section of State Highway 55 in Wright County was painted with 94 elliptical dots, spaced 223 feet apart, along a two-mile single-lane segment of the rural roadway with a 55 mph speed limit. Vehicle headway data collected prior to and after the treatments showed that the average headway increased from 2.36 to 2.62 seconds, or 22.89 feet at the mid-point of the test site (Minnesota Department of Public Safety 2006).

Michael, Leeming, and Dwyer (2000) implemented a method to collect tailgating data in an urban setting and assessed the effectiveness of two hand-held roadside signs admonishing drivers not to tailgate. One was "Please Don't Tailgate" sign and the other "Help Prevent Crashes Please Don't Tailgate." Data collected from over 25,000 drivers were studied. They found that the latter had a significantly positive impact on drivers' tailgating behavior compared with the former sign, increasing the average headway by 0.18 seconds.

Advisory signs could be part of tailgating treatments to help mitigate tailgating behavior. However, improper use of advisory message signs could distract drivers and cause inattention leading to rear-end crashes. To reduce the risk of distracting drivers, the use of graphical images to convey the meaning on roadway signs has been employed in many European countries. It is found in many studies that graphically presented information allowed faster responses than information presented by words (Staplin, Lococo, and Sim 1990; Hanowski and Kantowitz 1997; Bruce, Boehm-Davis, and Mahach 2000). Wang et al. (2007) conducted a pioneer study on the use of graphics on the dynamic message sign (DMS), a 1024x270 full matrix tri-color LED overhead message sign that is capable of displaying pre-programmed text and graphic messages. They found that most drivers preferred graphics over text and responded faster to graphic-aided messages than text-only messages. Due to these findings, proper graphics need to be designed and integrated into advisory signs in the development of feasible tailgating treatment systems.

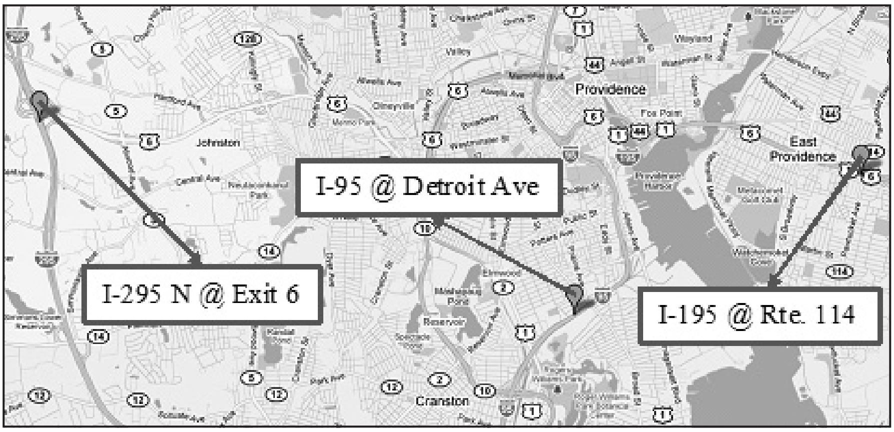
DESCRIPTION OF THE STUDY

Two approaches were employed in this study: a vehicle headway analysis to assess the tailgating situation on highways, and a questionnaire survey to find out the public's perceptions on tailgating and their preferences on possible treatments.

Vehicle Headway Analysis

In this approach, traffic at three test sites on I-95, I-195, and I-295 in Rhode Island were analyzed. The study examined highway traffic surveillance videos that captured eight-lane traffic taken by three highway surveillance cameras on I-95 at Detroit Ave, I-195 at Rte. 114, and I-295 North at Exit 6 (see Figure 1).

Figure 1: Locations of Highway Traffic Surveillance Cameras



Videos taken during both rush hour and non-rush hour on weekdays during a two-week period in December 2008 were provided by Rhode Island Department of Transportation (RIDOT). Videos taken on weekdays between 7:30 and 8:00 AM during rush hour and between 10:00 and 10:30 AM during non-rush hour were analyzed. Three 5-minute segments were randomly selected from each of the 30-minute video clips in the analysis. To determine the vehicle headway for a vehicle, a reference line was drawn in the recorded scene, and based on the time stamp (in 1/100 second) embedded in the video, the time when the front bumper of a vehicle reaching the reference line was recorded. By calculating the time difference that two consecutive vehicles crossed the reference line, vehicle headway in hundredths of a second was determined for the following vehicle. Traffic volumes were also collected by counting all the vehicles that appeared in the surveillance videos during the randomly chosen 5-minute time intervals. The traffic volumes confirmed the selection of the time periods for rush hour and non-rush hour traffic.

