ASSESSING DRIVERS' TAILGATING BEHAVIOR AND THE EFFECT OF ADVISORY SIGNS IN MITIGATING TAILGATING

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Summary: A human factors study was carried out to assess drivers' tailgating behavior and the effect of advisory signs in mitigating tailgating. Tailgating is a dangerous driving behavior and a leading cause of most rear-end crashes. Through a prior study, serious tailgating was identified on urban Rhode Island highways. It is critical to many urban traffic management authorities to understand tailgating and to explore means to mitigate drivers' tailgating behavior, especially on urban highways with high-speed and high-volume traffic. Properly designed advisory signs could reduce tailgating and related motor crashes. To assess drivers' behavior with regards to tailgating, a questionnaire survey was developed and given to a number of subjects with daily highway driving experience. The survey is designed to identify causes of tailgating and drivers' perceptions and engagements on tailgating behavior. Drivers' driving behaviors were further assessed through driving simulation under different traffic conditions. To help mitigate tailgating behavior, advisory signs and an educational video were developed. The effectiveness of these proposed counter-tailgating measures was assessed in the driving simulation. Subjects' real driving behaviors were further studied in a follow-up field study. Study results found that the majority had an incorrect sense regarding safe following distance and were tailgating while driving on highways. Heavy traffic was identified as the top tailgating cause. The simulation results confirmed the tailgating phenomenon observed on urban Rhode Island highways. The proposed advisory signs were found effective in mitigating tailgating behavior.

INTRODUCTION

Tailgating, or following with insufficient vehicle headway, is a severe form of aggressive driving (Sarkar et al, 2000) and a leading cause of rear-end crashes (Carter et al, 1995). According to the National Center for Statistics and Analysis (NCSA, 2010), out of an annual average of 5.9 million police-reported automobile accidents in the US during 2006-2008, rear-end crashes ranked the highest, with more than 1.8 million cases (30.4%), and resulted in more than 2,200 fatalities and approximately one-half million injuries each year. 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). To assess the tailgating issue on urban Rhode Island highways, traffic surveillance videos collected at three sites within the Providence metropolitan area were analyzed in a prior study conducted by the authors (Song and Wang, 2010). According to driver's reaction time, a quantified safe following distance has been given in the form of a “2-second rule” that a driver is advised to keep a vehicle headway of at least two seconds between his or her own car and the vehicle ahead. Driving with a vehicle headway less than 2 seconds is thus considered "tailgating". The results of the study revealed a serious tailgating situation on urban Rhode Island highways where more than 60% of drivers were tailgating during rush hours and 40% during non-rush hours.

To reduce tailgating and associated crashes, counter-tailgating measures are needed to help drivers maintain proper vehicle headway. Counter-tailgating measures such as advisory signs, pavement markings, and enforcement by the police were recommended in Hutchinson's study (2008) to help reduce rear-end crashes. Rama and Kulmala (2000) investigated the effects of two dynamic message signs (DMS) on driver's car-following behavior. Results showed that a sign about slippery road conditions reduced the mean speed by 1-2 km/hour in addition to the decrease caused by the adverse road conditions. Another sign about minimum following distance reduced the proportion of cars with a headway of less than 1.5 seconds by more than 30%, in addition to a speed reduction of 1 km/h. Michael et al. (2000) collected tailgating data in an urban setting from over 25,000 drivers and assessed the effectiveness of two hand-held roadside signs admonishing drivers not to tailgate. The research found that the sign with a reference to crashes had a greater impact on drivers, increasing the average headway by 0.18 seconds, when compared to the other one.

