Technical Report ECE.P54.2008.3
November 7, 2008

Interacting with a Keyboard and Display while Driving

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I. Abstract

In real life, myriads of sources become the cause for engendering driver distraction, the end result being unfortunate accidents. With the growing trends of technology, the portable laptops have become ubiquitous in almost all the environments. However, a need arises to analyze what a simple aspect of laptop that is, typing on a keyboard and simultaneously gazing the typed text for some time on the attached display screen, can have on the driver performance. We present the first study of obstacle testing and keyboard-display based driver interaction, examining its effects on the drivers navigating a typical freeway in a driving simulator. Drivers encountered a few critical events such as a barrel falling from a truck, merging vehicle from an elevated T shaped interchange, vehicle cutoff , deer incursions and lead vehicle braking events. Results showed that performing such an interaction had a significant effect on driver performance as measured by the lateral deviation from the lane center, the steering wheel angle variance and the frequency of collisions. Given that the keyboard-display interaction is one of the several elementary distractions, the results discussed would serve as the baseline for the comparatively bigger experiments to follow in the obstacle testing domain.

II. Introduction

Portable devices like music players, Apple Ipods , laptops etc. have witnessed a tremendous spurt in popularity in the recent years. While these devices provide a flavour of entertainment and information, their use has become increasingly common in one particularly dangerous situation : in-vehicle use while driving. Quite surprisingly, although a plethora of research has been done on the driver distraction while interacting with mp3 player, the authors could not find sufficient research literature describing the influence of a working on a laptop, just like typing a text and observing it on the display, on the driving performance. In some states of USA, working on laptops while driving is still legal. Laptops are installed in the police cruisers and in many situations the police officers have to use them to insert the leading vehicle plate number into their database. This situation, just like many others, leads to driver distraction.

Our group at UNH has developed and deployed the Project54 system that integrates all the electronic devices in a police cruiser (radar, radio, lights, sirens, etc.) into a single system. The group has been working on analyzing different factors that may lead to driver distraction. In our pilot experiment for obstacle testing, we tried to visualize what effect a laptop interaction might have on the driver performance. For this, a simple keyboard and display was set up. In this experiment, the participants drove in a driving simulator while occasionally performing tasks on the keyboard - display setup. Simultaneously, some critical events were added at some fixed locations to observe the distraction effects. Thus, the study aimed to provide an initial exploration into the effects of obstacle based driver distraction and keyboard-display interaction on driver performance.

III. Background

According to Stutts et al., 2003 , "Driver distraction is the momentary or transient redirection of attention from the task of driving to a thought, object, activity, event or person, and encompasses actions such as eating, grooming, talking with a passenger and so forth.". Also, "Driver distraction in its various forms contributes to an estimated 20 to 30 percent of all collisions. A US study determined driver distraction to be a factor in about nine percent of serious or fatal crashes, based on police-reported crashes involving over 32,000 vehicles from 1995 to 1999", as discussed in an article published on internet by the Canada Safety Council in January 2002[1].

Although accidents involving laptop distractions while driving are rare, still the possibility of hazardous driving issues while using a laptop cannot be discarded. Many people wish that they could have access to the Internet, they could send and receive email and do other online activities while using a laptop from their car. With broadband access and the cell phone coverage, their wish has come true but alongside, it has brought in the chances of some fatal crashes. As published on an internet resource in 2007, "According to United Press International, a person in a Toyota Corolla decided it would be a good idea to get some work done on his laptop as he drove to work. End result: a multi-car accident in which he dies."[3] Similarly, in one of the other cases, Oscar Hinojosa of Chico, Calif., was killed in a crash. Hinojosa's 1991 Honda Accord collided with a 2003 Hummer. Although the official cause of the crash was listed to be "unknown," there were some other signs Hinojosa might have been working on the laptop or possibly looking at it, California Highway Police [CHP] spokesman Sgt. John Pettigrew said [2]. Figure1 shows a person using a laptop in his lap while simultaneously driving on a roadway.

Figure 1: Person using a laptop while driving

In the above figure, we can see that the person's attention is diverted towards the laptop. The effects of such a scenario have been explored further in this paper.