All vehicles analyzed were classified by their vehicle headways in increments of seconds. Percentages of vehicles that broke the two-second rule, which means their headways were between zero and two seconds, were calculated. These vehicles were noted as tailgators. To find out if time of the day was a significant factor affecting tailgating, a hypotheses test using a paired t-test was employed to compare the tailgating situations (percentages of tailgators) between rush hour period and non-rush hour period on three test sites. The hypotheses are:

$$H_0 : \mu_d = 0$$

$$H_1 : \mu_d > 0$$

where $\mu_d = \mu_{\text{rush hour}} - \mu_{\text{non-rush hour.}}$

These analyses were further stratified by lane and bound (all lanes in the same direction) since all three highway segments were eight-lane highways with traffic in opposite directions (I-295 South bound was not well captured by the highway surveillance camera, thus its data were missing in this study).

In addition, a correlation analysis was conducted to investigate the functional relationship between tailgating and traffic volume. The percentages of tailgators at the randomly chosen time intervals during both rush hour and non-rush hour were regressed against respective traffic volumes in these time intervals. Analyses were made on different lanes as well as on different test sites.

Questionnaire Survey

Following the vehicle headway analysis, a questionnaire survey was designed and deployed in two phases to help find the causes of tailgating and to identify drivers' preferences on a few proposed tailgating treatments. The first phase was designed to identify the causal factors of tailgating and to gain insights about drivers' experiences and perceptions regarding tailgating on Rhode Island highways. Various components of tailgating treatments were presented to drivers on the second phase to obtain drivers' preferences on potential tailgating treatment systems. Some components presented in the survey were adopted from existing tailgating treatments in the United States as well as those currently used in some European countries.

The questionnaire survey was designed using Microsoft PowerPoint® and Visual Basic macros to present the questions and to collect subjects' answers on laptop computers. Questions in the survey might require either a single or multiple answers. The first phase of the survey contained 19 questions designed to collect drivers' opinions on tailgating and to find out drivers' perceptions of tailgating and its causes and effects. It also surveyed drivers' behavior when they were following other vehicles or being followed. The second phase of the survey was designed to find drivers' preferences on components of a tailgating treatment system. These components include: reference marking (pavement marking, roadside marking) and advisory message sign (dynamic message sign, variable message sign, or fixed road sign). This phase was presented with both auditory and written instructions starting with information about the proper headway to maintain while driving on highways. Six questions were presented in the second phase. The first question surveyed a subject's preference on reference markings. Four simulated driving videos with different reference markings built in (painted dots, painted arrows, neon/hot-pink roadside panels, and painted bars, as shown in Figure 2) were presented in a random sequence. According to the subject's answer, the preferred marking would then be incorporated in subsequent questions. The second question showed several text messages on fixed signs that could be used in conjunction with the markings (Figure 3). The third question inquired a driver's preference regarding graphic-aided messages. The subject was asked to choose between the advisory sign with only the preferred text message and one integrated with graphics (Figure 4). Questions four and five were essentially the same as the second and the third but the road-side fixed signs were replaced with overhead dynamic message signs. The last question was designed to capture a subject's preference on the type of advisory sign to be used in conjunction with the selected reference marking. By completing the second phase of the survey, a preferred tailgating treatment system would be identified.

The two phases of the survey were conducted at multiple locations in Rhode Island in order to obtain a representative sample of the Rhode Island driving population. The University of Rhode Island and the Warwick Mall were among several sites where the survey took place. Subjects with a valid driver's license were randomly recruited at the survey sites with voluntary participation. Prior to beginning the survey, each participant read and gave their consent on an electronic consent form, approved by the university's Institutional Review Board. The subject would then start taking the survey presented as PowerPoint slides on a laptop computer. Survey questions were presented one at a time with no time limit.[1] Answers could be made via a computer mouse and keyboard or via verbal communication with the survey assistant.

Figure 2: Screenshots of Driving Simulation Videos in the Questionnaire

A total of 210 subjects participated in the first phase. Among them, 91 (43.3%) were between 18 and 40 years old, 72 (34.3%) were between 41 and 60, and 47 (22.4%) were older than 60; there were 107 females (51.0%) and 103 males (49.0%). A total of 142 subjects participated in the second phase. Among them, 76 were females (53.5%) and 66 were males (46.5%); 63 (44.4%) were between 18 and 40 years old, 45 (31.7%) between 41 and 61, and 34 (23.9%) were older than 61. Age and gender percentages of the survey resembled the Rhode Island population.

