Honking Helps Overcome the Driving Too Slowly Problem in Driving Simulators

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In driving simulators, subjects sometimes drive more slowly than they would on real roads when not attending to driving. To address this problem, in two experiments, groups of 24 subjects drove through 138 intersections with green (53 %), yellow (36 %), or red lights (11 %). The speed limit was 35 mi/hr. In the second experiment, the following vehicle honked as needed.

The number of honks per subject varied from 0 to 6 for driving too slowly (less than 25 mi/hr) and 0 to 8 for delayed responses when a traffic light changed from red to green. Older drivers received 2.4 times more honks than younger drivers. Within 5 s after the following vehicle honked between intersections, the mean speed driven increased by 5 mi/hr. Similarly, with honking, the speed 5 s after the light changed increased by 8 mi/hr, both changes that lead to more realistic driving.

INTRODUCTION

Over time, driving simulators have been increasingly used to study motor vehicle safety (Akamatsu et al., 2013). Although fixed-base driving simulators are less expensive and easier to program than moving base simulators, fixed-base simulators are limited in how well the motion-limited scenarios represent the real world and the data collected reflect on-road driving (and may be used in place of them). Green (2005) notes that a particular limit of driving simulators, especially fixed-base simulators, is that the impression of speed is imperfectly represented. For example, when distracted, or when the external demands are great, subjects slow down too much. In contrast, in the real world, when people drive too slowly, other drivers honk at them and they respond by accelerating. In urban settings, this often occurs midblock between traffic lights. In addition, if drivers respond too slowly to a traffic light changing from red to green, other drivers will honk as well. Thus, this paper poses the following question, “Does having other vehicles honk change how people drive in a simulator?”

Given this question, what does the literature say about when and why drivers honk? Being a rather narrow topic, the literature on horns and horn use is limited. Among them are studies on desired horn acoustic qualities (e.g., Lemaitre et al., 2007, 2009; Shin and Lee, 2014), some classic studies examining the role of horn-honking as a facilitator or inhibitor of driver’s aggression (Doob and Gross, 1968; Diekmann et al., 1996), and a series of surveys from Japan and Korea on why drivers use horns (Takada et al., 2010; Takada et al., 2013; Takada et al., 2014; Takada et al., 2014). Based on his surveys, Takada notes that driver intentions (to gain another’s attention (1/2 of the responses), inform of other drivers of danger (1/4 of the responses), express gratitude, vent anger, etc.) are indicated by the timing of honks. Thus, the literature provides useful context concerning honking, but it does not directly address the question of interest.

Accordingly, three issues pertaining to honking in a simulated urban setting were examined. Specifically:

Issue 1: How often did honking occur? Were there any differences in frequency of occurrence due to driver age, gender, block, time within a block, or the triggering rule?

Honking was expected to occur a few times for each subject, but there was no basis to estimate what those counts would be. As older subjects tend to drive more slowly than younger subjects, they were expected to receive more honks, but there was no basis to estimate what those counts would be.

Issue 2: Did drivers alter their speed after honking occurred, and if so, by how much? Were there any lasting effects of receiving a honk?

Honking was expected to cause drivers to speed up, and based on the Integrated Vehicle-Based Safety Systems (IVBSS) experiment concerning lateral warnings (Green et al., 2008), a noteworthy change was expected within 1-2 seconds of when the honk occurred. Exactly how much of increase would occur was unknown.

Issue 3: After honking occurred, did drivers look for its source?

As the following vehicle was honking, and the sound was made to appear to be coming from the rear, subjects were expected to look at the virtual rear view mirror for confirmation. However, as the rear scene had limited useful content that could affect their driving (except for some intersections where subjects could be concerned they would be rear-ended if they stopped too abruptly), rear-mirror use was expected to be low. There was no data on which to make a more precise prediction of interior rear mirror use in this simulation.