IV. Keyboard and Display Setup

In our experiment, we left aside the difficult tasks like watching videos on a laptop and simply restricted ourselves to a very basic typing and an observing operation on the laptop. We tried to portray the above constraint by employing a keyboard and an attached display placed just above that keyboard. The task was further simplified by attaching keyboard and the display at a certain elevation such that some amount of a participant's horizon was still on the roadway while being involved in the designed task. Figure2 shows the experiment setup.

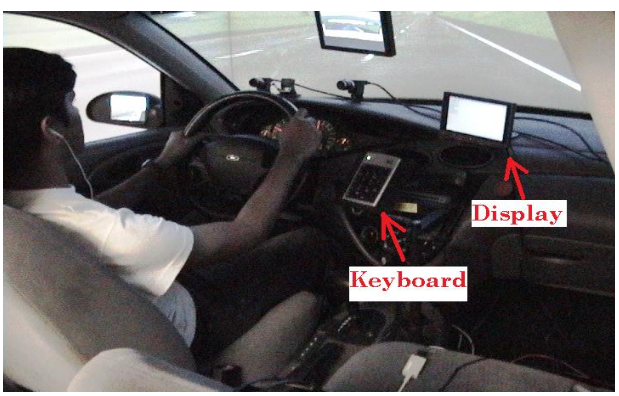


Figure 2: Keyboard – Display Setup

V. Experiment

We conducted a pilot study to investigate the influence of a simple keyboard and display interaction on the driving performance. The experiments were conducted in a high-fidelity driving simulator with a 180º field of view, a car cab and a motion base to simulate acceleration and deceleration tilt. The simulator is shown in Figure 3.

Figure 3: The Driving Simulator

The simulation presented a 4-lane and 6-lane freeway, each lane being 3.6 m wide, specifically in daylight with straight, curved and T-shaped interchange sections.

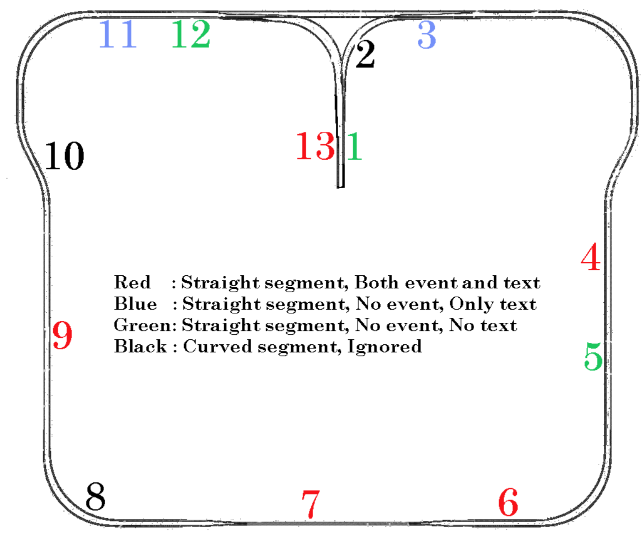


Figure 4: The Driving Scenario with 13 segments.

