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Effects of Nontraditional Messages in Dynamic Message Signs on Improving Safety, Compliance, and Avoiding Distraction

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16. Abstract
This project develops capability for future studies on the effects of nontraditional messages in dynamic message signs on improving driver safety and compliance and avoiding distractions. An online survey and a driving simulation game were designed, and a pilot run was conducted with a small number of students in the University of Illinois Urbana Champaign. Survey responses and simulation data were analyzed to reveal preliminary findings on notable effectiveness across different types of messages (e.g., humorous, emotionless, negative). The pilot study also provides guidelines and recommendations for running a large-scale survey and simulation game in the future.

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- Sean Martschinke, TRP Chair, Illinois Department of Transportation
- Alan Ho, Federal Highway Administration
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- Rochelle Gillespie, Illinois Department of Transportation
- Lisa Heaven-Baum, Illinois Department of Transportation
- Tracy Lillard, Illinois Department of Transportation

EXECUTIVE SUMMARY

This project focused on guidelines for using nontraditional messages in dynamic message signs to improve driver safety and compliance and to avoid distractions. The purpose of this project was to help Illinois Department of Transportation (IDOT) determine if nonstandard messages (i) cause a change in driver behavior and reduce crash frequency in the area of the signage in Illinois, (ii) increase engagement of the motoring public with safer driving practices, and (iii) have a lasting impact on drivers who see the messages (i.e., does the message stick).

This pilot project included three main tasks. First, the researchers conducted a literature review to investigate past studies on how drivers change behaviors upon seeing different types of dynamic messages and to learn from similar projects that experiment on the effect of drivers' behavior change caused by dynamic message signs. Second, they developed a web-based questionnaire and simulation game to capture drivers' opinions and behaviors toward dynamic messages in a semi-realistic environment. The web-based questionnaire collected drivers' demographic and socioeconomic information as well as their understanding, impression, and acceptance of nonstandard messages. The web-based simulation game provided participants with either an urban or a rural freeway driving environment to test their reactions to dynamic messages in an ongoing traffic stream. Third, the researchers conducted a preliminary proof-of-concept data analysis to demonstrate effectiveness of nontraditional messages and to develop a better understanding of how dynamic messages influence driver behaviors. The findings were used to provide suggestions on how IDOT may systematically present information on dynamic message signs in practice.

Some of the key findings are listed below.

- The literature review revealed that different nontraditional messages may have mixed impacts on encouraging safe driving practices.
    - Nontraditional messages were more memorable than traditional messages and helped drivers comply with speed limits.
    - In certain cases, nontraditional messages may have also distracted drivers and resulted in queues in traffic, and they could cause risks and hazards by inducing varying speeds.
- The proposed online survey and driving game seemed to be able to protect the privacy of respondents and were sufficiently robust and ready for larger scale adoption.
    - The driving game could simulate a rather realistic and complex environment. The configuration could be changed easily to test the influence of specific factors (e.g., lighting conditions, traffic congestion, road geometry, speed limits, and weather conditions).
    - Any type of nontraditional messages could be easily loaded and tested in the driving game.

- The driving game recorded real-time data trajectories that could be used for more sophisticated analysis (e.g., data mining, deep learning) than traditional questionnaire surveys.

- Our preliminary analysis of collected data from a small-scale survey showed the following:
  - Humorous messages should be avoided in encouraging drivers to decrease speed.
  - Emotionless messages were effective in discouraging drivers to speed.
  - Humorous messages were effective in encouraging drivers to reduce text messaging and calling when the driving speed is around 60–90 mph.
  - Humorous messages should be avoided in encouraging drivers to reduce honking when the driving speed is around 60–90 mph.
  - Negative (warning) messages were effective in encouraging drivers to buckle up when the driving speed is lower than 60 mph.

Additional statistical tests with alternative grouping of the messages (humorous vs. negative) also generate largely consistent findings. This study laid the foundation for a large-scale survey/game and comprehensive synthesis of collected data, which we expect to be carried out by IDOT in the coming months. The preliminary literature review and results of the driver survey/experiment provided preliminary recommendations for IDOT on the most effective messages for Illinois. The results suggested that proper types of nontraditional messages (especially negative and humorous ones) could be effective in causing changes in driver behavior and increasing safety compliance.

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CHAPTER 1: BACKGROUND

Dynamic message signs have been used for decades to inform drivers about roadway, traffic, or weather conditions (Shroeder & Demetsky, 2010). Most of the messages used in the past were standard and impersonal reminders. Recently, transportation agencies across the country, including Illinois Department of Transportation (IDOT), have started to use nontraditional messages (rhyming, serious, funny, cultural) for display on dynamic signs. In Illinois, such messages mainly address the following safety issues: (i) distracted driving (texting, talking on the phone, using apps, eating); (ii) impaired driving (alcohol, drugs, sleepiness); (iii) occupant restraint (seat belts—both front and back are required by law, child safety seats); (iv) vulnerable road users (motorcyclists, bicyclists, pedestrians); and (v) work zone safety. Examples of such messages include "OMG. Are you texting? I can't even" and "Slow Down in Work Zones, Give 'em a Brake." IDOT even promoted a Dynamic Message Sign Contest in 2018 that encouraged drivers to submit new clever messages that hopefully can be more effective in making roadways safer (Francis, 2018).

These nontraditional messages are expected to have higher effectiveness in modifying driver behavior, as they can catch drivers' attention and provoke an emotional response. Various empirical studies have shown strong evidence through surveys, mainly based on driver recollection and reflection, that these messages tend to be more memorable, personal, and more likely to change behavior (Boyle et al., 2014; Rodier et al., 2010; Schroeder et al., 2016). Quantitative studies that measured field driver speed in the proximity of a nontraditional message (Haghani et al., 2013; Harder & Bloomfield, 2008), however, found conflicting results on the effectiveness of even the same signs—suggesting that some messages could be more effective than others, while certain messages could be counterproductive (e.g., being distractive) as well. A recent research project at Virginia DOT (Shealy et al., 2020) offered empirical evidence about the effectiveness of a wide range of nonstandard messages that target a variety of driver behaviors. Empirical experiments with 300 drivers from Virginia and 80 selected messages (grouped by their target behavior, emotion, and theme) were conducted. Participants were measured in two ways: (i) answering survey questions on their perception of the messages, identifying the intent of the messages, and recalling the impacts and (ii) observing and recording drivers' neurocognitive response when they read the messages. This study found that Virginia drivers perceived all types of nontraditional safety messages as effective, particularly those about distracted driving and seat belt use as well as those provoking a negative emotion or citing statistics. Yet, it is not clear whether the Virginia findings would also apply to Illinois drivers.

This project aims to help IDOT determine if nonstandard messages (i) cause a change in driver behavior and reduce crash frequency in the area of the signage in Illinois, (ii) increase engagement of the motoring public with safer driving practices, and (iii) have a lasting impact on drivers who see them (i.e., does the message stick). This project includes a synthesis of current applicable research and a survey of Illinois drivers. The literature research summarizes the most current and methodologically sound practice that can be found in published documents. The driver surveys and online simulation game are developed and carried out with a small group of the targeted demographic population (university students) to quantify directly the effect and impact of these messages on Illinois drivers. The results illustrate what type of message (emotionless, negative,

humorous) changes driver behavior for increased compliance and decreased crash activity. This project also generates findings that will serve as guidance on when and where different kinds of messages may be most effective, providing a long-term benefit to IDOT and partner agencies.

The remainder of this report is organized as follows. Chapter 2 reviews the literature on the effect of dynamic message signs, empirical study, simulation-based study, and similar practices. Chapter 3 demonstrates the survey and game design. Chapter 4 summarizes collected data from a pilot survey. Chapter 5 conducts a preliminary analysis on messages with three types of emotions. Chapter 6 concludes and makes recommendations on nontraditional messages.

CHAPTER 2: LITERATURE REVIEW

Per guidance of the Technical Review Panel, a literature review and synthesis were conducted to summarize the current state of practice of using nonstandard messages in Illinois and peer states. It also documented findings on safety implications of these messages in the literature. The review primarily includes, but is not limited to, the following items. The first item is a comprehensive list of all nonstandard messages used in Illinois and peer states to date and a categorical clustering analysis to group them based on target behavior, theme, and emotion style. The second item is extensive literature research on empirical studies that observed effectiveness and relationships between the use of nonstandard messages and the changes in driver behavior and crash occurrence.

A school of empirical studies have been conducted on what and why dynamic messages are more memorable, personal, and more likely to change drivers' behaviors. Boyle et al. (2014), for example, investigated how effective dynamic message signs can modify driver or travel behavior. They conducted a survey for collecting responses toward message effectiveness in urban areas of four cities (Chicago, Houston, Orlando, Philadelphia) and concluded that most respondents had a good understanding of used dynamic message signs. Instead of urban areas, Schroeder et al. (2016) focused on how dynamic message signs affect driver awareness, understanding, and behavior changes in rural areas (four corridors in Nevada, Kansas, Missouri, and Minnesota/Wisconsin). Their study proposed that dynamic message signs were able to act as a useful and effective tool for safety and public service campaigns.

Some of the related literature has been focused on using simulation or semi-realistic environments to test drivers' reactions to dynamic message signs. Huang et al. (2013) investigated the effect of drivers' compliance to dynamic message signs through building a highway driving simulator. They focused on four driver demographics (age, gender, percentage of rural driving, and driving behavior questionnaire score) and constructed a regression model to estimate drivers' compliance speed. They found a dynamic message sign can reduce driving speed by 11%. Strawderman et al. (2013) focused on how the placement of a work-zone warning sign can affect driver speed compliance. They also used a driving simulator with 12 driving conditions (three work-zone placement distances × four warning sign designs) to test participants' speed change and speed compliance. A video-based simulation was also conducted to evaluate various dynamic message signs' impact on highway traffic (Song et al., 2016). Instead of discussing dynamic message signs' effectiveness, they suggested that the presence of dynamic message signs might cause drivers to decelerate on highways and pose safety hazards. A related questionnaire was used to ask participants for causes and risks associated with speeding up when drivers are approaching dynamic message signs.

Some research studies measured the effectiveness of dynamic message signs in more realistic settings. Haghani et al. (2013) investigated dynamic message signs' impacts on traffic conditions by installing probe-based sensors and Bluetooth sensors in Maryland. Schroeder et al. (2010) tested dynamic message signs' functionality in traffic diversion on I-95 and found that non-traffic-related messages could be a distraction to drivers and result in unintended queues. Recently, researchers in Virginia (Shealy et al., 2020) used neurocognition with brain scans to help capture changes to drivers' attention when they are presented with different dynamic messages. They applied functional near-

infrared spectroscopy instruments to collect drivers' neurocognitive responses and provide physical evidence of the effectiveness of dynamic messages. They also conducted comparative statistical analysis to study the effectiveness of different types of dynamic messages.

In summary, both positive and negative aspects of using dynamic message signs, and various types of nontraditional messages, were reported. In particular, there were a few researchers who mentioned how drivers' real-time reactions were affected by dynamic message signs, which has a significant impact on the messages' effectiveness. Nevertheless, most of the previous studies on dynamic messages focused on varying a few specific parameters, such as traffic and speed, instead of systematically analyzing a wider spectrum of environmental, operational, and human behavioral factors. In this study, therefore, we develop a new online simulation game and a questionnaire to collect drivers' real-time reactions to the presence of nontraditional dynamic messages under a wider variety of conditions, so that preliminary statistical analysis can be conducted to investigate positive and negative effects of dynamic message signs.

CHAPTER 3: SURVEY/GAME DESIGN

The survey includes two parts: an online simulation game with dynamic message signs and an online questionnaire. The simulation game is intended to collect participants' real-time reactions to different types of dynamic message signs in a semi-realistic environment. The questionnaire collects demographic and socioeconomic information of participants as well as their understanding, impression, and acceptance toward different types of dynamic messages. Moreover, after simulation, the online questionnaire collects participants' recollection and feedback of messages.

ONLINE GAME DESIGN

The purpose of the online simulation is to (i) develop an online semi-realistic driving environment, (ii) create an interface between drivers' behavior and keyboard input, (iii) generate different types of dynamic messages and random distractions, and (iv) collect and save real-time data, including control actions and vehicle movements.

The online simulation is developed by Unity Engine (version 2021.3.25f1, https://unity.com), which is a popular game development engine used to create a 3D simulation environment and provide convenient downloadable packages. Through Unity Engine, 3D models including vehicles, road segments, and dynamic message signs can be loaded conveniently onto a server to construct a semi-realistic immersive virtual environment. Moreover, participants' mouse and keyboard control as well as background AI-generated traffic can be coded and embedded in the simulation game.

To host the simulation online, Itch.io (https://itch.io) is selected as the server platform. Its advantages include providing highly customizable web pages and allowing participants to access the simulation game directly without any verification or login process. It also generates a URL for easy distribution. An online website TinyURL (https://tinyurl.com/app) is used to shorten the original URL to a memorable one for wider distribution.

To gather, process, and record data on the participants' controls, status, and reactions in the simulation game, PythonAnywhere (https://www.pythonanywhere.com) is used as a middleware. It is an online server provider that hosts servers coded in Python. Then, all processed data are sent to Amazon S3 cloud storage (https://aws.amazon.com/s3), where data are duplicated as backup and are stored for future retrieval.

Basic GUI Design

Each participant experiences three stages in the simulation: login, tutorial, and driving. Participants start the online simulation game via a URL. They see a login interface, as shown in Figure 1. Participants need to enter an arbitrary ID so the anonymous data collected from the game can be related to the questionnaire responses. They also need to select an area setting (rural vs urban) for the game. This page also explains the basic computer system requirements or recommendations (such as turning on the computer audio for driving noises). Participants are reminded to drive at least 3 miles in the game to qualify to win a gift card.