Figure 3: A Sample Survey Question

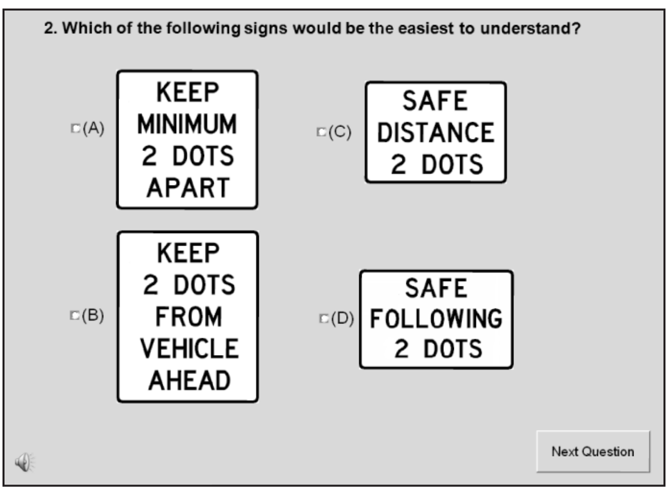
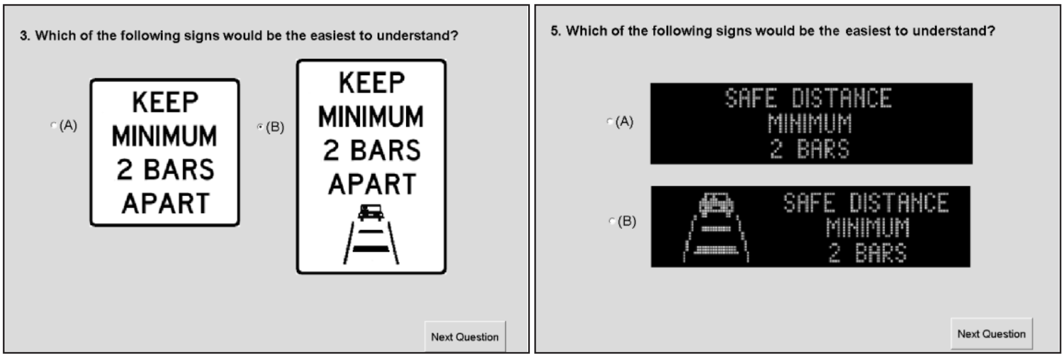


Figure 4: Text Signs and Graphic-aided Message Signs



RESULTS AND DISCUSSION

Vehicle Headway Analysis

The proportions of vehicles following with less than two seconds of vehicle headway, i.e., tailgators, on the three test sites on Rhode Island interstate highways were tabulated in Table 1. The statistics were shown by test sites, by day of the week, and by time of the day. From the analysis, 61.23% of vehicles were tailgating during rush hour and 39.21% during non-rush hour. Tailgating situations during rush hour and non-rush hour were compared through paired t-tests and were found to be significantly different (p values = 0) at all three locations. The rush-hour and non-rush hour tailgating percentages on different days of the week were not significantly different. Small variations in total tailgating percentage during each of these two periods were observed among different days of the week. This also held true within each site. The rush-hour tailgating percentage ranged from 62.24% to 70.96% on I-95, from 56.81% to 62.59% on I-195, and from 46.28% to 56.50% on I-295. The non-rush-hour percentage ranged from 40.62% to 45.24% on I-95, from 33.04% to 38.91% on I-195, and from 19.76% to 27.99% on I-295. The percentages on I-295 were lower than the other two sites since its traffic volume is much lower.

The distributions of vehicle headways for both rush hour and non-rush hour at the three test sites are shown in Figure 5. Vehicle headways collected ranged from less than one second to more than 30 seconds. It should be noted that large vehicle headways were not generally considered "following" and thus the distributions displayed here included only up to 10 seconds of vehicle headways. It is noticed that the majority drove with vehicle headways of less than two seconds during rush hour where more than half of that group were following with headways of less than one second. During non-rush hour, less tailgating behaviors were observed and most occurred in the one-second to two-second interval.

To further assess the tailgating situations, the percentages of the tailgators were classified by lane and bound and were tabulated in Table 2. It showed that vehicles in the high speed (innermost) lane exhibited the worst tailgating situation (highest tailgating percentage during rush hour) while the outermost lane had the lowest tailgating percentage (except the test site on I-295). This could be due to the fact that tailgating is correlated with speed, and vehicles travelling in high-speed lanes tend to follow the leading vehicles. Compared with their opposite bounds, higher percentages of tailgators were mostly observed on I-95 north bound and I-195 west bound, especially during rush hour. This might be due to the large vehicle volumes entering the Providence metropolitan area during rush hour as observed in surveillance videos (see traffic volume data in Table 2).

Table 1: Percentages of Tailgators

	Highway sections		I-95 @ Detroit Ave	I-195 @ Rte. 114	I-295 N @ Ex. 6	Total
Day of the week	Monday	RH*	70.96%	62.59%	54.58%	64.24%
		NRH*	45.24%	37.35%	25.50%	40.61%
	Tuesday	RH	66.54%	57.39%	56.50%	61.52%
		NRH	44.62%	34.46%	27.17%	39.79%
	Wednesday	RH	64.22%	60.92%	46.28%	58.85%
		NRH	41.58%	38.91%	27.99%	38.65%
	Thursday	RH	67.14%	56.81%	47.87%	63.84%
		NRH	43.71%	35.64%	19.76%	39.59%
	Friday	RH	62.24%	59.52%	53.09%	59.17%
		NRH	40.62%	33.04%	26.16%	37.02%
P value (α= 0.05)			0.000	0.000	0.000	
Total		RH	66.93%	60.50%	51.81%	61.23%
		NRH	45.52%	39.00%	25.31%	39.21%

*RH: Rush Hour, NRH: Non-rush Hour

It was noted that the tailgating situation was more serious during rush hour than non-rush hour due to the significant differences in their traffic volumes. A correlation between the percentage of tailgators and the traffic volume could exist. Therefore, linear regression analyses were next conducted to investigate the functional relationship between tailgating and traffic volume at all test sites. Figure 6 showed that strong correlations existed at all three test sites since their R^2 values were all greater than 0.85. It could be concluded that tailgating percentage increases as traffic volume increases among the three test sites. I-295 exhibited the most serious tailgating situation as it had the largest slope.