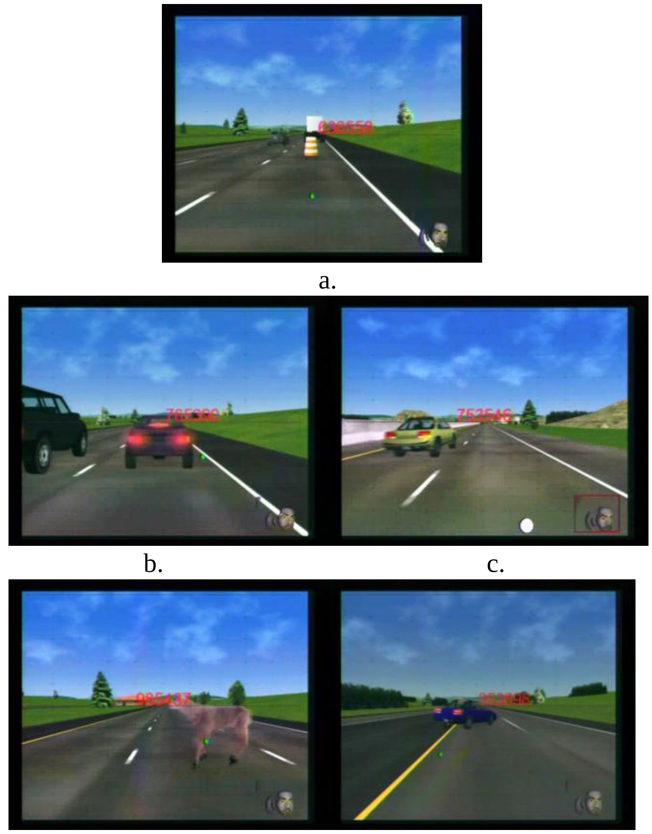
During the simulation, a six digit number appeared on the simulation screen and the subject was asked to type that number using the keyboard and the display setup. The text remained on the screen for five seconds, after which it would disappear, thus creating a sense of urgency for the subjects. In our analysis, the whole scenario was divided into 13 segments out of which 10 segments were straight and the remaining 3 were curved segments. The comparisons for the curved segments have been ignored. The 10 straight segments were further split up into three categories. The first category included 5 segments where an event occurred and the user had to type the text which appeared on the screen in conjunction with that event. The second category comprised of 2 segments where the user had only to type a text, no event being involved. The third and the last category consisted of 3 segments that were simple straight segments with no task or event involved. The map of the simulation scenario can be seen in Figure 4.

Five critical events namely a barrel falling from a truck, merging vehicle from an elevated T shaped interchange, vehicle cutoff , deer incursion and lead vehicle braking were created at some fixed locations in the scenario. The designed critical events are shown in Figure 5. Each critical event was designed to be a surprise event for the driver and required timely response to avoid a collision. The scenario was developed and run in Hyperdrive.

The simulation of a barrel falling from a moving truck was a knotty task. Due to the limitations of Hyperdrive, it was not possible to keep the barrel, a static entity, in motion with the truck, a kinematic entity. An attempt was made to create a barrel with dynamic properties and then relocate it along the roadway at a certain height above it. However, while Hyperdrive relocated the barrel along the roadway, the barrel could not be placed above the level of the roadway.

To overcome this problem, the possible positions of the barrel were pre-estimated, assuming it was in motion with the truck, and then the barrels were placed in midair at those specific coordinates. Initially, all the barrels placed in midair were made invisible and further during the simulation, the barrels were made to switch between visible and invisible states in a consecutive fashion to achieve synchronization with the motion of the truck. Finally, when the subject came within a suitable distance relative to the truck, a separate set of barrels set for a projectile-like motion was triggered in the same visible and invisible fashion to achieve an appropriate declivity. Since the barrels that were pre-placed were limited and not certain, the desired effect might not be obtained in case the number of barrels in midair reduced to zero when a subject approached the truck too slowly or he went on to a different lane.

The five events were so designed that a collision might not occur if the driver followed the speed limit directions and paid attention to the roadway. However, there were certain cases when the subjects went over a particular defined speed limit or went at a speed that was far below the speed limit. Thus, there might still be a possibility to further tune the designed events. The scenario was tested on four subjects, all four being the students of University of New Hampshire. We videotaped the experiments and recorded the lane positions and steering wheel angles from the simulator. A higher variance of lane position or steering wheel angle represents worse driving performance.



a. b. c. d. e.

Figure 5: Critical Events with a six digit number on the screen a) Barrel falling from a truck b)Lead Vehicle braking c) Vehicle Cutoff d) Deer Incursion e) Merging Vehicle from T shaped Interchange.