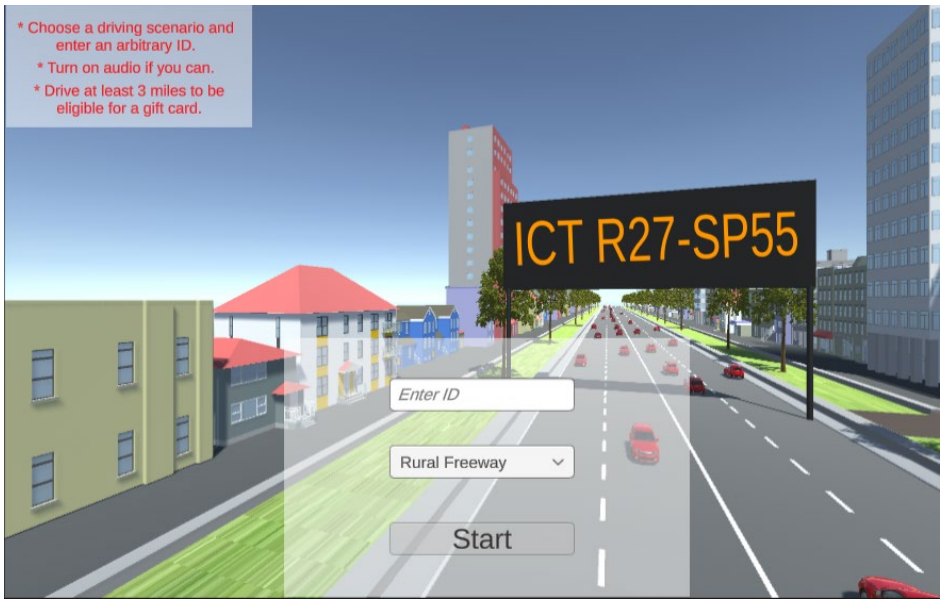


Figure 1. Screenshot. The login page of the simulation game.

Once a participant starts the game, he or she will be seated inside a vehicle on a four-lane freeway in either a rural or an urban setting (two lanes in each direction). The graphical user interface shows the vehicles and roadway geometry in 3D visualization, with clear indications of actual driving conditions (e.g., speed limit and surrounding vehicles). As one will experience in a real vehicle, participants will be able to observe the front and the rear of the vehicle through the front window, left-side mirror, and rear-view mirror. The default speed limit is 60 mph, and participants may speed up to 120 mph. Background traffic is generated automatically by AI based on a certain flow rate of our choice.

A quick tutorial introduces the basic game controls (keyboard definitions) first. Participants can either read the tutorial one by one or skip it to begin the simulation game directly. A button on the upper-left corner of the screen ("click here for help") will provide instructions in case of need. Participants can use the computer keyboard to accelerate, decelerate, honk at other AI vehicles (to force them to switch lanes), buckle/unbuckle their seat belt, and change lanes.

There is no fixed end to the game. Participants can end the game at any time by selecting the "click here to end the game" button on the upper center of the screen. After participants push that button, they will be directed to a survey questionnaire. (Further details are discussed in the Questionnaire section.) Data from the simulation game will save automatically and go to *PythonAnywhere* middleware and cloud storage as soon as the game ends. Figure 2-a and Figure 2-b show what a participant sees during the tutorial and driving stages, respectively.

Dynamic messages are shown in orange text on a black digital board outside the vehicle. The font size is larger than the font on signs in reality for clearer visibility. Figure 3 presents a sample board. These message signs are generated every 0.5 miles, and the content in the sign is drawn automatically from preset choices, as discussed in the Dynamic Messages section. There are 815 dynamic message signs uniformly generated in the simulation.

(a) Tutorial interface

(b) Driving interface

Figure 2. Screenshot. Basic GUI design for the online simulation game.

Figure 3. Screenshot. Nontraditional messages shown on a dynamic message sign.

Participants also see a simple front panel that displays real-time driving status, including the current speed, total distance traveled, seat belt use status, and crash status. The speed will display in white if it is at or under the speed limit. It will turn red and blink three times if the participant is over the speed limit. The same occurs for the seat belt status. The panel will display a red unbuckled logo if the participant is not buckled up. Participants are unbuckled by default (at the beginning of the game), and this is intended to test their seat belt use habit. Last, whenever a participant hits another car in the simulation game, a crash logo will cover the whole panel and last for three seconds. Figure 4-a, Figure 4-b, and Figure 4-c compare panels with and without these alarms.

(a) No alarm

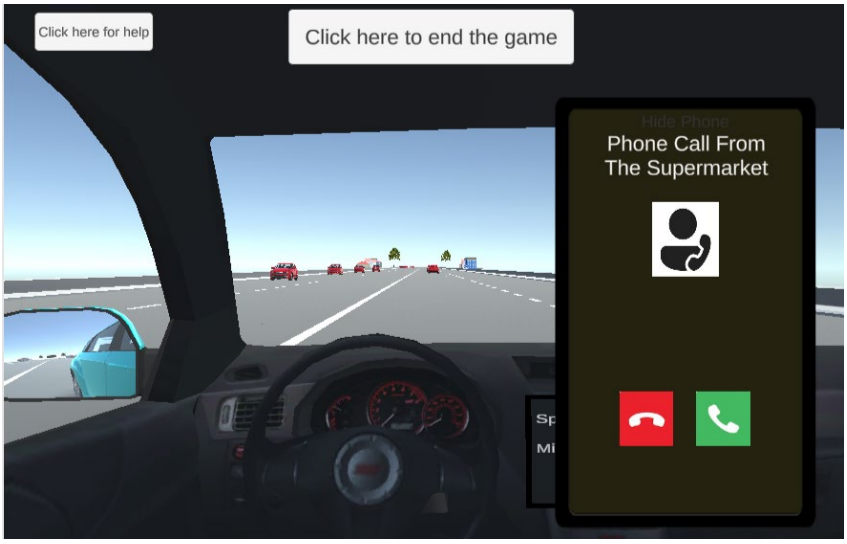
(b) Speed alarm

(c) Crash alarm

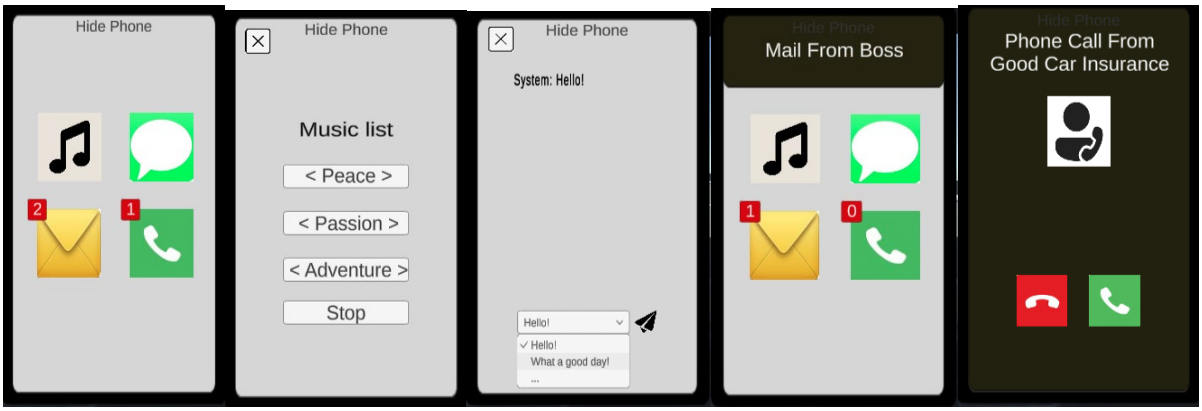
Figure 4. Screenshot. Panels with and without alarms in the online simulation game.

Additionally, the simulation provides a simple phone interface, which allows participants to play music, check emails/text messages, and answer calls. Participants can either show or hide the phone interface at any time while driving. When the phone interface is activated, as shown in Figure 5-a, the driver's vision is partially blocked, mimicking real-world eyesight distractions. Figure 5-b shows five possible phone interfaces at different stages of use. The first interface displays four possible application icons, which indicates that the phone is not in active use. Users can access different functionalities: music (upper left), texting (upper right), text messages (lower left), and phone calls (lower right). If the participant clicks on the music icon, he or she can further choose one of three types of music genres. If the participant clicks on the text messaging, email, or call icon, a corresponding dialog box will pop up. In the simulation game, emails and phone call events are automatically generated approximately every 40 and 80 seconds, respectively, to distract participants

and observe their behavior while distracted. Participants will hear alert sounds from the phone when such an event occurs but can either ignore or respond to the pop-up messages or phone calls. Phone call alerts automatically end after 10 seconds if participants do not interact with the phone interface.



(a) Activated phone interface



(b) Five possible interfaces for accessing music, texting, email, and phone calls

Figure 5. Screenshot. Phone interfaces in the simulation game.

Dynamic Messages

The main purpose of this game is to check which type(s) of dynamic messages are effective in changing driver behavior for increased compliance and decreased crash activity. As such, over 80 nontraditional messages are gathered and sorted into 15 categories based on the literature review (Shealy et al., 2020). Each nontraditional message is categorized by target behavior and emotion. There are five target behaviors (general safe driving, driving without a seat belt, distracted driving, impaired and drowsy driving, and general aggressive driving) and three emotions (emotionless, humorous, and negative). Table 1 lists the different types of nontraditional dynamic messages, their relative frequency of use in the simulation games, and some representative examples. Appendix A presents the complete list of messages used in the game.

Table 1. Nontraditional Messages Grouped by Target Behavior and Emotion

Index	Behavior	Emotion	Frequency of use (%)	Representative example
1	General safe driving	Emotionless	7.12	DRIVING SAFELY? I LIKE IT I LOVE IT
2	General safe driving	Humorous	4.66	SANTA'S COMING HAVE YOU BEEN A GOOD DRIVER?
3	General safe driving	Negative	6.01	757 FATALITIES SONS, DAUGHTERS STOP THE HEARTACHE
4	Driving without a seat belt	Emotionless	5.52	SEE YOUR BFF TONIGHT BUCKLE UP
5	Driving without a seat belt	Humorous	6.99	DUCK, DUCK, BUCKLE UP
6	Driving without a seat belt	Negative	6.87	72 WERE UNBUCKLED
7	Distracted driving	Emotionless	5.64	PLAY BALL! STRIKE THE DISTRACTIONS
8	Distracted driving	Humorous	11.53	AVOID AN APPSIDENT PHONES DOWN
9	Distracted driving	Negative	7.12	NO TEXT IS WORTH A LIFE
10	Impaired and drowsy driving	Emotionless	5.64	BE ALERT ARRIVE UNHURT

Index	Behavior	Emotion	Frequency of use (%)	Representative example
11	Impaired and drowsy driving	Humorous	6.38	DON'T BE TRICKED DUIS ARE NO TREAT
12	Impaired and drowsy driving	Negative	7.12	BLOWING .08 IS LIKE BLOWING $10,000
13	General aggressive driving	Emotionless	6.38	SPEEDING IS UNSPORTSMANLIKE CONDUCT
14	General aggressive driving	Humorous	4.91	IT'S OK TO BE A SLOW POKE
15	General aggressive driving	Negative	8.10	DO NOT TELL A LIE OBEY THE LIMIT

QUESTIONNAIRE

The purpose of the online questionnaire is to (i) investigate drivers' demographic and socioeconomic information, (ii) collect their opinion toward nontraditional dynamic messages, and (iii) accurately capture the effectiveness of dynamic messages on impacting drivers' behaviors. A total of 23 questions are presented to each participant via Google Forms. Among the 23 questions, one asks for the ID used in the online simulation (to establish connection while remaining anonymous), four are related to participants' opinions toward nontraditional messages, eight are related to their demographic and socioeconomic background, and 10 are related to their perception of driving experience and acceptable driving behaviors. Neither personal information nor any forms of identification were collected from the respondents. All questions and their corresponding intentions are listed in Table 2.

Table 2. Online Questionnaire Questions and Corresponding Categories

Question #	Question	Intention
1	Please enter the same ID you used in the driving game.	Logistics
2	Among all the messages you saw today, which one(s) were the most memorable and why?	Message Opinions
3	Do you think that any of the messages today were inappropriate? If yes, which ones?	Message Opinions
4	Which type of behavior do you think those message(s) were intended to address (select all that apply)?	Message Opinions
5	Given the following list of driving behavior, rank the importance of changing the behavior: not wearing seat belts, speeding, texting and driving, drinking and driving, and drowsy driving. (1=lowest, 5=highest)	Message Opinions
6	What is your gender?	Demographic
7	What is your marital status?	Demographic
8	Which college are you in?	Demographic
9	Which of the following best describes your academic status?	Demographic
10	What type of area do you live in?	Socioeconomic
11	On which type of roads do you drive the most?	Socioeconomic
12	Do you own a car?	Socioeconomic
13	Have you been involved in accidents during the past 5 years?	Socioeconomic
14	How often do you listen to music or radio during driving?	Driving Behaviors
15	How often do you send text messages during driving?	Driving Behaviors
16	How often do you call others during driving?	Driving Behaviors
17	How often do you honk at others during driving?	Driving Behaviors
18	How often do you buckle up during driving?	Driving Behaviors

Question #	Question	Intention
19	How often do you change lanes frequently during driving?	Driving Behaviors
20	How often do you overtake if trapped behind a slow-moving vehicle?	Driving Behaviors
21	If the speed limit is 25 mph, how fast do you consider as an acceptable speed?	Driving Behaviors
22	If the speed limit is 55 mph, how fast do you consider as an acceptable speed?	Driving Behaviors
23	If the speed limit is 70 mph, how fast do you consider as an acceptable speed?	Driving Behaviors

CHAPTER 4: PILOT SURVEY RESULTS

A small-scale deployment of the game/survey was conducted on February 16–26, 2024. Both physical and electronic flyers were distributed to 350 graduate students and 400 undergraduate students in the Department of Civil and Environmental Engineering at the University of Illinois Urbana-Champaign. A total of 118 responses were received by February 26, 2024, among which 80 finished at least 3 miles of driving in the online simulation game, and 66 of them also completed the online questionnaire. The remainder of this chapter summarizes the collected data.