To assess the correlations by different lanes, separate regression analyses were conducted and the results are shown in Figure 7.

As seen from Figure 7, strong correlations existed between tailgating and traffic volume in all lanes (R^2 ranging from 73.7% to 84.3%). Although the innermost lane had the lowest slope among all four lanes, its large intercept value (about twice the value of any other lane) made it the lane with the most serious tailgating problem.

The vehicle headway analysis provided strong evidence that serious tailgating occurred on major highways in Rhode Island and posed severe traffic safety concerns for highway driving. This finding strongly supported the need of a tailgating treatment system on Rhode Island highways. Since the tailgating situation was worse in the innermost lane, especially during rush hour, it might be more effective to place tailgating treatments, including roadside markings and advisory signs, on the left side of the innermost lane to mitigate tailgating behavior.

Figure 5: Distributions of Vehicle Headways

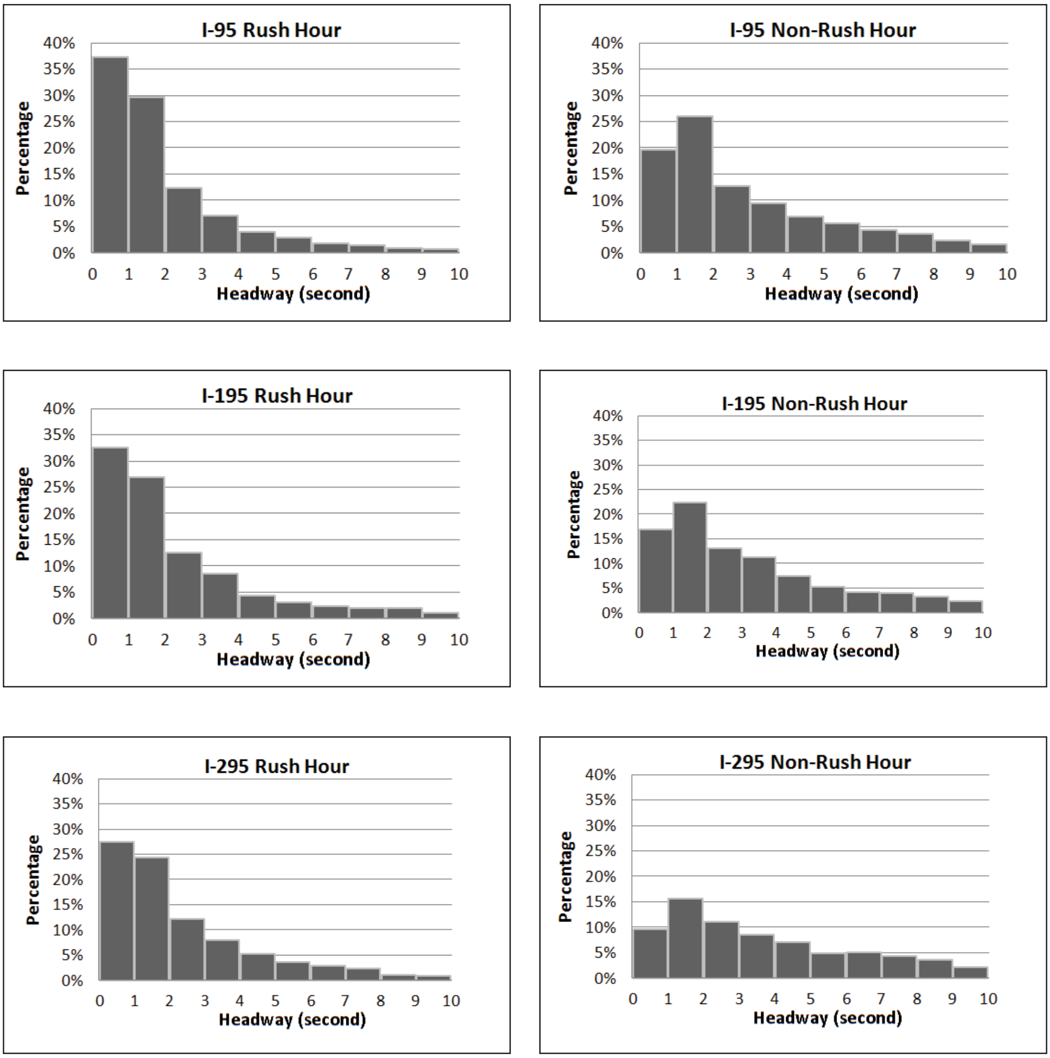


Table 2: Percentages of Tailgators and Traffic Volumes by Lane and Bound