VI. RESULTS AND DISCUSSIONS

The detailed collected data is presented in Table 1 at the end of this paper. The abbreviation St. has been inserted in the table to denote straight segments. The 'text trigger' field depicts if a text trigger was present at a specific location. However, 'text output' field indicates if a text was actually displayed on the screen. This was necessary because a text might not get displayed at a location due to a few reasons that are described further in this paper. Also, the table provides the information if a collision occurred during a typing task and its subsequent reasons. The bracketed characters in the 'reasons' column carry additional information about the collision, or why it did not occur. The character T indicates a collision due to the driver distraction based on the text display. The character N represents a collision avoidance due to the normalization factors that is, a subject won't collide during an event if he follows the speed limit constraints. DL stands for collision avoidance in case a subject was present in some different lane or in other words, since the subject was present in a different lane other than the lane in which the event was planned, no collision occurred. AT denotes collision avoidance for a particular subject in case the event trigger was unsuccessful in the presence of high ambient traffic. For example, there might be a case when during a merging vehicle event, the vehicle could be unable to merge into the lane of the subject because the headway distance between the subject and the leading vehicle (ambient traffic) might be too small for the merge to occur. Thus, the merge will not happen and so, no collision would occur. One particular field has been marked as "Ab Sl" under the data for user1 in Table 1. This actually denotes a particular case (merging vehicle event) when the subject went at a much higher velocity and thus, there was no chance for the merging vehicle behind the subject to catch up to him, overtake him and merge into his lane. The rest of the subjects, without any outside interference, went at acceptable speeds and thus avoided that particular situation.

The collected data has been analyzed in terms of collision frequency, lane variance and the steering wheel angle variance. Figure 6 shows a Collision chart for the four subjects. In case a collision did not happen due to a different lane condition or due to the presence of ambient traffic, those cases were not included to calculate the collision frequency.

Event	User1	User2	User3	User4
Barrel	Yes(T)	No(DL)	No(DL)	Yes(T)
Lead Vehicle Braking	Yes(T)	No(DL)	No(AT)	Yes(T)
Vehicle Cutoff	No(N)	Yes(T)	No(AT)	Yes(T)
Deer Incursion	No(N)	Yes(T)	Yes(T)	No(DL)
T shaped Interchange	Yes(T)	No(N)	Yes(T)	Yes(T)
Collisions	3/5	2/3	2/2	4/4

Figure 6: Collision Chart for four subjects
* T: Text, DL: Different Lane, N: Normalization, AT: Ambient Traffic, Total events = 5

Figure 7 shows a sample of the driver performance for a particular subject. For this particular user, some variables like acceleration, brake, velocity, lane position offset and steer were recorded to graphically visualize the driver performance in presence of an obstacle. The following graph presents the above variables for user1 due to driver distraction and collision with a car appearing on a T shaped interchange.

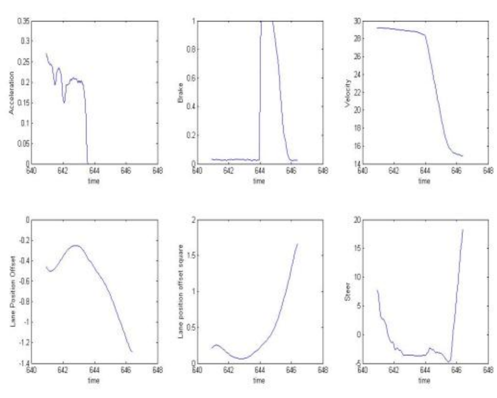


Figure 7: Graph for user1during T interchange collision
Row1: (Acceleration, Brake, Velocity) vs. Time
Row2: (Lane Position, Lane Pos square, Steer) vs. Time

While Figure 7 showed the driver performance in terms of steering wheel angle and lane position offset graphically, a detailed analysis recording the steering wheel angle variance and lane variance was also performed. Figure 8 and Figure 9 demonstrate the Average Steering wheel angle Variance chart and the Average Lane Variance chart for the four subjects. User 4, as shown in Figure 2, was wearing earphones, although it was not a part of the experiment. However, some important results came into picture. The average steering wheel angle variance for user 4 were found to be the highest amongst all the four subjects. Also, the average lane variance too followed the same criteria. Thus, the collected data for user4 indicates that wearing earphones while performing the typing task and/or during the event occurrence exacerbated the driving performance.

