Bridging the communication gap: a driver-passenger video link

Tai, Grace; Kern, Dagmar; Schmidt, Albrecht

Bridging the Communication Gap: A Driver-Passenger Video Link

Grace Tai*, Dagmar Kern[+], Albrecht Schmidt[+]

[*] RWTH Aachen
[+] Pervasive Computing and User Interface Engineering Group, Universität Duisburg-Essen

Abstract

In a recent large-scale naturalistic study, driver-passenger interactions were identified as a major source of driver distraction. According to this study, driver inattention to the road is often caused by conversation with passengers. This suggests that when driving and conversing with passengers, drivers attempt to bridge the visual communication gap with passengers by turning to look at them. In an online survey presented in this paper, responses confirmed that most drivers interact with their passengers while driving and and want eye contact during these interactions; however most would also prefer to keep their eyes on the road while driving. To address these conflicting preferences, a driving simulator user study was conducted with a monitor-based and a head-up display (HUD) video system. Results show that a video system can provide drivers with greater visual contact with passengers without degrading driving performance. Participants also had greater interest in using a HUD-based system.

1 Introduction

In an effort to develop systems that help drivers avoid accidents, much research has focused on determining what factors contribute to car accidents. Fatigue and mobile device usage have received a lot of attention, while driver distraction due to interactions with passengers has been largely overlooked. Studies that do investigate passengers as a source of distraction tend to focus on how the gender and age of the driver and passengers correlate to crash risk, e.g. (Geyer & Ragland 2004; Lerner et al. 2005; Stutts et al. 2005), but results have shown that passenger presence can have both protective and harmful effects on the drivers (Regan & Mitsopoulos 2001). Researchers seem to agree that more knowledge is needed to understand how passengers cause driver distraction and when this leads to a greater risk of accident. In (Vollrath et al. 2002), researchers found that although passenger presence had a positive effect on drivers, “passengers may also distract drivers’ attention in an amount which cannot be compensated for in all situations and by all drivers by cautious driving”. In

(Lerner et al. 2007), it is concluded that although adult drivers can be substantially distracted by passengers, the "causal basis of passenger influences" needs to be addressed further.

One of the difficulties in determining the effect of passenger interaction on crash risk is that previous studies, e.g. (Geyer & Ragland 2004), (Lerner et al. 2007), (Stutts 2001), and (Stutts et al. 2005), have relied heavily on police reports in large-scale databases like the NASS Crashworthiness Data System[1] or the Fatal Analysis Reporting System[2] to determine whether passenger presence affects driver distraction. Although these sources provide a great deal of data that apply to a large demographic, many records are often incomplete, e.g. *attention status* or *cause of accident* are listed as *'unknown'*. Detailed accident reports are also not completely reliable, since drivers are interviewed after a crash has occurred may not be cognizant of their pre-crash behavior or want to admit to being inattentive while driving.

In contrast, naturalistic studies on driver distraction, which instrument users' cars with sensors and cameras, are capable of obtaining objective and complete information about drivers' pre-crash behavior. Unfortunately, such studies are expensive to perform and require a large observation period in order to collect enough crash-related data for a meaningful analysis. Thus, the findings from a recent 100-car naturalistic study carry a significant amount of weight compared to previous studies.

1.1 The 100-Car Study

The 100-Car Naturalistic Driving Study (Dingus 2006) observed 241 drivers over a 12-to-13 month period in a metropolitan area. Findings suggested that driver's glances away from the forward roadway potentially contribute to a much greater percentage of driving incidents than previously thought. The study was able to identify "Passenger-Related Secondary Task" or conversation with a passenger as "the second most frequent cause of inattention". The most frequent cause of inattention was "Wireless Device Secondary Task", which is a concern already addressed by many researchers (McCartt et al. 2006).