To help drivers gauge their following distances, the effects of regularly-spaced markings on highway pavement were assessed. Helliar-Symons, Webster and Skinner (1995) studied pavement chevrons on a U.K. motorway. The markings were implemented with signs advising drivers to keep 2-second vehicle headways. The results were encouraging with a large reduction (56%) in crashes at the study site. Tailgating treatment programs employing the "dot" markings were pilot-tested in Pennsylvania and Minnesota. PENNDOT's program 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 dropped 60% after the implementation of reflective dots and advisory signs that help motorists gauge their distance behind leading vehicles (Roadway Safety Foundation, 2001). A similar project was piloted in Minnesota in 2006 to educate motorists on how to maintain a minimum safe following distance and to ultimately reduce rear-end crashes. Similar engineering elements to the Pennsylvania program were used. Headway data collected prior to and after the treatments showed that the average headway increased by 0.26 seconds, or 22.89 feet (Minnesota DOT, 2008).

Studies above demonstrated the effectiveness of advisory signs and pavement markings in reducing tailgating. Although measurable benefits of the treatments were identified, there were reported complaints about the pavement markings as they might distract drivers. Compared to pavement markings, advisory signs are less intrusive and distractive to drivers and are easier to implement and maintain. Given these advantages, a few advisory signs were proposed in this study and their effects in mitigating tailgating were assessed through a driving simulation.

DESCRIPTION OF THE STUDY

A questionnaire survey was employed to collect drivers' perceptions regarding tailgating and to assess their driving behavior. A driving simulation study was developed to assess drivers' real-time driving behavior and their responses to proposed counter-tailgating.

Assessing Drivers' Perception and Behavior regarding Tailgating

A nineteen-question questionnaire was designed to identify the causal factors of tailgating (Song and Wang, 2010). Through participants' responses, it expected to gain insights about drivers' experiences and perceptions regarding tailgating on urban highways and their attitudes toward tailgating when they were either actively or passively involved. The survey was presented as PowerPoint slides on a laptop computer. Subjects made their answers via mouse and keyboard or via verbal responses given to the research assistant. A total of 210 subjects participated in the survey. Age and gender percentages of the survey resembled the Rhode Island population.

Subjects who took the survey were invited to participate in a driving simulation experiment in the Driver Performance Lab at the University of Rhode Island. A fixed-base driving simulator (L-3Com, Inc.) consisting of a regular vehicle module and three 42-inch plasma monitors with 1024 x 768 image resolution was used in the simulation. Five networked computers generate the simulation by processing the driver's inputs to the vehicle's controls while perpetually updating the audio stream and the driving scene on four visual channels. Three of the channels display the drivers' forward view of 180° and one supports the LCD front panel. Subjects interacted with the simulator using the steering wheel and pedals that provided force feedback. Through an 8-minute highway driving scenario with a speed limit of 65 mph, the simulation first assessed participants' baseline driving behavior in its 1st trial. Subjects were asked to drive as he or she does in real life.

Assessing the Effect of Advisory Signs as Counter-Tailgating Measures

Counter-Tailgating Measures. Among several alternatives, two advisory messages were selected to be tested through driving simulation, one was "Keep Minimum 2 Seconds Apart" and the other was "Keep a Safe Following Distance". The first message, similar to those of the Minnesota tailgating project, used the words "2 Seconds" to alert drivers about the 2-second vehicle headway. Rather than the quantitative advice given in the first message, the second message used a qualitative advice. A subject would go through the highway driving scenario again with the advisory message posted on either a static roadside sign or an overhead DMS at the beginning of the scenario. The subjects were further asked to repeat the driving simulation experiment after viewing an 1-minute educational video to help them better guage their vehicle headways. With both auditory and visual instructions, the video instructed the subjects to use a roadside reference point, such as a sign or a marking pole, to gauge the vehicle headway, and to slow down if headway was less than 2 seconds. The effect of the educational video was assessed through vehicle headway measurements taken in this run of the driving simulation.

Design of Experiment. The driving simulation experiment was developed and designed to investigate two types of factors: main factors and blocking factors as shown in Table 1.

Table 1. Driving simulation experiment factors and levels

	Factors	Levels
Main Factors	Advisory Sign	No Sign, With Sign
	Educational Video	No Video, With Video
	Advisory Message	"Keep Minimum 2 Seconds Apart", "Keep a Safe Following Distance"
	Type of Sign	Static Roadside Sign, Overhead DMS
Blocking Factors	Traffic	Light, Heavy

Each subject participated in the driving simulation experiment took three trials. Table 2 depicts the setting of theses three trials. This experiment design would allow a pairwise comparison among different trials to assess the effects of the advisory signs and the educational video. Traffic condition was introduced as a blocking factor. In each trial, a subject could start driving with heavy traffic which changed halfway to light traffic and vice versa by random assignment.