Keeping aside user4, the average steering wheel variance and the average lane variance were found to be the largest for user1 amongst the rest of the three subjects. The collected data indicates that the driving performance for all the subjects deteriorated when each subject had to perform the typing task concurrently during an obstacle appearance. In comparison with the lane and steer variance data for the typing and event category, both variances decreased enormously when the subjects performed the typing task in the absence of an event. Also, these variances were smallest when neither some text nor an event appeared while driving.

Category	User1	User2	User3	User4
Event and Typing	62.74	6.787	6.031	96.29
Only Typing	3.284	1.556	1.262	18.15
No Event, No Typing	1.752	0.856	0.054	4.91

Figure 8: Average Steering wheel angle Variance

Category	User1	User2	User3	User4
Event and Typing	0.101	0.016	0.027	0.283
Only typing	0.085	0.006	0.009	0.072
No Event, No Typing	0.037	0.002	0.001	0.015

Figure 9: Average Lane Variance

The above detailed analysis suggests that the driver performance was worst when an event occurrence overlapped the typing task but improved drastically when the subject's attention was completely focused on the roadway. This result supports our hypothesis, that driver distraction and obstacle hindrance significantly impaired the driver performance.

VII. Conclusion and Future Directions

In this paper, we describe the influence of a keyboard and display interaction on the driver performance. We found that the performance decrement was eminent during an obstacle appearance and the typing distraction. However, it improved significantly during the absence of both, thus indicating the consequences of the keyboard-display interaction on driving performance.

Besides the simulation data collected from Hyperdrive, important data was collected from an eye tracker. The eye tracker provides valuable information about the pitch and the yaw of the gaze for the subject. Moreover, the eye tracker follows the gaze of the subject and gives the exact coordinates where the gaze of the subject intersects the simulation screen. These coordinates can be analyzed using different models, some of them being the world model and the screen pixel model. An attempt was made to correlate the gaze data collected from the eye tracker with the steering wheel angle and lane data collected from the simulation. However, that study could not be completed due to certain time constraints. A glimpse of the gaze data for the same user1 during the T interchange collision (see figure 7) has been displayed in the figure 10.

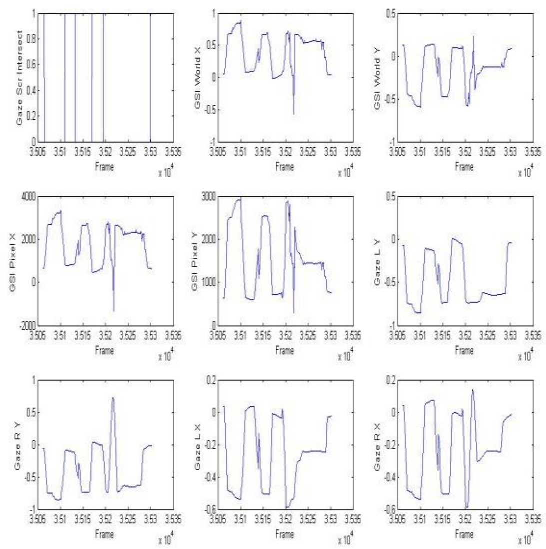


Figure 10: Eye tracker graph for user1 during T interchange collision
Row 1: (Gaze Screen Intersect, world coordinate X, Y)
Row2: (Gaze Pixel Coordinate X, Y, Gaze Left eye Pitch)
Row3: (Right Eye Pitch, Left eye Yaw, Right Eye Yaw)
All vs. Frame numbers

Some important inferences can be drawn from the above gaze data displayed in Figure 10. The three columns in row 1 of figure 10 provide information about three variables, gaze scr intersect, gaze world X coordinate and the gaze world Y coordinate. Gaze scr intersect provides binary information about whether the subject's gaze intersected the screen or not during a particular time interval. When this value is 1, the subject is assumed to be staring at the screen. On the other hand, the value 0 for the gaze scr intersect signifies that the subject's gaze is not intersecting the screen or in simpler words, the subject is looking away from the screen at some other world model object. The remaining two fields in row 1 give the coordinates where the gaze intersects the simulation screen. Similarly, the first two columns in row2 supply information about the coordinates in the pixel model where the gaze intersects the simulation screen. Also, the last column in row 2 presents the information about pitch for the left eye. Similarly, the pitch and the yaw data for the right eye can be obtained from the graph in Figure 10.