Lane	Time of the day	Highway Test Sites									
		I-95 @ Detroit Ave				I-195 @ Rte. 114				I-295 N @ Ex. 6	
		North		South		West		East		North	
		Percentage	Volume*	Percentage	Volume	Percentage	Volume	Percentage	Volume	Percentage	Volume
Innermost lane	RH	79.62%	40.13	70.27%	28.40	72.38%	30.17	67.76%	18.57	70.27%	33.28
	NRH	47.46%	10.60	46.09%	13.26	43.14%	11.90	36.47%	8.50	31.21%	8.62
2nd Lane	RH	72.96%	42.40	63.76%	29.07	65.84%	32.10	59.49%	22.30	28.08%	12.79
	NRH	46.67%	19.47	47.06%	18.33	43.35%	16.53	36.97%	14.06	17.68%	8.73
3rd Lane	RH	68.28%	38.47	53.93%	24.60	55.36%	28.00	55.81%	20.37	16.12%	5.21
	NRH	54.43%	21.13	45.31%	16.67	33.59%	12.80	36.62%	14.20	21.67%	5.48
Outermost lane	RH	62.58%	33.13	41.35%	13.87	52.78%	22.17	36.58%	9.70	44.62%	17.35
	NRH	41.78%	23.00	33.93%	15.33	26.55%	9.67	17.37%	5.57	29.97%	7.64
Total	RH	71.29%	154.13	59.93%	95.94	62.41%	112.44	57.47%	70.94	51.81%	68.63
	NRH	47.48%	74.20	43.23%	63.59	37.65%	50.90	34.17%	42.33	25.31%	30.47

*Traffic volume was measured in vehicles per minute (vpm).

Figure 6: Correlation Plots Between Percentage of Tailgators (P) and Traffic Volume (V) at Three Test Sites

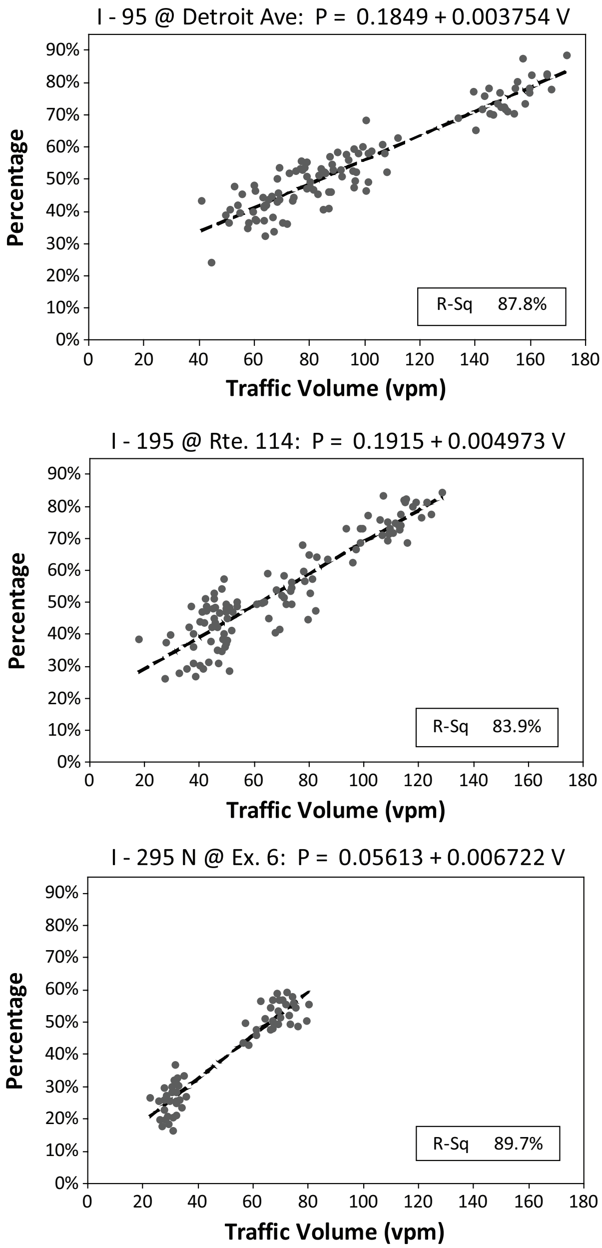
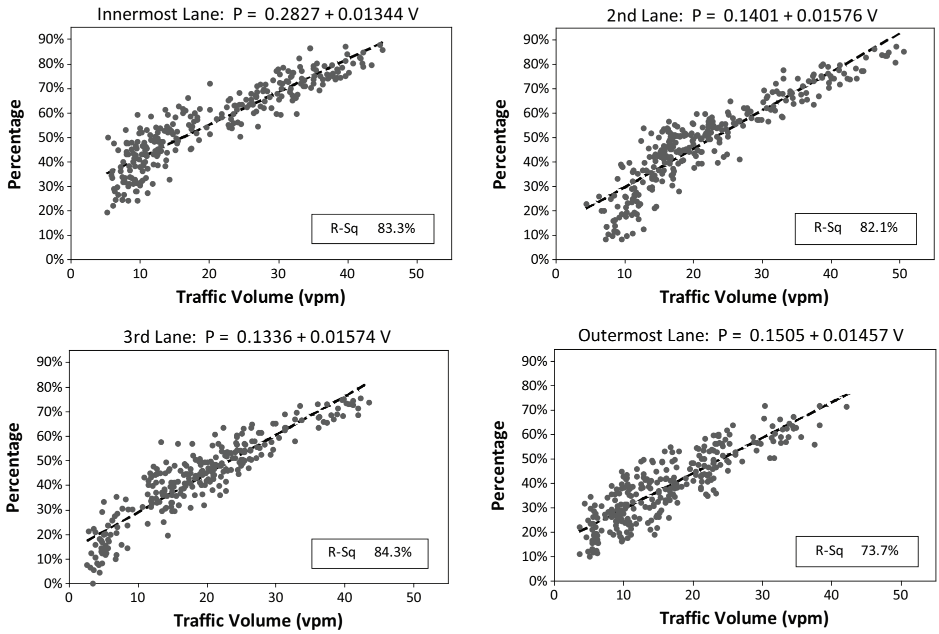