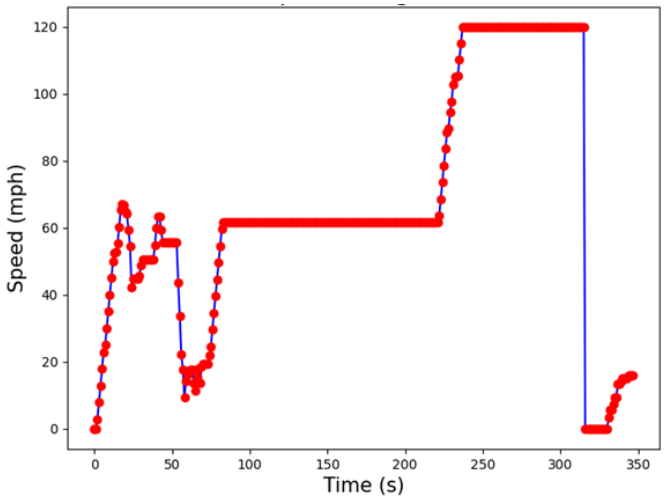
ONLINE SIMULATION GAME RESULTS

The online simulation tracks each participant's keyboard control records and the corresponding vehicle movements every second and saves them for later statistical analysis. Recorded real-time control data include, but are not limited to, (i) speed and location profiles; (ii) crash records, (iii) participants' seat belt status, (iv) participants' reactions to phone messages and/or phone calls, (v) participants' lane changing controls, and (vi) participants' honk actions. Table 3 and Figure 6-a to Figure 6-f show an example of real-time recorded data from the same participant in the simulation game. Table 3 lists all nontraditional messages seen by the participant as well as the corresponding times at which they passed those signs. For example, at the 159th second, the participant saw the message "DESIGNATED DRIVERS MAKE THE BEST NEW YEAR'S DATES," which reminded the participant to drive safely. Figure 6-a shows a participant's driving speed record every second. This participant obeyed the speed limit for the first half of the journey, while accelerating from 60 mph to the maximum speed of 120 mph at about the 250th second. Figure 6-b shows the participant's bird-eye-view driving trajectory, where the x- and y-axis represent the longitudinal and lateral locations with respect to the starting point. It also directly captures the participant's lane changing actions. The figure shows that this participant frequently changed lanes initially within the first mile, but then drove stably in the remaining 3.2 miles of travel. Figure 6-c records the participant's reaction to incoming phone calls. Every time a text message pops up or a phone call comes (with audio and visual prompts), a participant's behavior toward these distractions is represented by his or her interactions with the phone interface. This participant received phone calls at seconds 80, 160, 240, and 320, but only picked up those at the 160th and 320th seconds. Figure 6-d and Figure 6-e show whether the participant hit other cars or honked at other cars while driving, which is an important indicator of aggressiveness. In both diagrams, honking and two crashes happened around the 320th and 330th seconds. Recall that these crash times overlap with active phone usage near the 320th second, while the vehicle is traveling at 120 mph, which indicates strong safety hazards imposed by phone use at high speeds. Figure 6-f shows the participant's seat belt buckled/unbuckled status while driving. The participant started to buckle up only at the 260th second, soon after he or she saw two messages related to seat belt usage: "60% OF TEEN ROAD DEATHS IN VIRGINIA ARE UNBUCKLED" and "PROTECT YOURSELF BUCKLE UP," which were displayed to him or her at the 235th and 249th seconds. This observation indicates that dynamic messages do seem to have notable impacts on drivers' behavior on seat belt use.

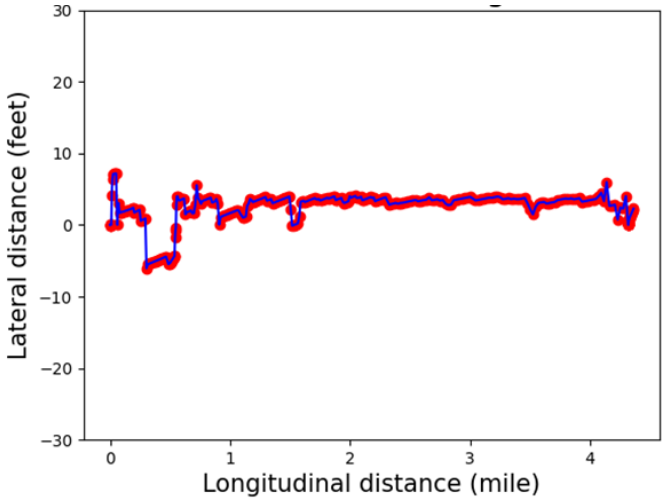
Table 3. Sample Record of Shown Nontraditional Messages from One Simulation Game

Index	Time (sec)	Nontraditional messages
0	16th	BE ON SANTA'S NICE LIST DRIVE POLITELY
1	77th	YOU HAD ME AT I DON'T TEXT AND DRIVE!
2	105th	DESIGNATED DRIVERS MAKE THE BEST NEW YEAR'S DATES
3	132nd	60% OF TEEN ROAD DEATHS IN VIRGINIA ARE UNBUCKLED
4	159th	9 OF 17 FATALITIES UNBUCKLED THIS YEAR
5	186th	MOM NEEDS YOUR HUG NOT YOUR TEXT
6	214th	MOM NEEDS YOUR HUG NOT YOUR TEXT
7	235th	60% OF TEEN ROAD DEATHS IN VIRGINIA ARE UNBUCKLED
8	249th	PROTECT YOURSELF BUCKLE UP
9	263rd	EDDIE SAYS DON'T TEXT & DRIVE THE TWITTERS FULL
10	277th	LIFE IS A HIGHWAY DRIVE SAFELY ALL DAY LONG

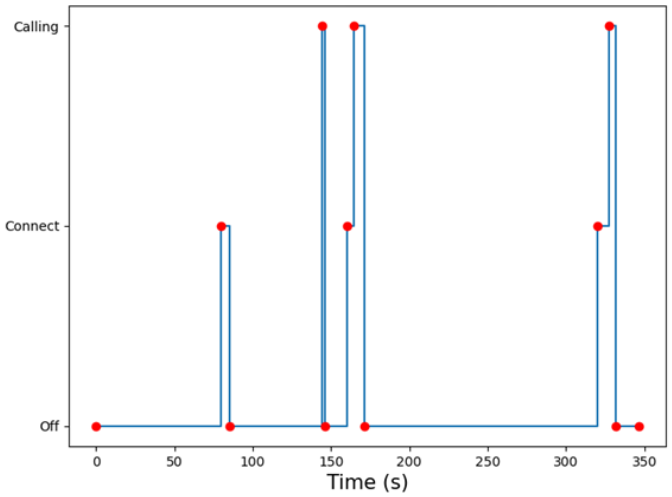
Index	Time (sec)	Nontraditional messages
11	291st	TEXTING & DRIVING IS CLEVER SAID NO ONE EVER
12	305th	TEXTING WHILE DRIVING? OH CELL NO.



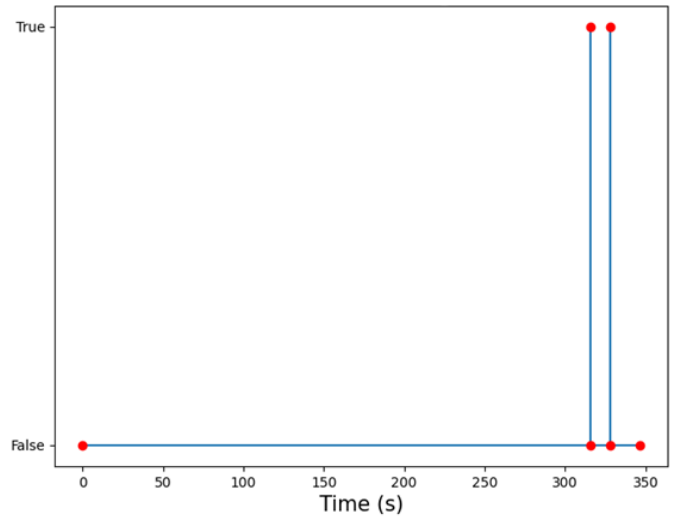
(a) Speed profile



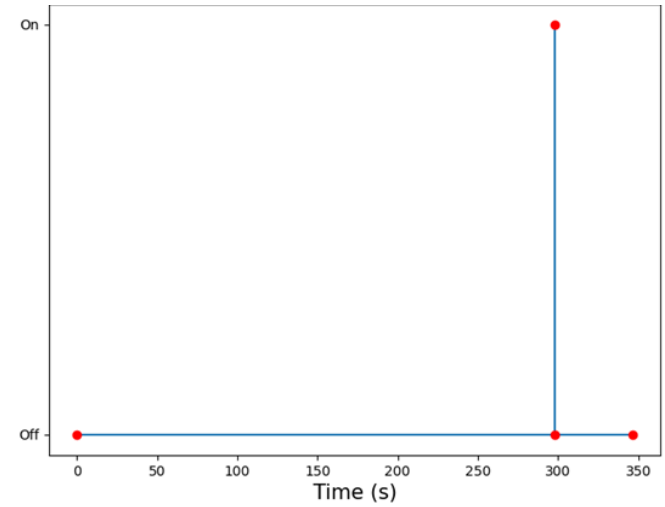
(b) Vehicle lateral location



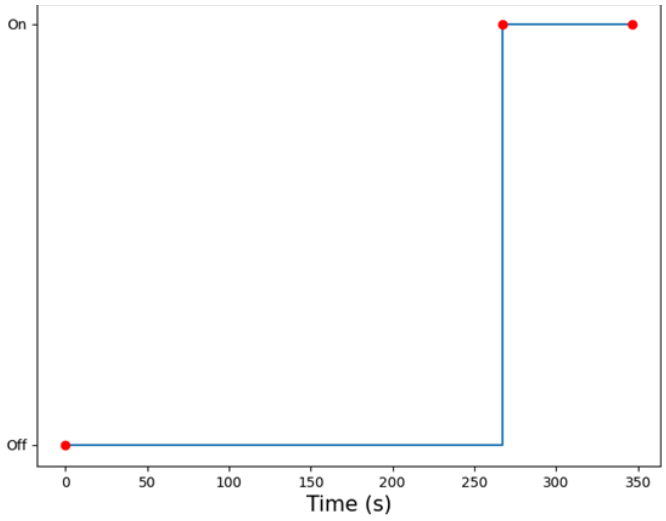
(c) Phone use status



(d) Crash status



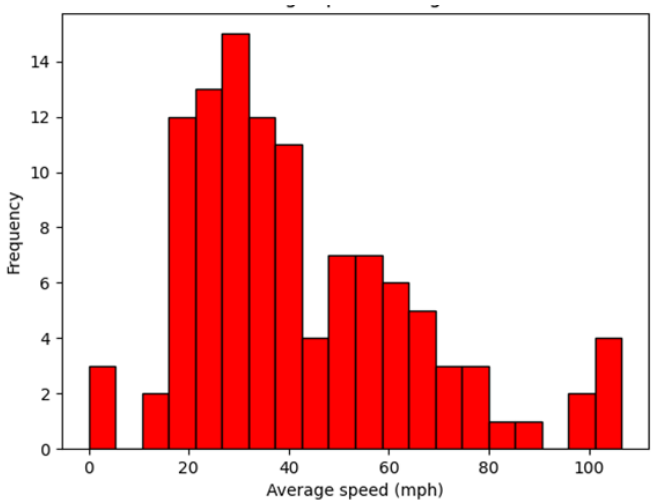
(e) Honk actions



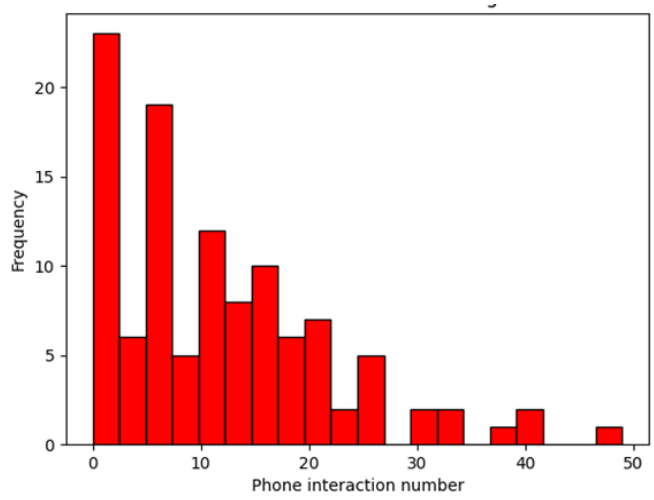
(f) Seat belt use status

Figure 6. Graph. Sample data records from the same participant.