METHOD

The experiments reported here, two of three being conducted, were part of a project to model driver decision making at intersections and examine the value of augmented
reality warnings (Hoehener et al., 2015). The first experiment (baseline driving) is described in Lin et al., (2015) and a report on the second experiment is being produced in which honking and augmented reality warnings were added. The third experiment (varying warning timing) is in process. All three experiments share the same virtual world, described later. This paper concerns what happened in response to honking, and how driving performance without and with honking differed (experiments 1 vs. 2).

Simulated World

The simulated urban world (Figure 1) consisted of 69 signalized intersections that were 200 m (660 feet) from center to center. The first five and last three intersections were for practice and for ending the block, respectively. The end-of-block intersections were included so subjects would not stop at the last test intersection because the end of the simulated world was reached.

Three scenario-related factors were varied in these experiments -- 3 traffic light states (green (36%)/yellow (53%)/red (11%)), 3 time-to-intersection durations (arriving at the stop line, 2.8 s / 3.5 s / 4.2 s after which the green changed to yellow), and traffic conflicts. Yellow lights were most frequent because responses to them were the focus of this research. Of the 69 intersections, there were potential traffic conflicts at 10 of them, all of which had either a yellow or green light. Conflict types were selected based upon NHTSA data for the relative frequency of those conflicts that could be accommodated with 10 intersections (Najm et al., 2001): 4 for LTAP/OD (Left Turn Across Path/Opposite Direction), 2 for SCP (Straight Crossing Path) and RTIP (Right Turn Into Path), and 1 for LTIP (Left Turn Into Path) and LTAP/LD (Left Turn Across Path/Lateral Direction). At other intersections, precursors to the conflicts examined occurred so when the actual conflicts would occur was unpredictable. For example, a crossing vehicle would approach an intersection and stop. In the second experiment, augmented reality warnings were presented when conflicts occurred.

Driving Simulator

A fixed-base National Advanced Driving Simulator MiniSim was used in these experiments (Figure 2). The simulator was equipped with three 24-inch LED monitors covering a 130-degree forward field of view of the road scene. There were two speakers in front of the subjects and two speakers behind them. The instrument cluster was shown on a 16-inch LCD monitor in front of and below the scene monitors. The simulator was controlled by a custom-built Intel i7 Sandy Bridge 3.20 GHz computer with a GeForce GTX 780 graphics card. In the second experiment, an eye-tracking device (Gazepoint GP3, 60 Hz) was installed above the instrument cluster to determine where subjects looked. Two cameras at the front and back of subjects and a camera in eye tracker

Figure 1. Typical road scene

Figure 2. Experiment configuration and a participant

Honking

The 300 ms horn sound sequence consisted of two 100 ms beeps separated by 100 ms. The sound was typical of a car in the U.S. and was found on the Internet. See http://www.soundboard.com/sh/Car_Horn_Sounds for an example. See also SAE standard J377 (Society of Automotive Engineers (2007).

Honking of a following vehicle in this experiment was triggered by two rules shown in Table 1. The conditions that triggered honking were determined by trial and error, and were intended to balance getting subjects to drive close to the desired speed with the annoyance of other drivers honking. The speed limit on the simulated urban roads was 35 mi/hr.

What constitutes driving too slowly is a judgment based on the speed of other vehicles in the traffic stream, the road surface, vehicle, and driver conditions, the sight distance, and
other factors. For this experiment, driving more than 10 mi/hr below the posted speed was too slow.

Table 1. Honk Rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>Honk When All Conditions Are True</th>
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</table>
| Honk Rule 1:                | • Vehicle speed < 25 mi/hr  
| Too slow between intersections | • Traffic light = “green”  
|                             | • Following vehicle is close (spatial center separation with following vehicle < 50 feet)  
|                             | • > 150 feet from center of intersection                                                                                                                                 |
| Honk Rule 2:                | • Vehicle speed < 10 mi/hr  
| Excess delay after light changes | • Time after red turns green ≥ 5 s  
|                             | • Following vehicle is close (spatial center separation with following vehicle < 50 feet)                                                                                           |