Previous research on the crash risk due to passengers suggests that certain combinations of gender and age of driver and passengers lead to higher crash risk while others lead to lower crash risk (Geyer & Ragland 2004), (Lerner et al. 2007), (Stutts et al. 2005). The 100-Car study, on the other hand, suggests that passengers are a major source of distraction, because they draw drivers' attention away from the road. Shortcomings in the 100-car study also suggest that distraction due to passenger interactions may have even been underestimated. In the study's setup, cameras did not record video of the backseat, making it difficult to determine when rear-seat passengers were present. Also, if the driver was talking but made no head turns, then the activity was marked as *Talking/Singing (with no passenger present)*. Similarly, interaction with the rear-view mirror was marked as Driving-related Inattention, ignoring the possibility that the driver was using the mirror to look at a rear-seat passenger.

[1] Maintained by the National Highway Traffic Safety Administration, detailed accident reports collected yearly on a sample of police-reported crashes in the US.

[2] Maintained by National Highway Traffic Safety Administration, data on all fatal crashes in the US.

In this paper, a survey of 132 participants who provided deeper insight into the behaviors that people exhibit when driving with passengers. Based on the results, a within-subjects user study was designed to determine the effect of a simple monitor-based video system and a gaze-aware head-up display (HUD) video system on a driver's gaze behavior and performance during lane-change driving task while conversing with passengers.

2 Online Survey on Driving With Passengers

To gain insight into how drivers interact with passengers while driving, an online survey was created. The survey contained 28 questions and was published in German and English. 132 licensed drivers (41% male, 59% female; 64% drive in Germany, 30% in the US) aged 18 to 73 (avg=34.5) took part. Participants had 15 years of driving experience on average. 52% drive frequently and 25% drive regularly but not everyday. All participants indicated that they engage in casual conversation when driving with passengers.

Participants were asked to rank their gaze preferences while conversing with passengers based on their own driving behavior. Most participants indicated that their highest preference was to keep their eyes on the road. For looking at rear-seat passengers, most preferred the rear-view mirror, and for front-seat passengers, most preferred side glances. About 50% are willing to turn and glance briefly at rear-seat passengers, and more than 25% would look for a few seconds at the front-seat passenger.

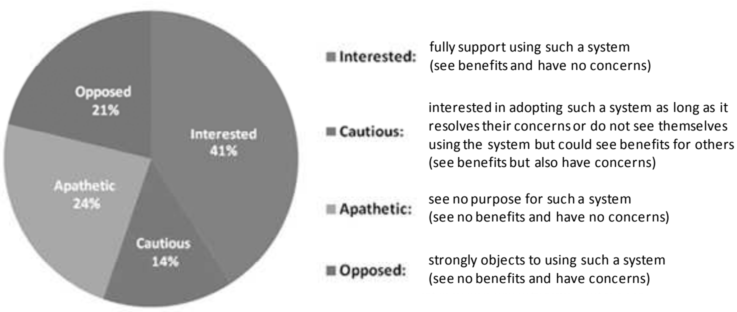

Figure 1: Attitudes towards Video System, Online Survey (N=132)

Participants were also asked about a video system that would enable drivers to see passengers without turning their heads while driving. As shown in Fig. 1, a majority saw benefits in using such a system. Also, more people would use the system to see the rear-seat passenger than the front-seat passenger. Participants who were concerned about the system said their main concern was that it would be "too distracting". Ironically, participants who saw benefits in the system felt that its main benefit was that it would be “less distracting”, helping them keep their eyes on the road. We designed a user study to address these opposing views.

3 User Study

In this user study, we chose to work with the Lane Change Test (LCT) (Mattes 2003) so that drivers had a specific driving task while conversing. We chose to investigate use of a center-console monitor display and a head-up display to present video image of the rear-seat passenger. The use of head-up displays in automobiles has received a lot of attention in the last decades (Gish & Staplin, 1995) and has been shown to offer benefits to drivers compared to traditional in-car displays (head-down displays) (Ablassmeier et al. 2007; Kiefer, 1998; Nowakowski et al. 2002). This position was preferred by 30% of the survey participants.