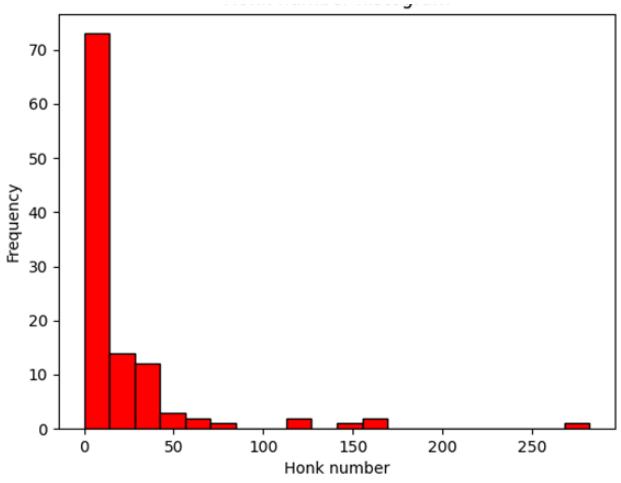
All participants' simulation data are sent to online cloud storage. In this way, an individual participant's data can be organized by attributes and merged with dynamic message data to enable statistical behavior analysis. Figure 7-a to Figure 7-f are histograms of all collected participant data (a total of 118 games, including those who did not drive more than 3 miles). Figure 7-a presents the average speed histogram, which has a mode of 25–30 mph and an average of 43 mph. The speed distribution is nearly normal, but there is a non-negligible portion of extreme speeds. Figure 7-b shows the histogram of phone interactions. The phone interaction number has a mode of 0–2 times and a mean of 11.8 times. Figure 7-c shows a histogram of the number of times participants honked at other cars. Interestingly, only a few participants honked, but those who did, honked a lot—indicating strongly opposite behavior among participants. The mode of the honking number is 0 times, and the mean is shockingly 20.2 times. Figure 7-d shows a histogram of the crash number. Nearly half of the respondents experienced at least one crash. The mode of the crash number is 0 times, and the mean is 1.18 times. Figure 7-e presents a histogram of the time it takes participants to buckle up their seat belts for the first time. Over 62% of participants who buckled up in the game (or 43 out of 74) buckled up their seat belts as they started to drive; 44 participants never buckled up throughout the simulation game. Figure 7-f shows a histogram of the distance traveled by participants. The mode of traveling distance is 3 miles and the mean is 3.43 miles. In summary, most participants drove within the speed limit and rarely made aggressive actions, while, on the other hand, we observed a small number of extremely aggressive behaviors as well.



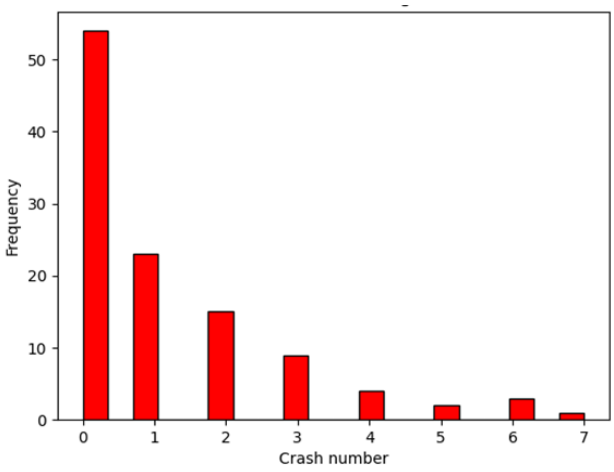
(a) Average speed



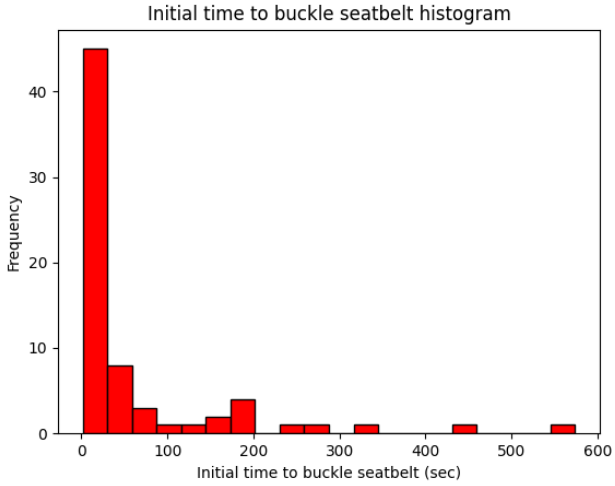
(b) Phone use number



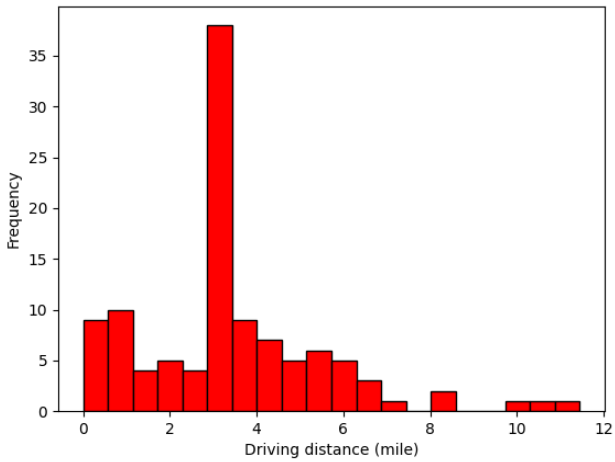
(c) Honk number



(d) Crash number



(e) Time to buckle seatbelt



(f) Travel distance

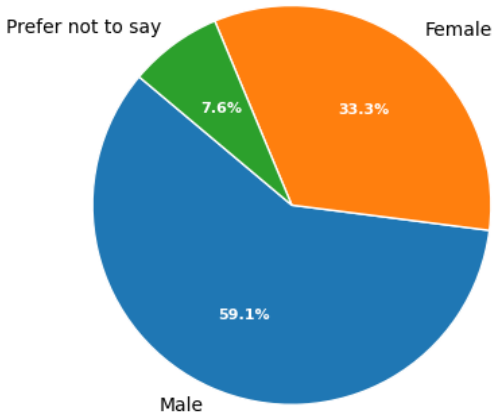
Figure 7. Graph. Histograms of attributes among 118 participants.

QUESTIONNAIRE DATA

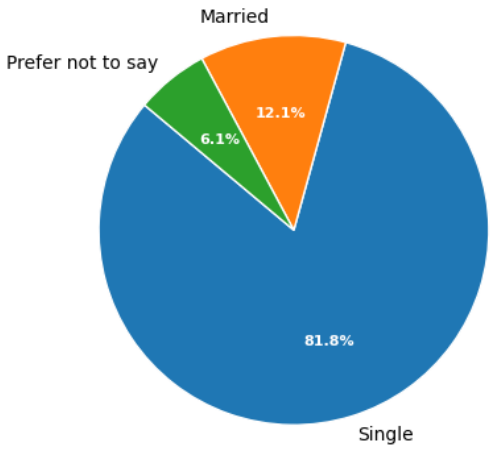
A total of 66 valid responses were collected from the questionnaire, and they are classified into four main categories: demographic information, socioeconomic information, driving experience and behavior perception, and opinions toward nontraditional messages. Histograms and pie graphs are plotted to show a clear view of these responses.

Demographic Information

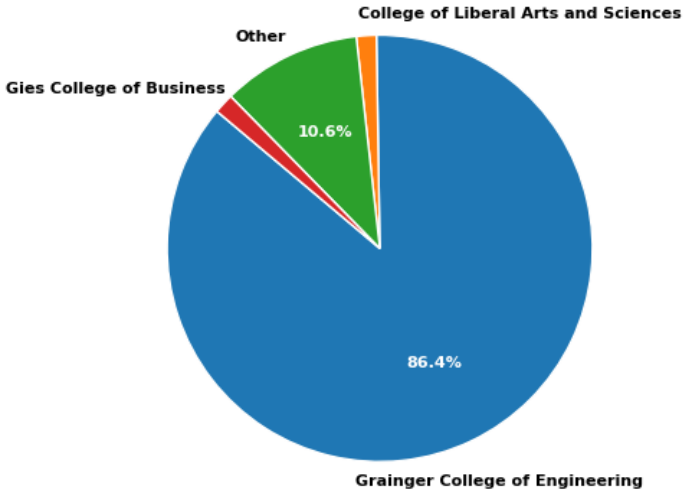
Figure 8-a to Figure 8-d plot pie graphs of participants' demographic information. Figure 8-a is the gender pie graph, which shows that the whole surveyed group is composed of at least 59.1% males and 33.3% females. These percentages largely match the demographic profile of students in UIUC's civil engineering department—indicating that males and females are largely equal in willingness to participate in the game/survey. Figure 8-b shows the marital status, indicating that 81.8% of the participants are single and 12.1% are married. Figure 8-c shows that most but not all (90%) participants are from the engineering college—indicating some participants from other colleges were invited by civil engineering students. Figure 8-d shows the distribution of their academic standing, where an approximately equal share of respondents are undergraduate, master's, and PhD students.



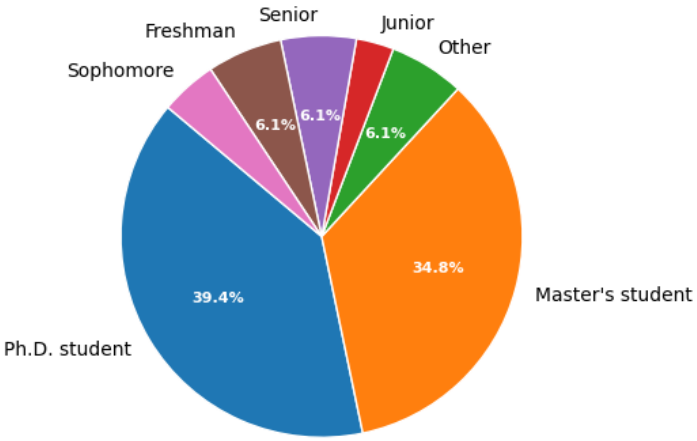
(a) Gender



(b) Marital status



(c) College status

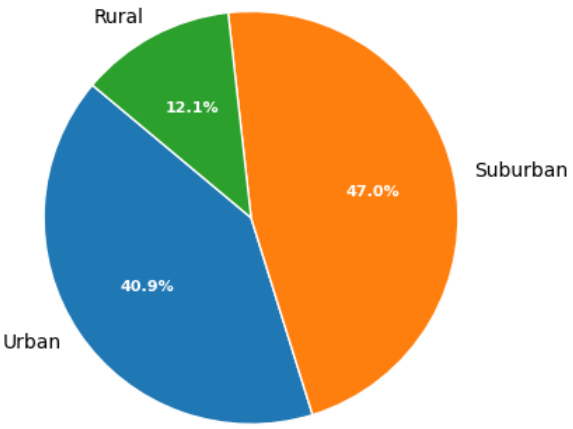


(d) Academic status

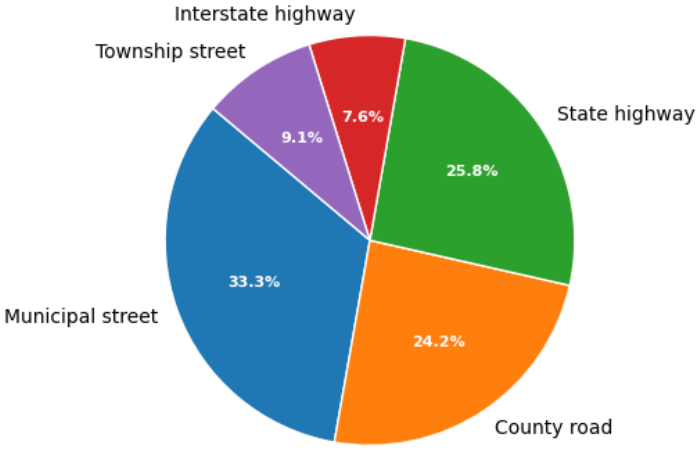
Figure 8. Graph. Demographic information of respondents.

Socioeconomic Information

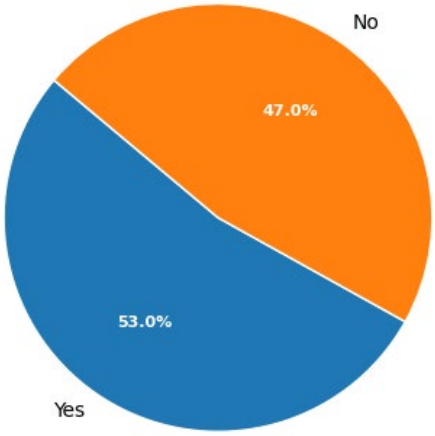
Figure 9-a to Figure 9-d plot pie graphs of the participants' socioeconomic information. Figure 9-a shows the participants' living area; nearly half of them live in suburban areas and half in urban areas. Figure 9-b indicates the driving experience with roadway types. The most driven road type is municipal streets (33.3%), and the least driven road type is interstate freeway (7.6%). Figure 9-c shows that only half of the participants have a car and/or possess legal driving ability. Figure 9-d presents responses to the question of whether an accident happened in the past 5 years, and 13.6% participants responded "yes" to this question.