Experiment Design and Procedure

The dependent variables for each rule were (1) the number of honks triggered, (2) the speed increase or decrease after honk occurred across a 10-second time window, and (3) where drivers looked after honking occurred. The independent variables were (1) subject age (young and old; 18-30 and over 65), (2) subject gender, (3) the honk rules (1 and 2), (4) the test block (first or second), and (5) when in each block honking occurred (beginning/middle/end, corresponding to intersections 1-23 / 24-46 / 47-69, respectively). The second block was the reverse sequence of intersections from the first block, except for a few start up (practice) and ending intersections. The first experiment also included a third block to collect data for highway driving for another project and a post-test survey that will be reported elsewhere.

After the test procedure was described, subjects practiced driving for 10 minutes in a small world similar to the test world while guided by the experimenter. Subjects were asked not to drive too slowly or screech the tires, an indication of excessive aggressiveness. Their task was to drive straight a series of intersections while following a lead vehicle, observing all traffic laws and lights, and not crashing. The task completion time for each block depended on how fast each subject drove and how many yellow lights they ran, but the time was typically less than 30 minutes.

Participants

In each experiment there were 24 licensed drivers, divided into 4 groups equal in age (18-30 (means of 21 and 22 for experiments 1 and 2, respectively), over 65 (means 71 and 72)) and gender. They were paid $50 for approximately 2 plus hours of their time. One subject who suffered from motion sickness in each experiment was allowed to withdraw but was paid in full. That subject was replaced. All subjects had normal or corrected normal vision. The younger and older groups drove means of approximately 10,500 miles and 11,500 miles per year for experiment 1 and 7,000 and 10,000 miles per year for experiment 2. Subjects in experiment 1 reported that they drove through a mean of 10 intersections per day with traffic lights. For experiment 2, the value was 11 traffic lights per day. Thus, subjects responded to traffic lights on a regular basis in their real world driving.

RESULTS

How often did honking occur?

In experiment 2, with 24 subjects, 2 blocks/subject, and 69 intersections of interest, there was a total of 3312 intersection exposures for each rule, though rules could be triggered more than once per intersection per subject. Overall, subjects received 139 honks. The number of honks varied with the rule, 73 for rule 1 (too slow between intersections) and 66 for rule 2 (excess delay after traffic light change).

As shown in Table 2, there were pronounced subject differences. Per subject, the number of honks experienced was from 1 to 13. The major difference was due to age, with the number of honks for older subjects being 2.4 times that of younger subjects (means of 4.1 and 1.7 honks per block). This finding is consistent with the predicted age difference. A Kruskal-Wallis test of the number of honks (which was not normally distributed) triggered during experiment revealed a significant difference between older and younger subjects (H(1)=21.623, p=0.000). However, between rules, the age difference is more pronounced for delays after the light changes (older to younger ratio of 2.9) than driving too slowly (ratio of 2.1). There were no gender differences of note.

Table 2. Mean ± Standard deviation of the Number of Honks per Subject per Block (69 intersections)

<table>
<thead>
<tr>
<th>Rule</th>
<th>Young</th>
<th>Old</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Male</td>
<td>Female</td>
<td>Male</td>
</tr>
<tr>
<td>1 - slow</td>
<td>1.1±0.7</td>
<td>0.9±0.4</td>
<td>1.9±0.4</td>
</tr>
<tr>
<td>2 - delay</td>
<td>0.6±0.4</td>
<td>0.8±1.1</td>
<td>2.2±1.0</td>
</tr>
<tr>
<td>Total Mean</td>
<td>1.7±0.9</td>
<td>4.1±1.3</td>
<td></td>
</tr>
</tbody>
</table>

Interestingly, there was a small increase in the number of honks between blocks (67 for the first, 72 for the second), the opposite of what was expected. As shown in Figure 3, there were significantly more honks in the first sub-block than in the 2 that followed (88 (63 %) for sub-block 1 > 23 (20 %) for sub-block 2 > 28 (17 %) for sub-block 3; Mann-Whitney U test, H(2)=49.56, p=0.000). If honks are thought of as arrivals over time in an operations research sense, their interarrival time should be an indicator of their independence. As the number of honks increased over time, the time between honks should also increase. There was no apparent pattern (Figure 4).
Did drivers alter their speed after honking occurred?