Table 2. Use of advisory signs and an educational video in the three trials

Trial	1st Trial	2nd Trial	3rd Trial
Advisory sign present	No	Yes	Yes
Watch educational video before the trial	No	No	Yes

To assess the design of advisory signs including advisory message and type of sign, subjects were randomly divided into four equal-sized groups where different advisory signs were evaluated. The four groups were shown in Table 3.

Table 3. The four experiment groups

Group	Advisory sign evaluated
1	"Keep a Safe Following Distance" on a static roadside sign
2	"Keep Minimum 2 Seconds Apart" on a static roadside sign
3	"Keep a Safe Following Distance" on a DMS
4	"Keep Minimum 2 Seconds Apart" on a DMS

Analysis of Experiment. About 1 minute into the scenario, there is a fixed sign zone where advisory signs were presented (empty zone for the 1st trial). A subject's driving behavior was recorded from this point until the completion of the simulation. In each trial, 8 vehicle headway measurements were taken at random points (4 per traffic condition), and a total of 24 headway data points were collected for each subject. Analysis of variance (ANOVA) was conducted to investigate the effect of the main and blocking factors on vehicle headways. The effect of the advisory signs was assessed by comparing vehicle headways collected between the 1st and the 2nd trials. Headways from the 2nd trial were used to assess the effect of advisory message and the type of sign and the interaction between them. The effectiveness of the educational video were examined by comparing vehicle headways collected between the 2nd and the 3rd trials. Traffic condition was assessed as a blocking factor in each ANOVA. A significant level of 0.05 was used in all cases.

Field Study. Twelve subjects who participated in the driving simulation experiment partook a follow-up field study. It allowed a comparison to be made between participants' driving behavior in the simulation and in real driving . In the 10-minute field study, each subject drove his or her own vehicle accompanied by a research assistant. All subjects took the same route by entering I-95 South from Exit 15 in Rhode Island and leaving at Exit 12. Then they returned to I-95 North through the reverse order back to their starting point. They were advised to stay in the inner lanes while driving on the highway to avoid traffic entering and exiting the highway and to maintain a 2-second vehicle headway following the instructions given in the educational video. The whole driving process was recorded from the driver's view. Eight headways were randomly collected from the video of each subject, four on each bound.

RESULTS AND DISCUSSIONS

Assessing Drivers' Perception and Behavior regarding Tailgating

In the questionnaire, subjects' understandings and perceptions of tailgating issue were surveyed. Distraction, speeding, and tailgating were considered as the top three leading causes of crashes, followed by road rage, DUI, changing lane without signaling, running red lights, etc. "Heavy traffic", "slow car ahead of my vehicle", and "I am in a hurry" were the top three causes for tailgating. The majority (84.3%) indicated that they were affected by tailgaters but reacted passively as indicated by their top choices "change lanes to let the tailgater pass" (34.1%).

Most subjects (70.0%) indicated that they did not usually follow others while driving on highways and 73.8% agreed that keeping safe vehicle headway was very important. The majority (77.1%) thought that they knew what the proper vehicle headway was and kept a safe headway most of the time (90.5%). From these results, it did not appear that a serious tailgating problem existed. When asked how much distance they maintain when driving at 60 mph on highways, 94.8% of subjects indicated that they maintained less than 11 car lengths, and almost half maintained less than 4 car lengths. A 2-second headway requires a distance of 11 car lengths at 60 mph (assuming a car length of 15 feet), therefore a severe tailgating issue was revealed as most drivers were probably tailgating without knowing they were doing so. Subjects' opinions were reliable since 78.6% of them preferred using car length over time to gauge headway.