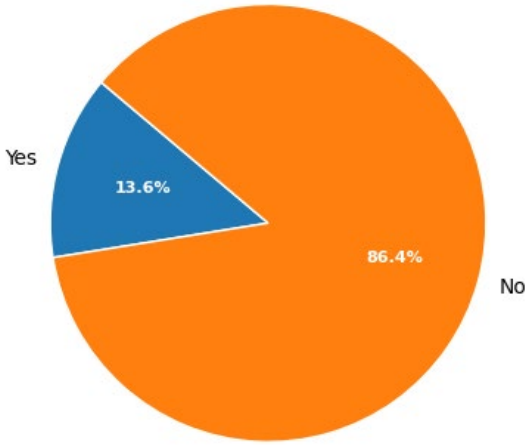
(a) Living area



(b) Most driven road type



(c) Car ownership

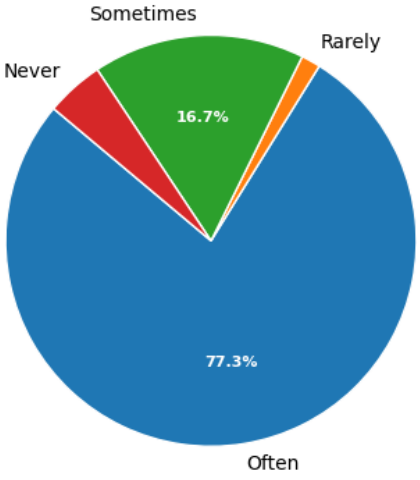


(d) Involved in an accident in past 5 years

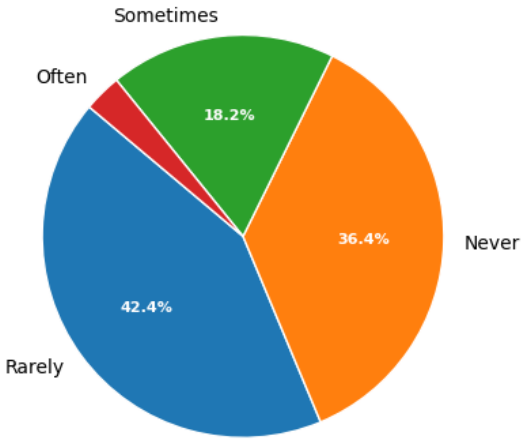
Figure 9. Graph. Socioeconomic information of respondents.

Driving Behavior Information

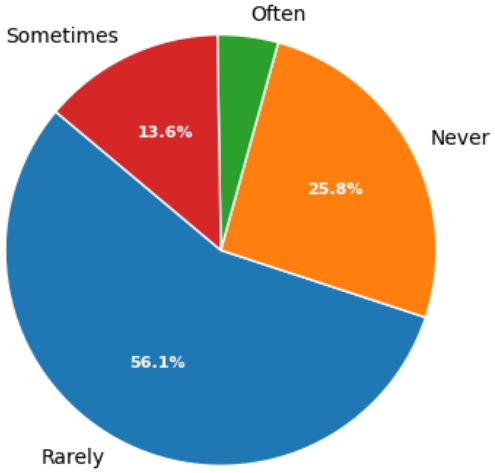
Figure 10-a to Figure 10-d plot pie graphs of participants' stated driving behavior. Each pie graph is related to a typical behavior that may cause distracted driving. Figure 10-a shows that 77.3% of participants often listen to music when driving. Figure 10-b shows that 36.4% of participants never send text messages when driving, while at least 18.2% of them do sometimes or often send text messages. Similarly for phone calls and honking, most participants responded "never" or "rarely" for phone calling, but there was still a small portion (18.1% and 16.7%) that selected "sometimes" or "often," as shown in Figure 10-c and Figure 10-d, respectively. In general, when driving, most people listen to music, rarely send text messages, rarely call others, and rarely honk at others.



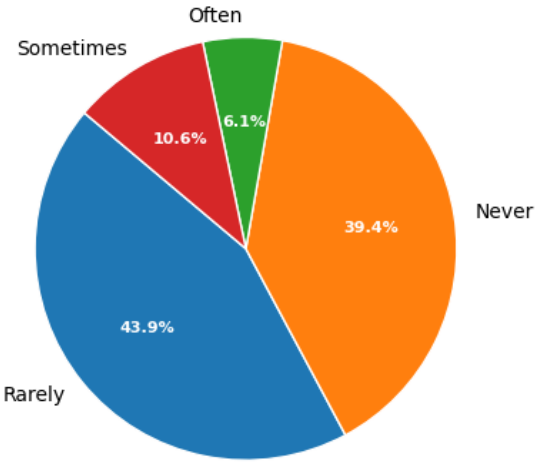
(a) Listening to music



(b) Sending text messages



(c) Phone calling



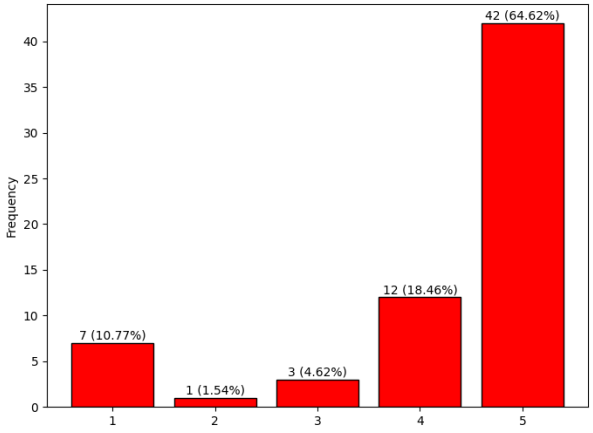
(d) Honking at others

Figure 10. Graph. Driving behaviors information of respondents.

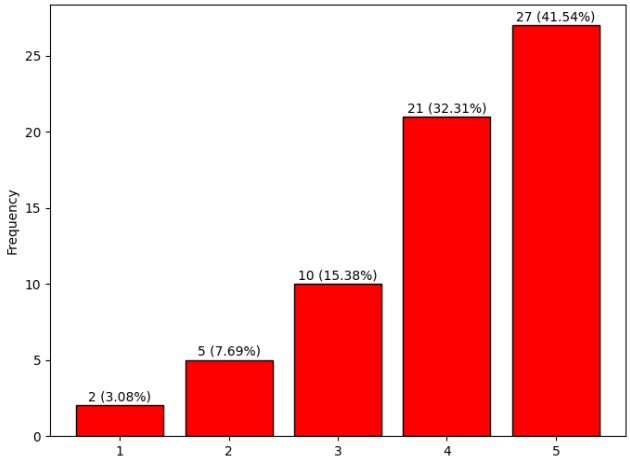
Impression on Nontraditional Messages

The questionnaire collected participants' opinions toward nontraditional messages through ranking the importance of different types of messages. The more people ranked a specific message higher, the more important and more sensitive such a message is to the safe driving behavior of the public. Figure 11-a to Figure 11-e show participants' ranking of the importance of nontraditional messages on changing a typical driving behavior. In sequence, Figure 11-a to Figure 11-e focus on messages' importance to not wearing seat belts, speeding, texting and driving, drinking and driving, and drowsy driving. We can compare the proportions of people ranking each target behavior as 1 (lowest) and 5 (highest). It is observed that 66.7% of participants rank speeding as 5, while 10.6% of participants rank not wearing seat belts as 1. This indicates that most participants regard speeding as the most important and dangerous behavior and not wearing seat belts as the least important and negligible behavior.

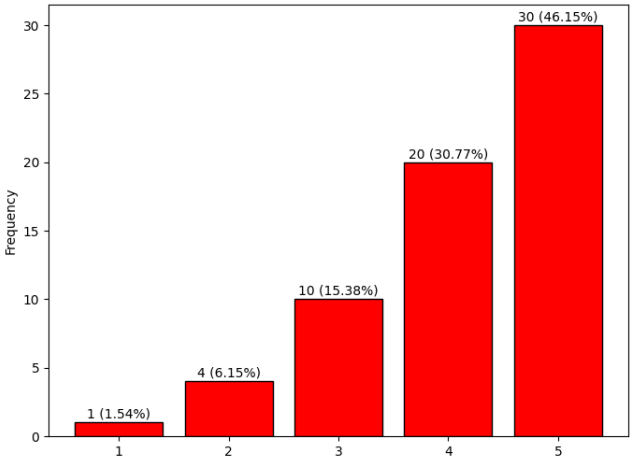
Participants were also asked to recall the most memorable and inappropriate messages they saw during the online simulation. Among the 66 questionnaire responses, 57 mentioned at least one most memorable message and 47 responded at least one inappropriate message. Figure 12-a to Figure 12-b present the composition of most memorable message types and inappropriate messages. Messages related to seat belts (28%) and speeding (26%) are the two most memorable message types. Among all responses to inappropriate messages, most people (76%) answered "no" recollection of such types of messages. A few participants answered that those related to long dynamic messages and phone calls were distracting for driving. Only 2% of participants gave specific messages that were considered offensive, which suggested that including a specific culture as part of the message (e.g., "Luck of the Irish won't help if you drive drunk") might not be appropriate. Some top responses to these two questions are listed in Table 4.



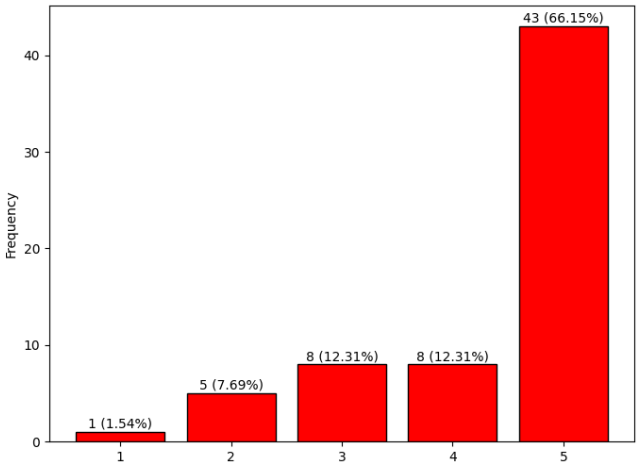
(a) Not wearing seat belts



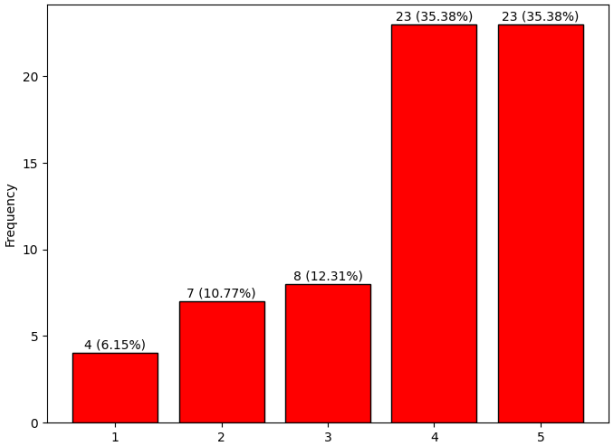
(b) Speeding



(c) Texting and driving

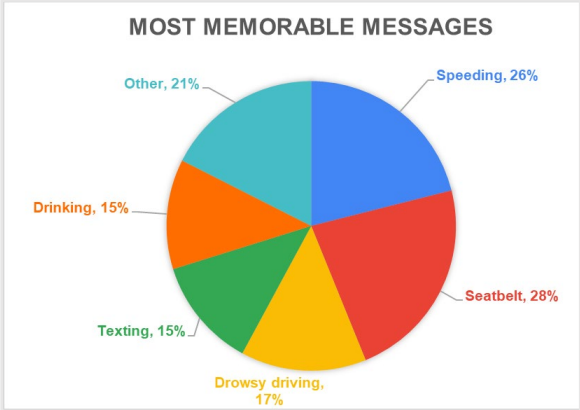


(d) Drinking and driving

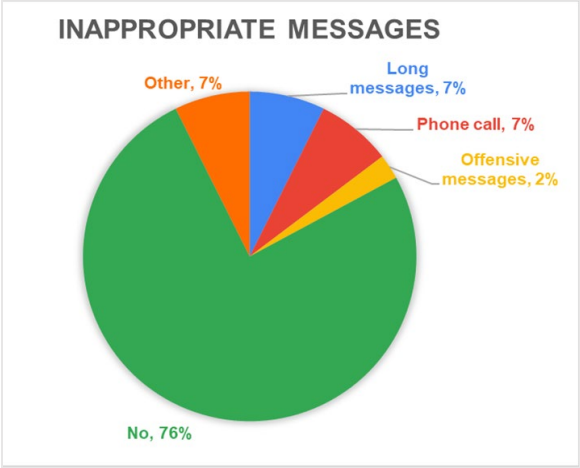


(e) Drowsy driving

Figure 11. Graph. Opinions toward nontraditional messages in the questionnaire.



(a) Most memorable messages



(b) Inappropriate messages

Figure 12. Graph. Most memorable and inappropriate messages.

Table 4. Sample Responses on Most Memorable and Inappropriate Messages

Top response	Among all the messages you saw today, which one(s) were the most memorable and why?	Do you think that any of the messages today were inappropriate? If yes, which ones?
1	"Buckle up and smell the rose"	"We pity the fool who texts & drives"
2	"72 were unbuckled"	"Luck of the Irish won't help if you drive drunk"
3	"It's the temperature not the speed limit"	"I think those messages contain too many words"
4	"It's ok to be a slow poke"	"I think they were ok. I think any jokes or puns that make it take longer to read or longer messages are distracting. short jokes/puns ok."

CHAPTER 5: PRELIMINARY DATA ANALYSIS

As mentioned in Chapter 4, each participant's simulation game experience generates a series of data trajectories that record their real-time actions to dynamic message signs seen along the drive. In this preliminary data analysis, we are interested in analyzing if, and how, different types of nontraditional messages can help improve safety with regard to five types of safety practice: (i) reducing average driving speed, (ii) discouraging speeding, (iii) reducing phone use while driving, (iv) reducing honking actions, and (v) encouraging seat belt usage.