Figure 7: Correlation Plots Between Percentage of Tailgators (P) and Traffic Volume (V) in Four Different Lanes



Questionnaire Survey

With the tailgating problem confirmed on Rhode Island highways, drivers' understandings and perceptions of the tailgating issues and their preferences for components of a potential tailgating treatment system were next collected in the questionnaire. The participants were first asked in the survey to select and rank the top three causes of crashes among 13. According to the weighted scores (3 points for the first ranked, 2 points for second and so forth), the top three leading causes of crashes were distraction, speeding, and tailgating (Figure 8).

When subjects were asked about the possible reasons for following other vehicles, the majority (70.0%) indicated that they usually did not follow others; when asked if they intentionally followed other vehicles while driving on highways, 67.6% of subjects indicated that they never did; when asked about the reasons for not following other vehicles, 49.5% of subjects indicated that it's safer not following others (Table 3).[2]

When asked about the definition which best described tailgating, 76.2% of the subjects chose "following too close to the vehicle ahead" and only 11.4% chose "insufficient following distance." This indicated that most drivers had only a qualitative idea of what tailgating means instead of a quantitative one. "Heavy traffic," "slow car ahead of my vehicle," and "I am in a hurry" were among the top three choices of tailgating causes (Table 4).

Figure 8: Pareto Chart of Major Causes of Crashes

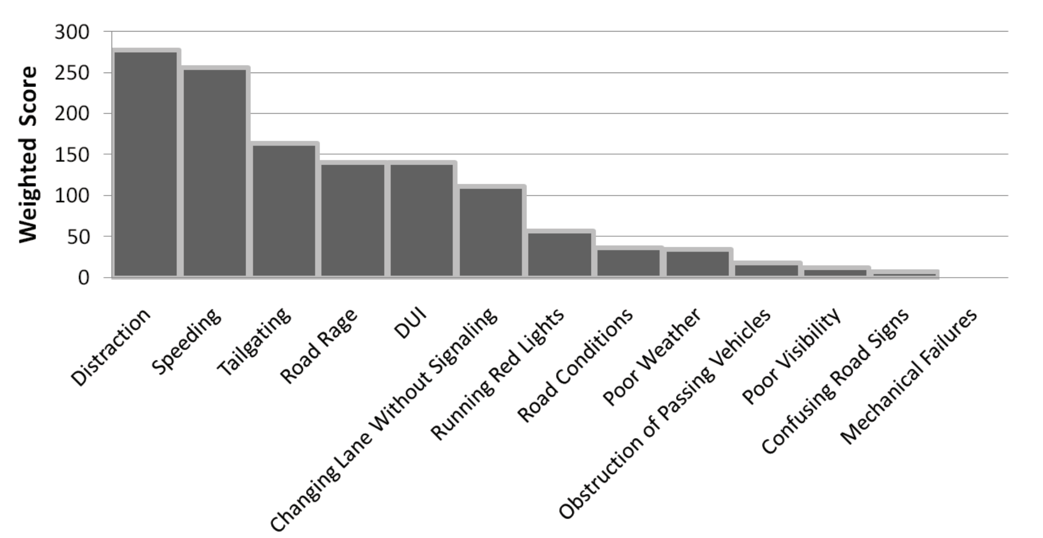


Table 3: Survey Questions Regarding Following Behavior on Highways

Why would you follow other vehicles while driving on highways?	It is easier to maintain speed.	13.8%
	It is safer.	1.4%
	It is less likely to get a speeding ticket.	14.8%
	I don't do that.	70.0%
Do you intentionally follow other vehicles while driving on highways?	Always.	0.0%
	Sometimes.	32.4%
	Never.	67.6%
Why would you not follow other vehicles while driving on highways?	It obstructs my view.	17.1%
	Others drive too slow.	3.4%
	It is safer.	49.5%
	It is against the law.	30.0%

Table 4: Applicable Causes of Tailgating (Multiple-choice)

Which of the following could cause you to tailgate while driving on highways? Mark all that apply.