To examine the effects of each rule, for each instance in experiment 2 where honking occurred, a matching instance in experiment 1 was found (same intersection, same subject age-gender group). (Note: None of the subjects from experiment 1 participated in experiment 2.) As shown in Figure 5, the effect of providing a honk is visibly pronounced as desired. The reason that the mean speed was less than the 25 mi/hr trigger is that the subject vehicle speed was constrained by the lead vehicle speed, and sometimes, for example, when accelerating after having stopped at a traffic light, the lead vehicle speed was less than 25 mi/hr.

A one-way ANOVA results showed that there is a significant between-rule difference in speed change in 5 seconds ($F(1, 134)=75.3, p=0.000$). The speed increase due to Rule 2 (delay after light change, Mean=17.7, SD=7.1) is greater than by Rule 1 (midblock speed was less than 25 mi/hr, Mean=7.4, SD=6.7). The change in speed within five seconds occurred as predicted, the desired consequence of honking. There were no statistically significant differences due to any other factors (gender, age, block, sub-block, or their interactions).

After honking occurred, where did drivers look?

The video of the subject’s face (showing where subjects looked) was manually synchronized with an audio-video recording of the forward scene (on which honking could be heard). The window of interest was from when the honk occurred until two-seconds later.

The analysis was only performed on 12 subjects (11 of them were in younger group) because the eye-fixation system was not sufficiently reliable for subjects who wore glasses or contacts. Although the low-cost eye-fixation system used had its limitations, where subjects looked was apparent, with only 4% of the responses being unknown. Specifically, subjects looked at the interior rear view mirror 43% of the time when a honk occurred, in contrast to normal glances on the road, which were rare. There were no glances to the exterior mirror in response to honking. When honking did not occur, glances to any rear view mirror were rarely observed. Thus, honking induced subject to look for the source of the honking sound from behind them, as would be the case in real driving.

Furthermore, across blocks, the number of honks was somewhat stable (26 for block 1, 20 for block 2). However, there was no tendency for subjects to stop looking at the mirror in response (40%=8/20 for the first honk in both blocks, 46%=12/26 for the second honk and beyond), suggesting the feature should not be turned off as subjects become accustomed to driving.

CONCLUSIONS

Per subject, honking to drive faster occurred from 0 to 6 times and honking to start moving occurred from 0 to 8 times
for the 138 intersections through which subjects passed. Every driver received at least one honk. Older drivers received more honks than younger drivers by a factor of 2.4, so providing honking for all drivers in simulator studies is important, but particularly older drivers.

More than 60% of the honks occurred in the first third of both test blocks. If anything, completion of the first subblock should lead to the desired adjustments in the second subblock. This raises questions about how much practice should be provided and when.

In response to honking by a following vehicle between intersections, subjects increased their speed by 5 mi/hr in 5 s. In experiment 2, when honking was not provided, the speed did not change. In the case of delay after a traffic light change (red to green), honking led to a speed increase of 20 mi/hr in 5 s vs. 12 mi/hr when it was not provided, a substantial difference. These changes led to driving performance that should more closely resemble the real world.

One next step could be to refine the triggering rules based upon the statistical distributions of speeds in urban settings for a particular posted speed as well as on the distributions of delays in responding to traffic lights.

Nonetheless, the primary finding stands -- drivers respond to honking of a following vehicle by speeding up to the posted speed if moving, and by beginning to move if not moving (or driving faster if they were just beginning to move). Others using driving simulators should include following vehicles that honk as was done here. Implementing honking is particularly important for driver distraction studies, where highly distracting and lengthy tasks can lead to driving at speeds that would be dangerous on a public road (e.g., 60 mi/hr on a road with a posted speed limit of 70 mi/hr and minimal traffic).

REFERENCES


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