We assume for simplicity that all participants' reactions to various messages are independent of each other, and the participants are memoryless of past messages. Since an average participant sees a new message sign almost every 20–40 seconds (every 0.5 mile, based on the driving speed), we choose to capture the effects of a nontraditional message simply by the difference between the participants' observed safety practices 10 seconds before and 10 seconds after passing that message sign. These periods will be referred to as "before" and "after" respectively.

Figure 13 shows an example on how the effects of a message on reducing speed are measured quantitatively. At the 277th second, a participant passed a sample message saying: "LIFE IS A HIGHWAY DRIVE SAFELY ALL DAY LONG," which belongs to category tag #1 in Table 1: "general safe driving" and "emotionless." The average speed in the before period of 267–277 seconds is 32 mph, and that in the after period of 277–287 seconds is 22 mph. The difference of average speeds, measured as the speed after passing the message minus the one before passing the message, is −10 mph. That particular message has a positive impact on reducing the average driving speed for this particular observation. However, we must use statistics to draw more confident conclusions. To do so, we make such measurements for each used dynamic message for each participant (grouped by the category of the dynamic message target behavior and emotion) and conduct similar measurements for each type of observed safety practice change. Then, we have 15 groups of messages as well as five types of safety practice observations, and apply statistical analysis. All participants' reactions to three types of emotion messages in the target behavior category "general safe driving" can be compared. For each of the five safety practice types, a two-sample t-test can be applied between any two message groups to generate the p-value and the t-statistic. If the p-value is smaller than 0.05, then we are 95% confident that the two groups do not statistically have the identical mean (or expected effect).

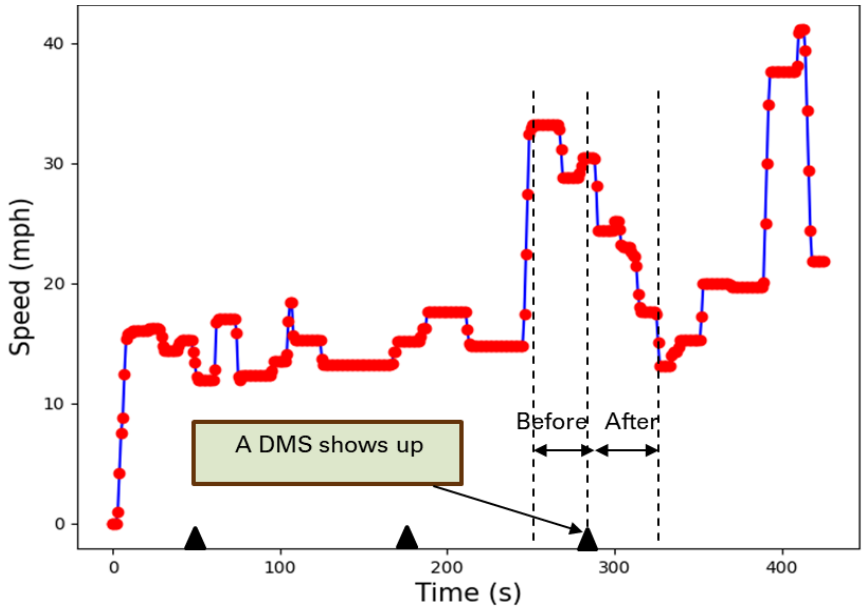


Figure 13. Graph. Quantitative analysis of speed reduction by message signs.

The remainder of this chapter will present preliminary analysis results on each of the five safety practice types.

AVERAGE SPEED REDUCTION

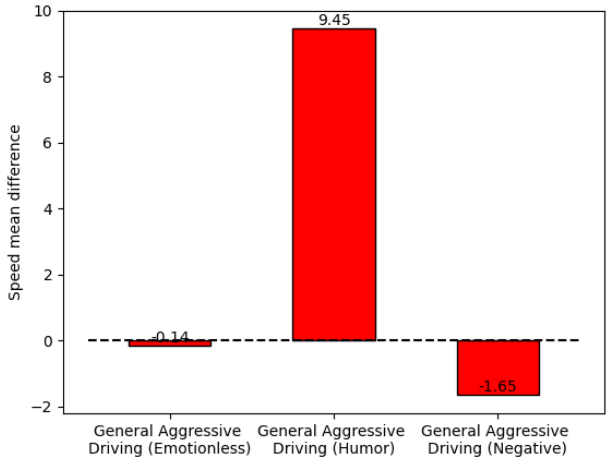
Before-and-after data related to messages from categories 14–16 in Table 1 ("general aggressive driving" + three types of emotions) are selected to analyze their impacts on average speed change. For each observation, the average speed difference is computed as Equation 1:

$$\Delta v = v_{after} - v_{before} \quad (1)$$

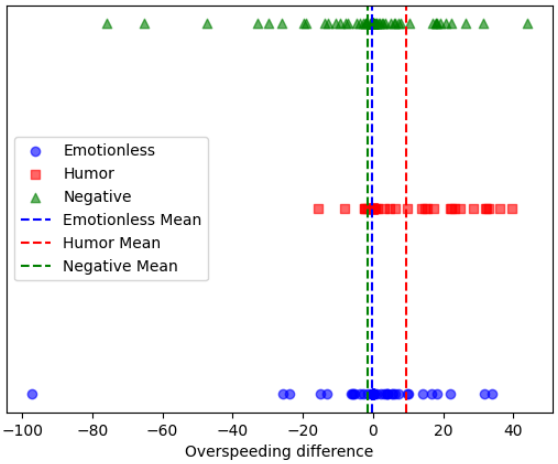
where v_{after} and v_{before} represent the average speed in the after and before period, respectively. A negative value of Δv indicates a decrease in the average speed after seeing the sign.

Figure 14-a and Figure 14-b show the means and distributions of Δv, respectively, for the three types of emotion messages. Negative emotion messages decrease the average speed by 1.65 mph, whereas emotionless messages decrease speed only marginally by 0.14 mph, and humorous messages have a strong "negative" effect of increasing speed by 9.45 mph.

Two-sample t-tests are conducted to see if there are statistically significant differences among these types of emotions. Table 5 reports the results. We find with 99% confidence that messages with a negative emotion are significantly more effective than emotionless or humorous ones. This also indicates strongly that humorous messages should probably be avoided if we would like to remind drivers to reduce speed.



(a) Mean of Δv



(b) Distribution of Δv

Figure 14. Graph. Effectiveness of three emotions in general safe driving to reduce speed.

Table 5. Two-Sample t-test between Three Emotions in Reducing Speed

	t-statistic	**p-value**
Humor vs Negative	−3.05	0.00
Humor vs Emotionless	−2.59	0.01

SPEEDING

Before-and-after data related to messages from categories 14–16 in Table 1 (“general aggressive driving” + three types of emotions) are selected to analyze their influences on speeding. For each observation, the speeding difference is computed as Equation 2:

$$\Delta O = 1(v_{after} \geq 60) - 1(v_{before} \geq 60) \quad (2)$$

where $1(\cdot)$ is a logical indicator function that equals 1 if the condition in the parentheses is true, or 0 otherwise; v_{after} and v_{before} represent the average speeds in the after and before period, respectively. A negative value of ΔO indicates the participant stops speeding after passing the message sign.

Figure 15 shows the mean of ΔO for three types of emotion messages. Emotionless messages can reduce speeding by 4%, while negative messages reduce speeding by 2%, and humorous messages have a counterproductive effect of increasing the chance of speeding by 11%.

Two-sample t-tests are conducted to measure the statistical difference among the three types of emotions. Table 6 presents the results. We find with 97% confidence that emotionless messages are more effective than humorous ones. Messages with a negative emotion also reduce speeding compared with humorous ones, implying that humorous messages should be avoided in reminding drivers about speeding. In general, this is consistent with findings on speed reduction—possibly because humorous messages make drivers feel less serious about speed limits.

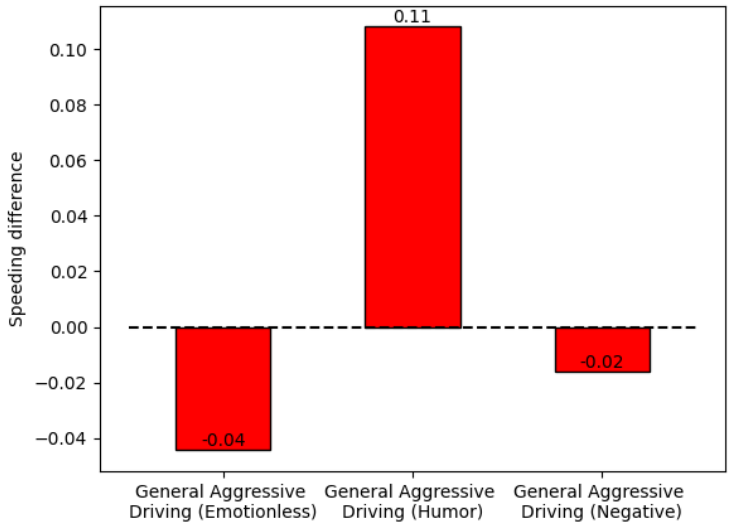


Figure 15. Graph. Effectiveness of three emotions to avoid speeding.

Table 6. Two-Sample t-test between Three Emotions to Avoid Speeding

	t-statistic	**p-value**
Humor vs Negative	−1.81	0.07
Humor vs Emotionless	−2.25	0.03

PHONE INTERACTIONS

Before-and-after data related to messages from categories 7–9 in Table 1 (distracted driving + three emotions) under a high speed around 60–90 mph are selected to analyze their impacts on reducing phone interactions. For each observation, the change in phone interaction number is computed as in Equation 3:

$$\Delta P = P_{after} - P_{before} \quad (3)$$

where P_{after} and P_{before} represent the phone use number in the after and before period, respectively. A negative ΔP represents the reduction of phone use after seeing a message sign. Figure 16 shows the mean of ΔP for three types of emotion messages. Humorous messages on distracted driving can best reduce phone interactions by 0.67 times, while emotionless and negative messages increase phone interactions by 0.17 and 0.22 times, respectively.

Two-sample t-tests are conducted to measure the statistical difference among the three emotions. Table 7 presents the results. In particular, we find with 95% confidence that humorous messages are more effective than emotionless ones. This implies that humorous messages could be effective in reminding drivers to avoid phone use when they are driving at speeds between 60–90 mph.

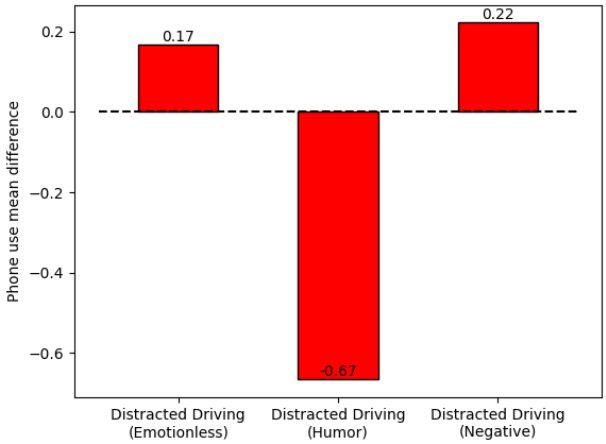


Figure 16. Graph. Effectiveness of three emotions in distracted driving messages to reduce phone use.

Table 7. Two-Sample t-test between Three Emotions in Distracted Driving Messages to Reduce Phone Use

	t-statistic	**p-value**
Humor vs Negative	1.65	0.11
Humor vs Emotionless	2.16	0.05

HONKING

Before-and-after data related to messages from categories 1–3 in Table 1 (general safe driving + three types of emotions) when driving at speeds between 60–90 mph are selected to analyze their effects on reducing honking. For each observation, the difference in honking number is computed as Equation 4:

$$\Delta H = H_{after} - H_{before} \quad (4)$$

where H_{after} and H_{before} represent the number of honking actions in the after and before period, respectively. A negative ΔH represents a reduction of honking after seeing a message sign.

Figure 17 shows the mean of ΔH for three types of emotion messages. Negative messages can reduce honking by 0.2 times, and emotionless messages do not have notable impacts on the honking number, while humorous messages have a counterproductive effect by increasing honking.

Two-sample t-tests are conducted to measure the statistical difference among three types of message emotions. Results are shown in Table 8. We find that, with 98% confidence, negative messages are more effective than humorous ones in reducing the frequency of honking. Humorous messages probably should be avoided when the driving speed is around 60–90 mph.

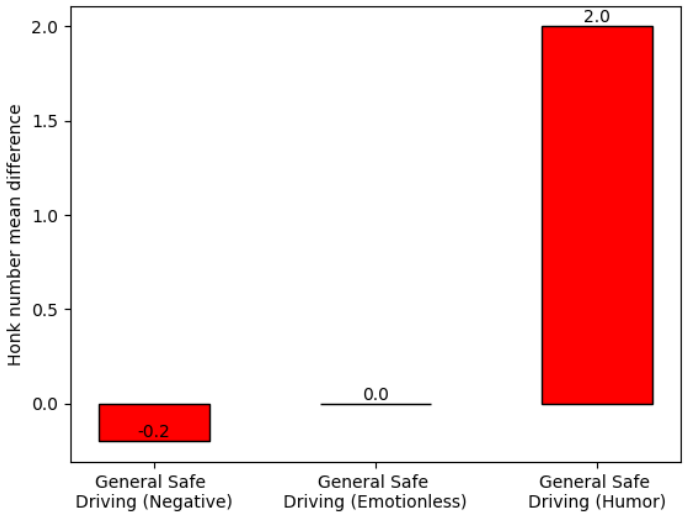


Figure 17. Graph. Effectiveness of three emotions in general safe driving to reduce honking.