Heavy traffic	Slow car ahead of my vehicle	In a hurry	Poor visibility	Distraction	Weather conditions	Hypermiling*
36.1%	20.7%	19.5%	5.8%	9.8%	7.1%	1.0%

* The act of driving using techniques that maximize fuel economy such as following a truck closely to reduce wind resistance.

When asked about their reactions when being tailgated, most indicated they were affected by tailgators, and most drivers affected by tailgators reacted passively (Table 5). The top choice was "change lanes to let the tailgator pass" (34.1%).

Table 5: Reactions When Being Tailgated (Multiple-choice)

How would you react if you were followed too closely? Mark all that apply.						
Change lanes to let the tailgater pass	Slow down to force the tailgater to get away	Speed up	Make a gesture at the tailgator	Ignore the tailgator	Tap the brake	Call the police
34.1%	17.2%	12.1%	4.9%	15.7%	12.5%	3.6%

When asked about safe vehicle headways, the majority of subjects (77.1%) indicated they knew what the proper vehicle headway was, 73.8% indicated that keeping a safe vehicle headway was very important, and 90.5% believed they always kept a safe vehicle headway or at least most of the time (Table 6). Along with the results shown in Table 3, it did not appear that serious tailgating problem existed on Rhode Island highways.

Table 6: Survey Questions Regarding Safe Vehicle Headway

Do you know the proper vehicle headway to maintain while driving on highways?			
Yes	77.1%	No	22.9%

How important is it for you to keep a safe vehicle headway while driving on highways?				
Very important	Important	Average	Slightly important	Not important
73.8%	17.6%	2.4%	6.2%	0.0%

Do you maintain a safe vehicle headway while driving?				
Always	Most of the time	Sometimes	Rarely	Never
35.7%	54.8%	8.6%	1.0%	0.0%

When questioned "how much distance do you maintain when driving at 60 mph on highways," 95% of subjects indicated they maintained a vehicle headway less than 11 car lengths, and almost half maintained less than four car lengths (Figure 9). These answers exposed a serious tailgating issue by showing that the majority of drivers who took the survey did not know what the proper vehicle headway was, and drove with insufficient following distance. When driving at 60 mph, a two-second vehicle headway requires a following distance of 11 car lengths (assuming a car length of 15 feet). Although 75.2% of subjects indicated in another question that they maintained a vehicle headway equal to or greater than three seconds, it is not likely they kept three seconds of headway, which is about 16 car lengths. Subjects' opinions on vehicle headway expressed in car lengths could be more reliable since 78.6% of them preferred using car lengths to measure vehicle headway. This finding from the survey, in fact, did not contradict but confirmed the serious tailgating situation identified in the vehicle headway analysis.

When asked about components in an effective tailgating treatment system, 63.8% of subjects preferred a combination of both advisory message signs and reference markings. A total of 37.3% of subjects selected the painted horizontal bars as pavement markings, followed by painted arrows and neon panels (Table 7). Some thought the roadside neon panels were distracting while others felt that the arrows might suggest drivers to speed up. Compared with other age groups, drivers over 60 preferred the painted arrows (32.3%) over painted bars (29.4%) although the difference was not significant. Female and male drivers did not show any difference in their answers.