Our objectives were 1) to determine if the systems have a positive effect on communication between the driver and rear-seat passenger, and 2) to determine if the systems distracted the driver significantly. Additionally, we were interested in knowing if the gaze-aware HUD video system would be preferred over the Monitor video system and if there would be fewer concerns about distraction with the HUD video system.

3.1 Setup and Participants

Real carseats were installed into the driving simulator according to a midsize passenger car interior. A 42” monitor was then placed on a table in front of the seats, and a PC steering wheel was attached to the table. A plexiglass windshield was setup for the head-up display. Video of the rear-seat passenger was captured from a webcam on to an 8” LCD display above the center console (see Fig. 2, right). For the Monitor video system, this display faced the driver; for the HUD, it faced the windshield (see Fig. 2, middle). To ensure consistent visibility of the HUD image (see Fig. 3, right), the lighting conditions were fixed. Another 8” display was placed in front of the rear-seat passenger to show video of the driver.

For tracking users’ eye gaze, a Tobii X120 Eye Tracker was integrated into the setup (see Fig. 3, left). A gaze interaction was developed so that the HUD video system would be cognizant of the user’s gaze. The interaction was designed so that the video image would attract less attention while in the driver’s peripheral field of view. When the driver gazes at the video image, it is fully visible (100% opacity on LCD) but never fully blocking the driver’s view. Otherwise, the video image on the windshield is almost transparent (10% opacity).

16 participants (8 female, 8 male) took part in the study over the course of one week, none of whom participated in the first user study. Participants ranged in age from 20 to 29 (avg=24.3, sd=2.7) and have had their driving licenses for 5.8 years on average. Half of them drive on a weekly basis and most (65%) drive regularly to very often with passengers. Participants were each scheduled for one hour time slots and received €10 after completing the study.

Figure 2: LCT screenshot (left), Driver with no video system (middle-top), Driver using video system (middle-bottom), Monitor display (right-top), Rear-seat webcam (right-bottom)

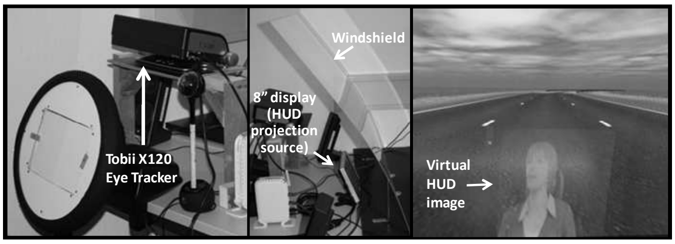

Figure 3. Eye tracker placement (left), HUD setup (middle), virtual HUD image (right)

3.2 Study Design

The study was designed based on the LCT and our driving simulator setup with two within-subject variables, Video System and Conversation Task. For the Video System, there were three levels–No video system, Monitor video system and HUD video system. For the Conversation Task, there were two levels–Article and Game (see section 4.1). The dependent variables of this study were the *average deviation from lane position* and *reaction time to lane change signals* measured by the LCT, the eye glance behavior of the driver analyzed from video, and the drivers' forward gaze data recorded by the Tobii eye tracker.

Participants first filled out a user background form. Next, the driving task was demonstrated to the participant before the participant drove once alone without talking. Then, the eye tracker calibration was completed, after which the 2 passengers were introduced. The passengers and the participant conversed for 2 minutes while waiting for the next driving task. The participant was not informed that this was a planned part of the study. Next, the participant drove 6 times, with every combination of video system and conversation task levels. The order of the conditions was permutated. Each drive lasted about 3 minutes (at 60km/hr). For Article tasks, the rear-seat passenger read a short article out loud, after which the article was discussed. For Game tasks, the rear-seat passenger had a mystery identity. The driver and front-seat passenger took turns asking questions, to which the rear-seat passenger answered “Yes” or “No”. For the HUD video system, the gaze interaction was explained to the participant. At the end, the participant drove once more alone and filled out a feedback form.