The findings found from the survey indicated that the majority of Rhode Island drivers had an incorrect sense regarding safe vehicle headway and were following other vehicles too closely on highways (Song & Wang, 2010). Through the baseline test (1st phase) of the driving simulation, it found that the average vehicle headway kept by subjects was 1.02 seconds, half of the safe following distance. Figure 1 shows vehicle headway distributions in different traffic conditions. It shows that almost all subjects participated in driving simulation were tailgating. Heavy traffic caused subjects to further decrease their vehicle headways. Both the survey and the simulation confirmed the serious tailgating on urban Rhode Island highways identified in the prior study.

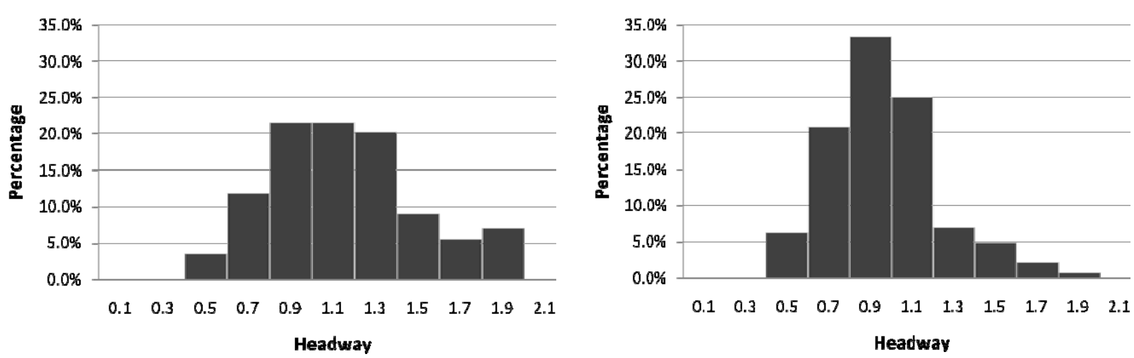

Figure 1. Distributions of the collected vehicle headways in light traffic (left) and in heavy traffic (right) from the baseline test of driving simulation

Assessing the Effect of Advisory Signs as Counter-Tailgating Measures

A total of 36 licensed drivers participated in the simulation study. None of them had previous experience with a driving simulator. Vehicle headway statistics are shown in Table 4.

Table 4. Vehicle headway statistics (in seconds) by group and trial

Group	1st Phase		2nd Phase		3rd Phase	
	Mean	Std	Mean	Std	Mean	Std
1	1.06	0.33	1.15	0.45	2.05	0.27
2	0.92	0.48	1.11	0.53	1.99	0.34
3	1.00	0.31	1.29	0.41	2.18	0.40
4	1.08	0.43	1.40	0.50	2.07	0.31
Total	1.02	0.42	1.24	0.48	2.07	0.35

The effect of the presence of the advisory signs was assessed through ANOVA on the 1st phase (w/o advisory signs) and the 2nd phase (with advisory signs) data. The results showed that the presence of the advisory sign was a significant factor (p = 0.000) as the average headway increased from 1.02 seconds in the 1st phase to 1.24 seconds in the 2nd phase. Traffic condition was also significant (p = 0.000). Average headway was 1.22 seconds in light traffic and 1.04 seconds when traffic was heavy indicating that subjects tended to follow closely in heavy traffic.

The effects of the advisory message, type of sign and the interaction between them were assessed through ANOVA on the 2nd phase results. The type of sign affected subjects' vehicle headway in a significant way with a p-value equal to 0.000, while the advisory message was not a significant factor (p = 0.440) and neither was their interaction (p = 0.090). Compared to static signs, advisory messages posted on overhead DMSs were found to be more effective in increasing vehicle headway (0.21 seconds more). The advisory message "Keep a Safe Following Distance" or "Keep Minimum 2 Seconds Apart" did not make a noticeable difference in vehicle headways.