Table 8. Two-Sample t-test between Three Emotions in General Safe Driving to Reduce Honking

	t-statistic	**p-value**
Humor vs Negative	−2.90	0.02
Humor vs Emotionless	−1.34	0.27

SEAT BELT USE

Before-and-after data related to messages from categories 4–6 in Table 1 (driving without seat belt + three types of emotions) and having a speed lower than 60 mph are selected to measure the impacts on seat belts. Note that only those not buckled in the before period are involved in this analysis. For each observation, the change in seat belt status is computed as the effect of message signs in Equation 5:

$$\Delta B = 1(\text{buckled after} \mid \text{unbuckled before}) \qquad (5)$$

where $1(\cdot)$ is the logical indicator function that equals 1 if the condition in the parentheses is true, or 0 otherwise. ΔB equals 1 if an unbuckled participant chooses to buckle up his or her seat belt after seeing a message sign, or equals 0 otherwise. It can be interpreted as the conditional probability of changing the buckling status. Figure 18 shows the mean of ΔB for three types of emotion messages. For drivers previously not using a seat belt, negative messages can be most effective in reminding about 77% to buckle up, emotionless messages can remind about 60%, and humorous messages are least effective, only reminding 31% of participants to buckle up.

Table 9 shows the two-sample t-tests results. With 98% confidence, we conclude that negative messages are more effective than humorous ones. This implies that negative messages could be most effective in encouraging drivers to buckle up.

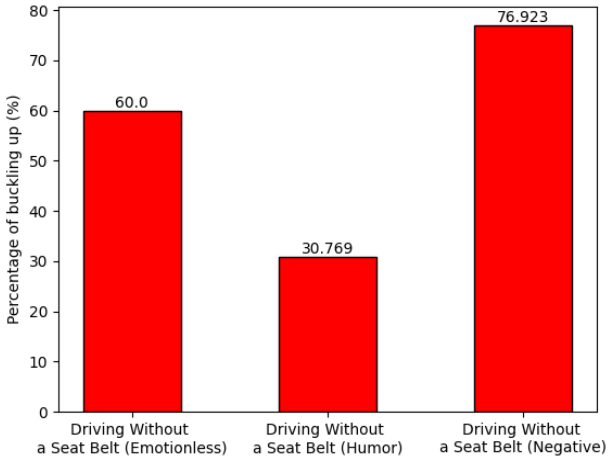


Figure 18. Graph. Effectiveness of three emotions in encouraging seat belt use.

Table 9. Two-Sample t-test among Three Emotions in Encouraging Seat Belt Use

	t-statistic	**p-value**
Humor vs Negative	2.56	0.02
Humor vs Emotionless	0.85	0.41

ALTERNATIVE MESSAGE CATEGORIES

Please note that the categories of dynamic messages used in the previous sections are based on those from the literature (i.e., Shealy et al., 2020). For some messages, especially for those under the category of "emotionless," their differences to "humorous" or "negative" can be subtle and highly reliant on drivers' interpretation and cultural background. For example, the message "DRIVING SAFELY? I LIKE IT I LOVE IT" is classified as "emotionless" in Shealy et al. (2020); however, it also may be considered "humorous" if one knows this is referring to the title of a song. Similarly, some of the "emotionless" messages may be treated as "negative" due to individual drivers' emotional mood or perceptions. To test the robustness and accuracy of our statistical results, we conducted another before-and-after analysis, using the same sample data and target driving behaviors, but with only two message categories: humorous and negative. All messages in the emotionless category are partitioned and re-grouped into the humorous and negative categories. Appendix C presents the new list of messages by these two groups. Table 10 summarizes their relative frequency of use in the simulation games, under the new categories.

Table 10. Nontraditional Messages Grouped by Target Behavior and Adjusted Emotion

Index	Behavior	Emotion	Frequency of use (%)
1	General safe driving	Humorous	13.70
2	General safe driving	Negative	3.80
3	Driving without a seat belt	Humorous	13.57
4	Driving without a seat belt	Negative	5.97
5	Distracted driving	Humorous	17.23
6	Distracted driving	Negative	7.19
7	Impaired and drowsy driving	Humorous	11.80
8	Impaired and drowsy driving	Negative	7.19
9	General aggressive driving	Humorous	11.13
10	General aggressive driving	Negative	8.42

Table 11 summarizes the two-sample t-tests results for five target safe driving behaviors with the new message categories in specific driving speed ranges. With 96.6% confidence, we conclude that the negative messages are more effective than humorous ones in encouraging speed reduction for those driving slower than 60 mph. With 98% confidence, we conclude that negative messages are more effective than humorous ones in avoiding speeding. With 96.5% confidence, we conclude that

humorous messages are more effective than negative ones in avoiding phone use when drivers are driving at 60–120 mph. With 96.8% confidence, we conclude that negative messages are more effective than humorous ones in encouraging seatbelt use when drivers are driving at 40–120 mph. These results are generally consistent with those found in the previous subsections. The only exception is about reducing honking, where no statistically significant difference is found.

Table 11. Two-Sample t-test among Emotions with New Categorization

Safety Behavior / Practice	Message Category	Speed Range (mph)	Mean (Humorous)	Mean (Negative)	t-statistic	p-value
Average speed reduction	(9) (10)	0–60	4.26	−2.17	2.18	0.034
Speeding	(9) (10)	0–120	0.11	−0.03	2.37	0.019
Phone interaction	(5) (6)	60–120	−0.46	0.2	−2.16	0.035
Honking	–	–	–	–	–	–
Seatbelt use	(1) (2)	40–120	0.37	0.0	2.24	0.032

CHAPTER 6: CONCLUSION

This project completed three main tasks. First, a literature review was conducted to investigate past studies researching driver behaviors and different types of dynamic message signs as well as to explore similar projects experimenting on the effect of drivers' behavior change caused by dynamic message signs. Second, a web-based questionnaire and simulation were developed to capture drivers' opinions and behaviors toward dynamic message signs in a semi-realistic environment. Third, a preliminary data analysis was conducted to develop a better understanding of how dynamic message signs influence driver behaviors and to provide suggestions how IDOT may systematically present information on dynamic message signs in practice. Some of the key findings are listed below:

- Avoid humorous messages when encouraging drivers to decrease speed.
- Use emotionless messages to discourage drivers from speeding.
- Use humorous messages when encouraging drivers to reduce frequency of texting and calling when driving speed is 60–90 mph.
- Avoid humorous messages when discouraging drivers from honking at another driver when driving speed is 60–90 mph.
- Negative messages are recommended in encouraging drivers to buckle up when driving speed is lower than 60 mph.

The proposed online driving game and survey are able to protect the privacy of respondents and are sufficiently robust for future extensions and adaptations to a more complex environment, such as lighting conditions, weather conditions, road geometry, or traffic congestion. Additionally, any type of nontraditional messages can be easily loaded and tested in the driving game. It is also possible to investigate nontraditional messages' effectiveness using a more sophisticated model, such as trajectory data mining and deep learning, rather than making simplified assumptions and using traditional statistical tests. The online driving game is expected to handle larger-scale experiments and provide more comprehensive and valuable information in the future.

This study produces a synthesis of the available literature and preliminary data analysis of the driver survey/experiment, and the findings provide recommendations for IDOT on the most effective messages for Illinois. The result illustrates what type of message (emotionless, negative, humorous) changes driver behavior for increased compliance and decreased crash activity. This project also generates findings that will serve as guidance on when and where different kinds of messages may be most effective, providing a long-term benefit to IDOT and partner agencies.

REFERENCES

Boyle, L., Cordahi, G., Grabenstein, K., Madi, M., Miller, E., & Silberman, P. (2014). *Effectiveness of safety and public service announcement (PSA) messages on dynamic message signs (DMS)* (Report No FHWA-HOP-14-015). Federal Highway Administration.

Francis, J. (2018). Unusual highway signs grab drivers' attention. *News Channel 20,* November 29. https://newschannel20.com/news/local/unusual-highway-signs-grab-drivers-attention.

Haghani, A., Hamedi, M., Fish, R., & Norouzi, A. (2013). *Evaluation of dynamic message signs and their potential impact on traffic flow* (Report No. MD-13-SP109B4C). Maryland State Highway Administration.

Harder, K. A., & Bloomfield, J. R. (2008). *The effectiveness and safety of traffic and non-traffic related messages presented on changeable message signs—Phase II* (Report No. Mn/DOT 2008-27). Minnesota Department of Transportation.

Huang, Y., Strawderman, L., & Garrison, T. (2013). Dynamic Message Signs, Driver Characteristics, and Speed Reduction. IIE Annual Conference. Proceedings

Rodier, C. J., Lidicker, J. R., Finson, R. S., & Shaheen, S. A. (2010). *An evaluation of the consequences and effectiveness of using highway changeable message signs for safety campaigns* (Report No. CA10-1124). University of California PATH. https://trid.trb.org/view/919831

Schroeder, J., Plapper, E., Zeng, H., & Krile, B. (2016). *Public perception of safety messages and public service announcements on dynamic message signs in rural areas* (Report No. FHWA-HOP-16-048). U.S. Department of Transportation. Federal Highway Administration.

Shealy, T., Kryschtal, P., Franczek, K., & Katz, B. J. (2020). *Driver response to dynamic message sign safety campaign messages* (Report No. FHWA/VTRC 20-R16). Virginia Transportation Research Council. http://www.virginiadot.org/vtrc/main/online_reports/pdf/20-r16.pdf

Shroeder, J., & Demetsky, M. (2010). *Evaluation of driver reactions for effective use of dynamic message signs in Richmond, Virginia* (Report No. FHWA/VTRC 10-R16). Virginia Transportation Research Council.

Song, M., Wang, J., Cheung, Sam., & Keceli, M. (2016). Assessing and mitigating the impacts of dynamic message signs on highway traffic. *International Journal for Traffic and Transportation Engineering*, *6*(1), 1–12.

Strawderman, L., Huang, Y., & Garrison, T. (2013) The effect of design and placement of work-zone warning signs on driver speed compliance: A simulator-based study. *IIE Transactions on Occupational Ergonomics and Human Factors*, 1(1), 66–75. https://doi.org/10.1080/21577323.2012.714839

APPENDIX A: NONTRADITIONAL MESSAGES

Table 12. List of Nontraditional Messages Used in the Simulation Game

Behavior	Emotion	Messages
General safe driving	Emotionless	NOBODY PUTS BABY IN A HOT CAR
		DON’T YOU FORGET ABOUT ME AS YOU DRIVE ON BY
		LIFE IS A HIGHWAY DRIVE SAFELY ALL DAY LONG
		BE OUR GUEST DRIVE POLITELY
		DRIVING SAFELY? I LIKE IT I LOVE IT
	Humor	BE ON SANTA'S NICE LIST DRIVE POLITELY
		WHAT'S SCARIER YOUR COSTUME OR YOUR DRIVING?
		BE A FIREWORK SPARK RESPONSIBLE DRIVING
		ZERO FATALITIES A GHOUL WE CAN ALL LIVE WITH
		SANTA'S COMING HAVE YOU BEEN A GOOD DRIVER?
	Negative	843 VA FATALITIES THIS YEAR DRIVE SAFELY
		375 MILLION US VEHICLE INJURIES IN 2017
		843 TRAFFIC DEATHS IN VIRGINIA THIS YEAR DRIVE ALERT
		757 FATALITIES SONS, DAUGHTERS. STOP THE HEARTACHE
		843 FATALITIES ON VIRGINIA ROADS IN 2018
Driving without a seatbelt	Emotionless	PROTECT YOURSELF BUCKLE UP
		SECURE THE FUTURE BUCKLE YOUR CHILD
		DON’T LEAP FROM YOUR SEAT BUCKLE UP
		SEE YOUR BFF TONIGHT BUCKLE UP
		BUCKLE UP SAVE $25 AND YOUR LIFE
	Humor	DON’T MAKE ME STOP THIS CAR! BUCKLE UP

Behavior	Emotion	Messages
		DUCK, DUCK, BUCKLE UP
		AWWWWW SNAP! YOUR SEAT BELT!
		BUCKLE UP AND SMELL THE ROSES
		PEACE LOVE SEATBELTS BUCKLE UP!
	Negative	72 WERE UNBUCKLED
		9 OF 17 FATALITIES UNBUCKLED THIS YEAR
		153 ROAD DEATHS IN VA THIS YEAR 66% UNBUCKLED
		37% FATALITIES WERE NOT WEARING SEATBELTS
		60% OF TEEN ROAD DEATHS IN VIRGINIA ARE UNBUCKLED
Distracted driving	Emotionless	GOLD MEDAL DRIVERS DON'T TEXT AND DRIVE
		MAKE IT TO THE END ZONE DRIVE ALERT
		DON'T LET SAFETY BE A HAIL MARY DRIVE ALERT
		PLAY BALL! STRIKE THE DISTRACTIONS
		BLOW THE WHISTLE ON DISTRACTED DRIVING
	Humor	GET YOUR HEAD OUT OF YOUR APPS
		TEXTING WHILE DRIVING? OH CELL NO.
		DON'T DRIVE IN-TEXT-ICATED
		AVOID AN APPSIDENT PHONES DOWN
		TEXTING & DRIVING IS CLEVER SAID NO ONE EVER
		WHO YA GONNA CALL? NOBODY YOU'RE DRIVING
		YOU HAD ME AT "I DON'T TEXT AND DRIVE!"
		THE FORCE IS STRONG WHEN YOU PUT DOWN THE PHONE
		EDDIE SAYS DON'T TEXT & DRIVE THE TWITTERS FULL