The fixed gaze followed by abruptly changing world model and screen pixel coordinates indicate that the subject first gazed at the keyboard for some time, then looked at the text on the screen and then again stared at the keyboard for a certain time interval. Also, the eye pitch and the yaw denote the angular change in the gaze direction for a person. The variations in pitch and yaw would have remained minimal in case the subject had been staring in a particular direction. However, the prominent angular variations for the left and right eye pitch and yaw again signal that the subject looked at the keyboard, then at the screen and again at the keyboard during the same time interval. The gaze data collected from the eye tracker was analyzed in the worldview software. Using this software, video frames were extracted which verified that the subject stared at the keyboard-display setup when an event occurred or when the subject used the keyboard display setup.

In the future attempts, the study correlating the eye tracker data and the simulated data can be further improved. The eye pitch variance and yaw variance can be included in the analysis, giving special attention towards the data collection rates for both, the simulation and eye tracker. Also, it would be interesting to see what differences or improvements might occur if audio is used to announce the text/number instead of displaying it on the screen.

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Segment	1	2	3	4	5	6	7	8	9	10	11	12	13
Type	St.	Curved	St.	St.	St.	St.	St.	Curved	St.	Curved	St.	St.	St.
Name				Barrel		Lead Vehicle Braking	Cutoff		Deer				Tpoint
User1													
Text trigger	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Text output	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	No	Yes
Event	No	No	No	Yes	No	Yes	No	No	Yes	No	No	No	Yes
Steer Var	2.611	12.556	3.284	47.24	0.49	40.656	-	16.573	156.21	24.60	-	0.622	6.845
Lane Var	0.033	0.0108	0.085	0.062	0.024	0.0962	-	0.0005	0.22	0.056	-	0.005	0.026
Collision	-	-	-	Yes	-	Yes	No	-	No	-	-	-	Yes
Reason	-	-	-	T	-	T	Ab SL	-	N	-	DL	-	T
User2													
Text trigger	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Text output	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Event	No	No	No	Yes	No	Yes	Yes	No	Yes	No	No	No	Yes
Steer Var	0.02	4.36	0.263	16.82	1.214	2.0705	3.9934	8.2736	5.8479	6.6027	2.848	1.334	5.207
Lane Var	5E-7	0.1598	3E-6	0.006	0.002	0.0015	0.0083	0.0033	0.033	0.021	0.011	0.003	0.031
Collision	-	-	-	No	-	No	Yes	-	Yes	-	-	-	No
Reason	-	-	DL	DL	-	DL	T	-	T	-	-	-	N
User3													
Text trigger	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Text output	No	Yes	Yes	Yes	No	Yes	No	Yes	Yes	Yes	No	No	Yes
Event	No	No	No	Yes	No	Yes	No	No	Yes	No	No	No	Yes
Steer Var	0.045	3.525	1.262	1.082	0.010	14.7379	-	22.351	1.962	6.835	-	0.106	6.345
Lane Var	0.001	0.0098	0.009	0.002	8E-5	0.0516	-	0.1888	5E-4	0.0071	-	0.002	0.054
Collision	-	-	-	No	-	No	No	-	Yes	-	-	-	Yes
Reason	-	-	-	DL	-	AT	AT	-	T	-	DL	-	T
User4													
Text trigger	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Text output	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Event	No	No	No	Yes	No	Yes	Yes	No	Yes	No	No	No	Yes
Steer Var	0.697	50.982	18.15	47.05	13.26	193.487	182.89	13.679	4.3975	24.183	-	0.771	53.64
Lane Var	0.006	0.0608	0.072	0.025	2E-2	0.5411	0.0195	0.6525	0.576	0.1277	-	0.005	0.251
Collision	-	-	-	Yes	-	Yes	Yes	-	No	-	-	-	Yes
Reason	-	-	-	T	-	T	T	-	DL	-	DL	-	T

Table 1 : The collected data