3.3 Results and Discussion

3.3.1 Data Analysis

Using the LCT analysis tool, we obtained 5 values of *average deviation from lane position* (in meters) and *reaction time to lane change signals* (in seconds) for each participant. Reference values were averaged from the first and last drives. Video footage of the participant was analyzed to obtain eye glance data from the study. Eye glance data was recorded as number of *glances* (≤ 2 seconds) and *looks* (> 2 seconds). The 2-second cutoff was chosen based on studies indicating that inattention of more than 2 seconds greatly increases the risk of an accident (Dingus 2006; Zwhalen et al., 1988). Reference values were taken from the initial conversation period in the driving simulator, during which there was no driving.

Using Tobii Studio, gaze data was measured for all drives (except the reference drives) based on two areas of interests (AOIs)–Whole Screen and HUD Area (see Fig. 4). The HUD Area was at the bottom-center of the screen, covering about 24% of the total screen. This corresponds to the same area used by the gaze interaction algorithm in the HUD system to determine when to increase/decrease the opacity of the video. The Whole Screen was a covered the entire screen. Values for # fixations and total fixation length were determined for each AOI and divided by total duration of the driving segment for comparison purposes.

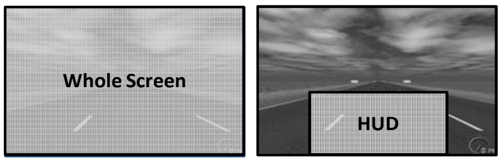

Figure 4: Areas of interests (AOIs) used in analyzing Tobii gaze data

3.3.2 Driving Performance

Participants had similar average deviation values for all conditions and for the two conversation tasks (see Table 1). A repeated measures ANOVA confirmed that there was no significant effect on average deviation due to the Video System or the Conversation Task.

Another measure of driving performance was reaction time to lane change signals (see Table 2). Paired t-tests between the Reference data and each passenger-accompanied driving situation showed a significant change in reaction time for all conditions at $p<.05$ or $p<.01$ except for No Video System and Article. A repeated measures ANOVA did not find a significant effect on reaction time due to the Video System or the Conversation Task. These results suggest that drivers are capable of maintaining lateral steering ability and situation awareness in the presence of the video systems.

		Avg Deviation (meters)	
		Mean	Standard Error of Mean
VideoSystem	Reference	0.51	0.03
	No Video System	0.54	0.04
	Monitor Video System	0.52	0.02
	HUD Video System	0.50	0.02
ConversationTask	Article	0.50	0.01
	Game	0.54	0.03

Table 1: Mean average deviation for second user study (N=14)

		ReactionTime (seconds)	
		Mean	Standard Error of Mean
VideoSystem	Reference	1.40	0.06
	No Video System	1.51	0.06
	Monitor Video System	1.53	0.06
	HUD Video System	1.50	0.05
ConversationTask	Article	1.50	0.05
	Game	1.53	0.04

Table 2: Mean reaction times for second user study (N=14)

3.3.3 Gaze Behavior

An overview of the averaged data collected on drivers' gaze behavior is shown in Table 3. All glances/min and looks/min data in the Reference condition were significantly different from all other conditions, $p<.01$[3]. Thus, drivers significantly reduced their glances at both passengers when driving. With a video system present, drivers **never** turned to see the rear-seat passenger and slightly reduced how often they turned to see the front-seat passenger.

With the Monitor video system, all but two drivers used the system to have greater visual contact with the rear-seat passenger (but not for more than 2 seconds at a time). At the same time, although drivers generally glanced more frequently at the Monitor display when using the Monitor video system, they actually spent slightly more time fixating on the forward roadway compared to when no video system was present. Thus, most drivers experienced distraction due to the presence of the video system but many seem to have compensated by also increasing their concentration on the forward roadway.

Drivers also looked more often at the HUD area when driving with the HUD video system. A repeated measures ANOVA found that the Video System had a significant effect on # fixa-

[3] SPSS result from comparing column means in Table 3 with Bonferroni correction.

tions/min at HUD Area, F(2, 22)=7.995, p=.002. Post-hoc paired t-tests found a significant difference between HUD Video System and the other two conditions, p<.01 with Monitor Video System and p<.05 with No Video System. Thus, drivers glanced more often at the HUD area (see Fig. 3) and were actively using the HUD to look at the rear-view passenger.