Behavior	Emotion	Messages
		WE PITY THE FOOL WHO TEXTS & DRIVES
	Negative	NO TEXT IS WORTH A LIFE
		MOM NEEDS YOUR HUG NOT YOUR TEXT
		YOUR PHONE OR YOUR LIFE? YOUR CHOICE
		ONE TEXT CAN END IT ALL
		IS YOUR TEXT WORTH THE RISK?
Impaired and drowsy driving	Emotionless	DON'T SNOOZE WHILE YOU CRUISE
		BE ALERT ARRIVE UNHURT
		DROWSY DRIVING IS LOUSY DRIVING
		WE'VE GOT A FEVER THE ONLY CURE IS SOBER DRIVERS
		DRINKING AND DRIVING DON'T MIX
	Humor	YOU'RE NOT A FIREWORK DON'T DRIVE LIT
		LUCK OF THE IRISH WON'T HELP IF YOU DRIVE DRUNK
		A DUI WILL EMPTY THE POT O GOLD DRIVE SOBER
		DESIGNATED DRIVERS MAKE THE BEST NEW YEAR'S DATES
		DON'T BE TRICKED DUIS ARE NO TREAT
	Negative	BLOWING .08 IS LIKE BLOWING $10,000
		JUST BUZZED? NICE TRY, THAT'S A DUI
		DRIVE HAMMERED GET NAILED
		DON'T LET YOUR TAILGATE END WITH A CELLMATE
		DRINKING AND DRIVING A GRAVE MISTAKE
	Emotionless	SPEEDING IS UNSPORTSMANLIKE CONDUCT

Behavior	Emotion	Messages
General aggressive driving		MARCH MADNESS? KEEP AGGRESSION ON THE COURT
		NO SHOT CLOCK DRIVING A CAR SLOW DOWN
		KEEP RIVALRIES OFF THE ROAD DRIVE CALM
		COMMUTING ISN'T A COMPETITIVE SPORT RELAX
	Humor	I THINK WE NEED SOME SPACE ONE DRIVER TO ANOTHER
		IT'S OK TO BE A SLOW POKE
		IT'S A SPEED LIMIT NOT SPEED SUGGESTION
		SPEEDING CAN LEAD TO SKID MARKS
		THAT'S THE TEMPERATURE NOT THE SPEED LIMIT
	Negative	DO NOT TELL A LIE OBEY THE LIMIT
		SPEED KILLS SLOW DOWN
		KEEP YOUR DISTANCE SAVE A LIFE
		LEAVE SOME SPACE SURVIVE THE DRIVE
		DON'T BE NEXT KEEP YOUR DISTANCE

APPENDIX B: CONSENT DOCUMENT FOR THE GAME/SURVEY

IRB Number: IRB23-0348
IRB Approval Date: 01/25/2024

Principal Investigator Name and Title: Yanfeng Ouyang, Professor
Department and Institution: Civil and Environmental Engineering, Illinois Center for Transportation
Contact Information: Tel: 217-333-9858, E-mail: yfouyang@illinois.edu
Sponsor: Illinois Department of Transportation (IDOT)

The consent is being sought for research, and participations are voluntary. The purpose of this project is to determine: (i) if non-standard driver messages cause a change in driver behavior and reduce crash frequency in the freeway area of the signage inside Illinois, (ii) if the messages increase engagement of the motoring public with safer driving practices, and (iii) if the messages have a lasting impact (does the message stick) on drivers who see the messages. You will be asked to complete one 10-min online survey form and one 5-min online driving simulation. No identifiable information is collected, and all reactions are anonymous throughout the study. You will not directly benefit from the result of this study.

BACKGROUND

You are being asked to take part in a short online survey, which is conducted by a research group from the University of Illinois Urbana Champaign. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether you want to volunteer to take part in this study.

Dynamic message signs have been used for decades to inform drivers about roadways, traffic, or weather conditions. Most of the messages used in the past were standard and impersonal reminders. Recently, transportation agencies across the country, including Illinois Department of Transportation (IDOT), started to use non-traditional messages (rhyming, serious, funny, cultural) for display on these dynamic signs. In Illinois, such messages mainly address the following safety issues: (i) distracted driving (texting, talking on the phone, using apps, eating); (ii) impaired driving (alcohol, drugs, sleepiness); (iii) occupant restraint (seat belts – both front and back are required by law, child safety seats); (iv) speeding vulnerable users (motorcyclists, bicyclists, pedestrians); (v) work zone safety. Examples of such messages include “OMG. Are you texting? I can’t even” and “Slow Down in Work Zones, Give ’em a Brake.” IDOT even promoted a Dynamic Message Sign Contest in 2018 which encouraged drivers to submit new clever messages that hopefully can be more effective in making roadways safer. These non-traditional messages are expected to have higher effectiveness in modifying driver behavior, as they can catch drivers’ attention and provoke an emotional response.

STUDY PROCEDURE

It will take you approximately 15 minutes to complete this survey, including one online driving simulation game and one online questionnaire.

First, you need to read and complete a consent form. Then from the submission page of the consent form, you can find a link to the 5-min driving simulation. To begin the simulation, you need to provide an arbitrary ID. Do not enter any ID related to your private information. This ID will also be the password to retrieve a gift card if you are selected.

In the simulation, you can choose to accelerate, decelerate, or change lanes by pressing certain keyboard buttons. The simulation tracks all control records and vehicle movements.

After completion of simulation game, you will be directed to a web-based online questionnaire which will ask about your demographic information. It will take you 10 minutes to fill in the form. Some questions will also ask your understanding and opinion of the messages from the game.

Upon submission of the questionnaire, you will be provided with a dialog webpage, where you can enter your ID and check if you have won a gift card.

RISKS

The risks of this study are minimal.

BENEFITS

The information you provide in this survey will help develop a better understanding of driving behavior and dynamic messaging signs in the State of Illinois.

HOW WILL THE RESEARCHERS PROTECT MY INFORMATION?

All procedures in this study are anonymous. We will not collect any identification information from you.

WHO WILL HAVE ACCESS TO THE INFORMATION COLLECTED DURING THIS RESEARCH STUDY?

Efforts will be made to limit the use and disclosure of the data collected (e.g., simulation game records) to people who have a need to review this information.

The data may be used or seen by other people beyond the research team during or after this study. Examples include:

- **University officials, government officials, study funders, auditors, and the Institutional Review Board may need access to the study records to make sure the study is done in a safe and appropriate manner.**
- **Collaborating with researchers at other institutions who are involved with this sponsored research project.**

HOW MIGHT THE INFORMATION COLLECTED IN THIS STUDY BE SHARED IN THE FUTURE?

The Illinois Center for Transportation may keep the collected data for study recordkeeping and for potential use in future research projects.

PERSON TO CONTACT

If you have questions, complaints or concerns about this study, you can contact Prof. Yanfeng Ouyang at 217-333-9858. If you feel you have been harmed as a result of participation, please call Yanfeng Ouyang at 217-333-9858 who may be reached during weekdays.

If you have any questions about your rights as a research subject, including concerns, complaints, or to offer input, you may call the Office for the Protection of Research Subjects (OPRS) at 217-333-2670 or e-mail OPRS at irb@illinois.edu. If you would like to complete a brief survey to provide OPRS feedback about your experiences as a research participant, please follow the link here or through a link on the OPRS website: https://oprs.research.illinois.edu/. You will have the option to provide feedback or concerns anonymously or you may provide your name and contact information for follow-up purposes.

VOLUNTARY PARTICIPATION

Research studies include only people who choose to take part. You can tell us that you don't want to be in this study. You can choose to stop the study at any time.

COSTS AND COMPENSATION TO PARTICIPANTS

There is no cost to participate in this study. We will randomly select 5 respondents and reward each with $20 gift cards.

CONSENT

I confirm I have read the information in this consent form and have had the opportunity to ask questions. I voluntarily agree to take part in this study.

APPENDIX C: ALTERNATIVE MESSAGE GROUPS

Table 13. List of Nontraditional Messages Used in the Simulation Game

Behavior	Emotion	Messages
General safe driving	Humor	NOBODY PUTS BABY IN A HOT CAR
		DON’T YOU FORGET ABOUT ME AS YOU DRIVE ON BY
		LIFE IS A HIGHWAY DRIVE SAFELY ALL DAY LONG
		BE OUR GUEST DRIVE POLITELY
		DRIVING SAFELY? I LIKE IT I LOVE IT
		BE ON SANTA'S NICE LIST DRIVE POLITELY
		WHAT'S SCARIER YOUR COSTUME OR YOUR DRIVING?
		BE A FIREWORK SPARK RESPONSIBLE DRIVING
		ZERO FATALITIES A GHOUL WE CAN ALL LIVE WITH
		SANTA'S COMING HAVE YOU BEEN A GOOD DRIVER?
	Negative	843 VA FATALITIES THIS YEAR DRIVE SAFELY
		375 MILLION US VEHICLE INJURIES IN 2017
		843 TRAFFIC DEATHS IN VIRGINIA THIS YEAR DRIVE ALERT
		757 FATALITIES SONS, DAUGHTERS. STOP THE HEARTACHE
		843 FATALITIES ON VIRGINIA ROADS IN 2018
Driving without a seatbelt	Humor	DON’T MAKE ME STOP THIS CAR! BUCKLE UP
		DUCK, DUCK, BUCKLE UP
		AWWWWW SNAP! YOUR SEAT BELT!
		BUCKLE UP AND SMELL THE ROSES
		PEACE LOVE SEATBELTS BUCKLE UP!
		PROTECT YOURSELF BUCKLE UP

Behavior	Emotion	Messages
	Negative	SECURE THE FUTURE BUCKLE YOUR CHILD
		DON'T LEAP FROM YOUR SEAT BUCKLE UP
		SEE YOUR BFF TONIGHT BUCKLE UP
		BUCKLE UP SAVE $25 AND YOUR LIFE
		72 WERE UNBUCKLED
		9 OF 17 FATALITIES UNBUCKLED THIS YEAR
		153 ROAD DEATHS IN VA THIS YEAR 66% UNBUCKLED
		37% FATALITIES WERE NOT WEARING SEATBELTS
		60% OF TEEN ROAD DEATHS IN VIRGINIA ARE UNBUCKLED
Distracted driving	Humor	GOLD MEDAL DRIVERS DON'T TEXT AND DRIVE
		MAKE IT TO THE END ZONE DRIVE ALERT
		DON'T LET SAFETY BE A HAIL MARY DRIVE ALERT
		PLAY BALL! STRIKE THE DISTRACTIONS
		BLOW THE WHISTLE ON DISTRACTED DRIVING
		GET YOUR HEAD OUT OF YOUR APPS
		TEXTING WHILE DRIVING? OH CELL NO.
		DON'T DRIVE IN-TEXT-ICATED
		AVOID AN APPSIDENT PHONES DOWN
		TEXTING & DRIVING IS CLEVER SAID NO ONE EVER
		WHO YA GONNA CALL? NOBODY YOU'RE DRIVING
		YOU HAD ME AT "I DON'T TEXT AND DRIVE!"
		THE FORCE IS STRONG WHEN YOU PUT DOWN THE PHONE
		EDDIE SAYS DON'T TEXT & DRIVE THE TWITTERS FULL

Behavior	Emotion	Messages
		WE PITY THE FOOL WHO TEXTS & DRIVES
	Negative	NO TEXT IS WORTH A LIFE
		MOM NEEDS YOUR HUG NOT YOUR TEXT
		YOUR PHONE OR YOUR LIFE? YOUR CHOICE
		ONE TEXT CAN END IT ALL
		IS YOUR TEXT WORTH THE RISK?
Impaired and drowsy driving	Humor	DON'T SNOOZE WHILE YOU CRUISE
		BE ALERT ARRIVE UNHURT
		DROWSY DRIVING IS LOUSY DRIVING
		WE'VE GOT A FEVER THE ONLY CURE IS SOBER DRIVERS
		DRINKING AND DRIVING DON'T MIX
		YOU'RE NOT A FIREWORK DON'T DRIVE LIT
		LUCK OF THE IRISH WON'T HELP IF YOU DRIVE DRUNK
		A DUI WILL EMPTY THE POT O GOLD DRIVE SOBER
		DESIGNATED DRIVERS MAKE THE BEST NEW YEAR'S DATES
		DON'T BE TRICKED DUIS ARE NO TREAT
	Negative	BLOWING .08 IS LIKE BLOWING $10,000
		JUST BUZZED? NICE TRY, THAT'S A DUI
		DRIVE HAMMERED GET NAILED
		DON'T LET YOUR TAILGATE END WITH A CELLMATE
		DRINKING AND DRIVING A GRAVE MISTAKE
	Humor	SPEEDING IS UNSPORTSMANLIKE CONDUCT

Behavior	Emotion	Messages
General aggressive driving		MARCH MADNESS? KEEP AGGRESSION ON THE COURT
		NO SHOT CLOCK DRIVING A CAR SLOW DOWN
		KEEP RIVALRIES OFF THE ROAD DRIVE CALM
		COMMUTING ISN'T A COMPETITIVE SPORT RELAX
		I THINK WE NEED SOME SPACE ONE DRIVER TO ANOTHER
		IT'S OK TO BE A SLOW POKE
		IT'S A SPEED LIMIT NOT SPEED SUGGESTION
		SPEEDING CAN LEAD TO SKID MARKS
		THAT'S THE TEMPERATURE NOT THE SPEED LIMIT
	Negative	DO NOT TELL A LIE OBEY THE LIMIT
		SPEED KILLS SLOW DOWN
		KEEP YOUR DISTANCE SAVE A LIFE
		LEAVE SOME SPACE SURVIVE THE DRIVE
		DON'T BE NEXT KEEP YOUR DISTANCE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