Subjects participated in the 3rd phase were shown an educational video prior to the driving simulation to educate them how to gauge their following distance per the 2-second rule. Compared to the results obtained from the 2nd phase, the vehicle headway was significantly increased (p = 0.000) in the 3rd phase by 0.84 seconds. Subjects were able to maintain a safe following distance after viewing the educational video. Traffic condition still affected vehicle headway in a significant way (p = 0.000). Average headway was 1.75 seconds in light traffic and 1.56 seconds when traffic was heavy, still considered tailgating though.

Twelve subjects partook the field study conducted mostly during the non-rush hours (between 10 AM and 4 PM.) Through a frame-by-frame analysis on the recorded videos, it found that the average vehicle headway was 1.83 seconds. Despite the subject's efforts to maintain a 2-second vehicle headway, it was observed that other drivers often cut in and thus reduced headways. The findings indicated that maintaining a safe following distance in real driving was difficult without an effective tailgating treatment system in place. The advisory sign proposed in this study could be a good candidate to be included in a more sophisticated tailgating treatment system.

CONCLUSIONS

A human factors study was carried out to assess drivers' tailgating behavior and responses to various counter-tailgating measures. Both the survey and the simulation study identified serious tailgating issue and indicated a need for counter-tailgating measures on urban highways. The use of advisory signs and an educational video as counter-tailgating measures to advise drivers to maintain a safe following distance was studied via driving simulation. The findings provided promising evidence that tailgating could be mitigated by employing the proposed counter-tailgating measures. Most subjects were able to maintain a 2-second vehicle headway in the simulation after viewing the educational video. It was, however, difficult for them to do so in real driving. It is recommended that a more sophisticated tailgating treatment system containing the proposed advisory signs be considered for urban Rhode Island highways. The effect of the system could be augmented with education. It is hoped that this study could help lead the way in developing effective tailgating treatment systems for US urban highways and encourage more research in this area.

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REFERENCES

Carter, C., May, A.J., Smith, F.J., & Fairclough, S.H. (1995). An evaluation of an in-vehicle headway feedback system. In S.A. Robertson (Ed.), *Contemporary Ergonomics*, 287-292. London: Taylor and Francis.

Dingus, T.A., McGehee, D.V., Manakkal, N., Jahns, S.K., Carney, C, & Hankey, J.M. (1997). Human factors field evaluation of automotive headway maintenance/collision warning devices. *Human Factor*, *39*(2), 216-229.

Helliar-Symons, R., Webster, P., & Skinner, A. (1995). The M1 chevron trial. *Traffic Engineering and Control*, *36*(10), 563-567.

Hutchinson, P.T. (2008). *Tailgating*. Safety Centre for Automotive Safety Research, University of Adelaide, Australia, Research Report # CASR046.

Michael, P., Leeming, F., & Dwyer, W. (2000). Headway on urban streets: observational data and an intervention to decrease tailgating. *Transportation Research F*, *3*(2), 55-64.

Minnesota DOT. (2006). Minnesota Tailgating Pilot Project, Report and Summary, http://www.dot.state.mn.us/trafficeng/tailgating/index.html. Accessed March 5, 2008.

National Center for Statistics and Analysis. (2010). *Estimate of motor vehicle traffic crashes by year, manner of collision and crash severity, GES 2006-2008*. CATS 2010.00454.

National Center for Statistics and Analysis. (2010). *Fatal motor vehicle traffic crashes by year and manner of collision, FARS 2006-2008*. CATS 2010.00454.

Rama, P. & Kulmala, R. (2000). Effects of variable message signs for slippery road conditions on driving speed and headways. *Transportation Research F*, *3*(2), 85-94.

Roadway Safety Foundation. (2001). Saving lives: RSF recognizes nine outstanding highway safety projects. Road Safety Reporter.

Sarkar, S., Martineau, A., Emami, M., Khatib, M., & Wallace, K. (2000). Aggressive driving and road rage behaviors on freeways in San Diego, California: spatial and temporal analyses of observed and reported variations. *Transportation Research Record*, 1724, 7-13.

Song, M., & Wang, J.H. (2010). Studying the tailgating issue in Rhode Island and its treatment. *Proceedings of the 51st Annual Transportation Research Forum*, Arlington, Virginia, 55-71.