		Reference (No driving)	No Video System	Monitor Video System	HUD Video System
		Mean	Mean	Mean	Mean
At Front-seat Passenger	# glances/min	3.6	0.3	0.2	0.2
	# looks/min	1.1	0.0	0.0	0.0
At Rear-Seat Passenger	# glances/min	3.5	0.1	0.0	0.0
	# looks/min	1.4	0.0	0.0	0.0
At Monitor Display	# glances/min	.	.	4.1	.
	# looks/min	.	.	0.0	.
At HUD Area	# fixations/min	.	13.9	12.4	19.3
	fixation length/min (seconds)	.	3.3	3.0	5.6
At Rest of Forward Roadway (Not HUD Area)	# fixations/min	.	74.6	73.0	73.0
	fixation length/min (seconds)	.	29.2	30.4	27.4

Table 3: Gaze behavior for second user study (N=14 for glances/looks, N=12 for fixations)

Drivers also looked at the HUD area longer when the HUD video system was present. A repeated measures ANOVA showed a significant effect on fixation time/min at HUD Area due to the Video System, p<.05. Post-hoc paired t-tests only showed a significant difference between the Monitor and HUD conditions, p<.05. This suggests that although drivers glanced significantly more often at the HUD area when the HUD image was visible, they did not fixate on the HUD area for significantly longer than when no video system was present. The significant difference between the Monitor and HUD conditions can be explained by the drivers' gaze being divided between the Monitor display and the road.

An interesting side observation was that drivers showed more signs of cognitive distraction during the Game task than the Article task. With the Monitor video system, they glanced significantly less (60% decrease) at the Monitor display, p<.01. Similarly, with the HUD video system, they fixated significantly less (37% decrease) on the HUD area, p=.013. A repeated measures ANOVA also showed that drivers spent significantly less time (17% decrease) fixating on the forward roadway, F(1, 11)=10.019, p=.009.

3.3.4 Driving Errors

Driving errors consist of missing lane changes or incorrect lane changes, e.g. changing to the middle lane when a change to the left-most lane was indicated. Four participants committed a total of 11 driving errors–3 missed lane changes and 8 incorrect lane changes. All errors occurred during the Game task, suggesting that it created a greater mental workload than the Article task. Most errors (7) occurred when no video system was present and 2 occurred with each video system. This result was not significant; however, it suggests that the systems did not exacerbate the cognitive distraction that drivers experienced. To the contrary, drivers appeared to be more susceptible to cognitive distraction when no video system was present.

3.3.5 User Feedback

Participants were asked whether they preferred to see rear-seat passengers while driving and conversing with them: 9 preferred visual contact and 7 did not. Most participants preferred the rear-view mirror for gazing at the rear-seat passenger and quick glances for the front-seat passenger. Passengers also rated the difficulty level of driving with the different Video System conditions (1=not difficult, 5=difficult). No Video System was rated the easiest (1.3), and Monitor Video System (2.7) and HUD Video System (2.6) had similar ratings.

More participants saw potential in the gaze-aware HUD video system than the Monitor video system (8 participants to 2). Surprisingly, 3 of the participants who did not prefer visual contact with passengers while driving said they would also use a system similar to the HUD system. These results suggest that a gaze-aware HUD video system has greater potential than a monitor-based system to satisfy drivers' needs for visual contact with passengers.

4 Conclusion

Many studies (Dingus 2006; Lerner & Boyd. 2005; Regan & Mitsopoulos 2001), as well as our own survey, attest that when passengers are present, drivers often engage in conversation and other activities with them while driving. Even though most drivers prefer to keep their eyes on the road, many would also like some visual contact when interacting with passengers. Results from our user studies indicate that drivers can have more visual contact with passengers without significantly degrading their driving performance. Participants expressed greater interest in using the HUD video system over the Monitor system and especially liked the HUD system's gaze interaction. Using the HUD, they also turned less to look at the front-seat passenger and spent more time fixating on the forward roadway.