Figure 9: Vehicle Headways Maintained by Drivers When Driving at 60 mph

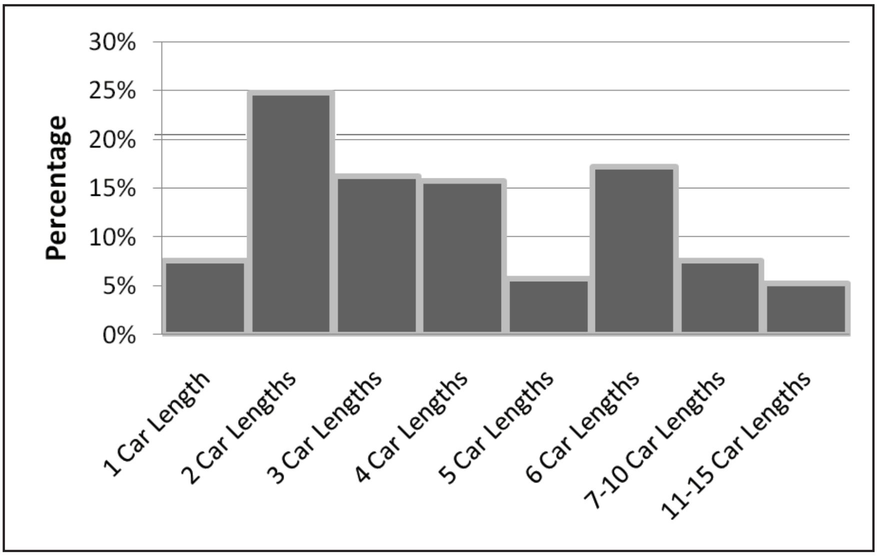


Table 7: Subjects' Preference on Reference Markings

Which of the following would be most effective in helping you maintain a proper following distance?	Painted dots	9.4%
	Painted arrows	33.2%
	Neon panels	20.1%
	Painted bars	37.3%

When asked which sign message would be the easiest to understand, most subjects (40.2%) chose the lengthiest-worded one (for example, "Keep 2 bars from vehicle ahead") over others. "Safe distance 2 bars" ranked second (Table 8). This might be due to the fact that subjects were in a static environment where they could take as much time as they want to read the messages, and in that case, more information in the message helped their understanding. Since lengthier messages could demand more drivers' attention in real driving, graphics could be used to help drivers better understand the message while demanding less attention. When graphics were added to text sign message, graphic-aided message signs were mostly preferred (86.6%) over text-only ones.

Table 8: Subjects' Preference on Messages (If Painted Bars Were Preferred)

Which of the following signs would be easiest to understand?	Keep Minimum 2 Bars Apart	21.8%
	Keep 2 Bars from Vehicle Ahead	40.2%
	Safe Distance 2 Bars	33.1%
	Safe Following 2 Bars	4.9%

When similar questions were asked with regard to overhead dynamic message signs, similar responses were obtained. Among responders, 45.1% preferred the sign with the lengthiest wording and 81.7% preferred it with graphics. When asked about which traffic sign drivers most likely would pay attention to while driving, subjects preferred the overhead dynamic message signs (46.7%) over the fixed road signs (29.6%) and the roadside variable message signs (23.9%).

The findings of the first phase survey showed that the majority of drivers considered tailgating a serious offense and one of the top three major causes of highway crashes. Most of them, however, had only a qualitative sense of what tailgating was about and did not know what the proper vehicle headway was while following other vehicles on highways. As most indicated in the survey, they did not maintain sufficient vehicle headways. This finding confirmed the observations made in the vehicle headway analysis. From the second phase of the survey, it was found that the majority preferred regularly-spaced horizontal bars painted on pavement as reference marking to help drivers gauge safe following distance. Coupled with the pavement marking, most of them preferred employing overhead graphic-aided dynamic message signs to communicate to drivers about safe following distance.

CONCLUSION AND FUTURE WORK

This study examined the tailgating issues in Rhode Island, identified causes and effects of tailgating, and surveyed drivers' preferences on possible tailgating treatments. Through the vehicle headway analysis, a serious tailgating situation (61.23% vehicles were tailgating) was identified during rush hour. Less tailgating was observed during non-rush hour but there were still 39.21% of vehicles following with insufficient headways. Tailgating percentages classified by lane and bound showed that tailgating was worse in the innermost lanes and on bounds with high traffic volume. Tailgating percentages were correlated with the traffic volumes in the correlation analysis, and the serious tailgating situation in innermost lanes was confirmed. The results of the vehicle headway analysis suggested a need for an effective tailgating treatment system in Rhode Island.

The findings of the survey indicated that the majority did not know what the proper vehicle headway was and maintained insufficient vehicle headways while following other vehicles on Rhode Island highways. This confirmed the observations made in the vehicle headway analysis. Among the proposed tailgating treatments, the majority preferred horizontal bars painted on pavement as a means to help maintain safe following distance, and overhead graphic-aided dynamic message signs as a way to advise drivers about safe following distance. Based on this study, it is concluded that a proper tailgating treatment system should be developed and implemented on Rhode Island highways. Survey results suggested horizontal bar pavement markings and overhead dynamic message signs displaying graphic-aided advisory messages.

The components of a tailgating treatment system surveyed will be further examined in a follow-up study where a driving simulation experiment will be designed and conducted. Results obtained from the driving simulation, coupled with the findings from the survey, will lead to the recommendation of an effective tailgating treatment system. Field studies will be conducted after the implementation of the recommended system. Before and after statistics would be collected and analyzed to assess the effectiveness of the system in mitigating tailgating behavior and reducing rear-end crashes. The findings could contribute to the development of a standard tailgating treatment system to be included in MUTCD and help facilitate more efficient and safer driving on U.S. highways.

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Endnotes

1. No time constraint was given since the questionnaire was designed to capture as much of the subjects' responses as possible at this stage.

2. The word "following" was used in the first few questions in the first phase of the survey to investigate drivers' general following behavior, including both tailgating and non-tailgating.

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