Unlike other studies on passenger-related crash risk, this work does not try to determine which driver-passenger combinations lead to greater risk. Instead, we recognize that visual contact is a natural element of human communication; and we present a solution that shows potential for accommodating this need in the driving context. Further tests still need to be completed to improve our prototype and test it under conditions with higher driving workload and more types of passenger interactions; however, driving performance and user feedback from our user study indicate that our solution may be a step in the right direction.

5 References

Ablassmeier, M., Poitschke, T., Wallhoff, F., Bengler, K. & Rigoll, G. (2007). *Eye Gaze Studies Comparing Head-up and Head-down Displays in Vehicles*. 2007 International Conference on Multimedia and Expo. Beijing: IEEE Press, S. 2250-2252.

Dingus, T.A. (2006). *The 100-Car Naturalistic Driving Study. Phase II, Results of the 100-Car Field Experiment*.Washington, D.C.: NHTSA.

Geyer, J.A. & Ragland, D.R. (2004). *Vehicle Occupancy and Crash Risk*. Berkeley: UC Berkeley Traffic Safety Center.

Gish, K.W. & Staplin, L. (1995). *Human Factors Aspects of Using Head Up Displays in Automobiles: A Review of the Literature*. Washington, D.C.: NHTSA.

Kiefer, R.J. (1998). *Quantifying head-up display (HUD) pedestrian detection benefits for older drivers*. 16th International Technical Conference on Experimental Safety Vehicles. Windsor: NHTSA, S. 428-437.

Lerner, N. & Boyd, S. (2005). *Task Report: On-Road Study of Willingness to Engage in Distracting Tasks*. Washington, D.C.: NHTSA.

Lerner, N., Freedman, M., Zador, P., Simons-Morton, B. & Duncan, D. (2007). *Passenge Age and Gender Effects on Adult Driver Fatal Crash Rate*. 4th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design. Stevenson : University of Iowa Public Policy Center.

Mattes, S. (2003). *The lane-change-task as a tool for driver distraction evaluation*. IHRA-ITS Workshop on Driving Simulator Scenarios. Dearborn: NHTSA.

McCartt, A.T., Hellinga, L.A. & Braitman, K.A. (2006). Cell phones and driving: review of research. *Traffic Injury Prevention*, 7(2), 89-106

Nowakowski, C., Friedman, D. & Green, P. (2002). An Experimental Evaluation of Using Automobile HUDs to Reduce Driver Distraction While Answering Cell Phones. *46th Human Factors and Ergonomics Society*, S. 1819-1822,

Regan, M.A. & Mitsopoulos, E. (2001). *Understanding Passenger Influences on Driver Behaviour: Implications for Road Safety and Recommendations for Countermeasure Development*. Monash: Monash University Accident Research Centre.

Stutts, J.C. (2001). *The Role of Driver Distraction in Traffic Crashes*. Washington, D.C.: AAA Foundation for Traffic Safety.

Stutts, J. C., Knipling, R. R., Pfefer, R., Neuman, T. R., Slack, K. L. & Hardy, K. K. (2005). *Guidance for implementation of the AASHTO strategic highway safety plan: A guide for reducing crashes involving drowsy and distracted drivers*. Washington, D.C.: Transportation Research Board.

Vollrath, M., Meilinger, T. & Krüger, H.P. (2002). How the presence of passengers influences the risk of a collision with another vehicle. *Accident Analysis & Prevention*, 5(34), 649-654.

Zwhalen, H.T., Adams, C.C. & DeBald, D.P. (1988). Safety aspects of CRT touch panel controls in automobiles. *Vision in Vehicles II*, S. 335-344.

Contact Information

Grace Tai
RWTH Aachen
GraceYuanTai@gmail.com

Dagmar Kern, Albrecht Schmidt
Pervasive Computing, Universität Duisburg-Essen
dagmar.kern@uni-due.de, albrecht.schmidt@acm.org