Divided attention while driving

[Technology](), [Mobile Phone]()

Cars, Calls, and Cognition: Investigating Driving and Divided Attention Shamsi T. Iqbal, Yun-Cheng Ju, and Eric Horvitz Microsoft Research One Microsoft Way, Redmond, WA 98052 {shamsi, yuncj, horvitz}@microsoft. com ABSTRACT Conversing on cell phones while driving an automobile is a common practice. We examine the interference of the cognitive load of conversational dialog with driving tasks, with the goal of identifying better and worse times for conversations during driving. We present results from a controlled study involving 18 users using a driving simulator. The driving complexity and conversation type were manipulated in the study, and performance was measured for factors related to both the primary driving task and secondary conversation task. Results showed significant interactions between the primary and secondary tasks, where certain combinations of complexity and conversations were found especially detrimental to driving. We present the studies and analyses and relate the findings to prior work on multiple resource models of cognition. We discuss how the results can frame thinking about policies and technologies aimed at enhancing driving safety. Author Keywords driving have become commonplace. The cognitive, visual, and physical demands of such tasks can compromise the primary task of driving. Users may often overestimate their ability to divide their attention with secondary tasks because of the sense that driving is near automatic in many situations and can thus be safely shared with other tasks. However, it may be difficult to switch full attention back to driving in a timely manner so as to observe and respond appropriately when driving challenges arise, and such attentional challenges can have costly consequences [18]. The data linking the use of phones while driving to increases in accidents and fatalities has sparked legislation aimed at limiting cell phone usage during driving to handsfree configurations. However recent research has shown that using devices in a hands-free manner is no less harmful than the use of handheld devices [16]. Thus, phone use would have to be stopped entirely to avoid the challenge they present to driving safety. Unfortunately, people are unlikely to give up phone interactions while driving, and complete bans of phone use in this setting are unlikely. Our goal is to better understand the interference between the cognition tapped for phone conversations and for driving. Insights about such potential interference would help to characterize better and worse times for phone conversations during driving, highlighting when drivers could more safely engage in phone conversations if absolutely needed. As a first step, we set out to understand how different types of cell phone conversations during varying levels of driving engagement affects driving performance and also the performance of the driver on the call itself. We sought to understand the findings in terms of interactions between cognitive resources used in driving and in handling common secondary tasks associated with phone conversations. We conducted a controlled study with 18 participants driving within an interactive driving simulator. The participants drove on routes composed of segments that posed different types of navigation challenges. While driving, the participants would occasionally have to respond to a cell phone call, pushing a button to initiate a hands-free interaction. The cell phone calls were one of three kinds of engagement: listen to news and facts (assimilate), answer questions (retrieve), and provide directions (generate). In addition, for each driving trial, we asked drivers to either focus mainly on their driving, on the conversation, or do their best to both drive and handle the phone-based tasks. Driving, Attention, Dual task performance, Cell phones ACM Classification Keywords H5. m. Information interfaces and presentation (e. g., HCI): Miscellaneous. General Terms Experimentation, Human Factors, Measurements INTRODUCTION Driving automobiles is often perceived as a fluid, nearly automatic process, and drivers often engage in secondary activities while driving [1, 7, 8, 31, 32]. Although some peripheral tasks are rapid and require only momentary shifts in attention from the primary driving task [10], other secondary activities may require more time and effort, and can lead to prolonged periods of divided attention [15, 23]. With the proliferation of mobile devices and people's desire to remain connected, talking on the phone, reviewing email, and even composing email messages and texting while Not surprisingly, we found that drivers perform better on simpler routes than on complex routes when they are engaged in phone tasks. Drives on the simpler routes were associated with a lower incidence of collisions, sudden braking, and missed turns. We also found that specific types of phone conversations interfere more significantly with driving, presumably because task requirements and chunking associated with the calls interferes with cognition that is relied upon for driving. We discuss how certain tasks may steal attention from the driving task and/or make demands in other ways on the cognitive resources that are used in controlling and navigating a car. RELATED WORK driving a car demands resources associated with visual perception, spatial working memory, and motor responses and coordination [19, 37]. Performing secondary tasks may draw on resources used during driving [24], which may lead to performance degradations in one or both tasks. We study commonplace dual-task situations that people face when they engage in phone conversations while driving. Different types of conversations may engage different mixes of cognitive, spatial, and verbal resources that may compete in different ways with the challenges of driving as well as the structural nature of the conversations. In this research, we study the interaction of classes of conversational tasks that we characterize broadly as assimilation, retrieval, and generation. Our goal is to understand how these different types of conversational tasks conflict with driving and to identify whether certain combinations of driving challenge and conversation tasks are associated with increased or diminished risk. Effects of performing secondary tasks while driving We first discuss research on the ability of people to handle concurrent tasks. We focus on prior research and reflection within cognitive psychology on the allocation of attention in dual-task settings. Divided Attention and Dual-Task Challenges From the perspective of Multiple Resource Theory (MRT) of cognition [36], humans harness varying quantities of different kinds of cognitive resources (e. g., short- and longterm memory, attention, reasoning, etc.) to solve problems. In dual-task settings, people are challenged with completing two distinct tasks, creating potential contention for cognitive resources required to solve each one. It has been demonstrated that shifting resources from one task to another can improve the performance on the second task [25, 27], and as the difficulty of one task increases, the performance on the other decreases [38]. MRT further suggests that, for concurrent tasks, performance on both may be maintained if the tasks are in separate processing stages (e. g., response selection versus perceptual activities), or involve different processing mechanisms (e. g., spatial and analog information versus verbal and linguistic information) [36, 38]. Finally, the theory of automaticity proposed by William James suggests multiple processes can go on simultaneously, when they are habitual, involving minimal conscious control [17]. While automaticity can be obtained through training and practice [22, 33], its success also depends on consistency of the task [12]. Introduction of a second task has been shown to impact performance in many dual-task contexts. Basic research on performance in rarified dual-task settings has been done in studies of shared attention in visual search [1]. However, it is not clear if results demonstrated on low-level dual-task challenge problems, formulated and studied in psychology labs, holds for switches between higher-level and more complex tasks (e. g., switching from driving to attending to a cell phone call) and how well attention can be selectively allocated, or divided across these two tasks. Pursuing such an understanding is the main thrust of this work. The prior work on dual-task challenges provides a useful framing for research on performance tradeoffs in the setting of driving a car while talking on the phone or interacting with an in-vehicle system [16, 21]. While a seasoned driver may show an overriding automaticity in piloting a vehicle, Dual-task scenarios of driving and performing secondary tasks such as conversing on the phone, texting, interacting with in-vehicle controls has been an area of active research. Studies have shown that dialing or answering the phone, adjusting the radio or interacting with music players have negative influences on driving, [7, 8, 32], as well as reasoning and conversing during driving [9] . Using phones during driving has been shown to have catastrophic effects. For example, drivers with phones have slower braking reaction time [1, 20], have impaired steering control [8], and are more likely to have an accident [29, 35]. Moreover, no value of hands-free phones has been found, debunking beliefs that removing the need to physically hold phones reduces distraction during driving [29, 34]. These findings reinforce the hypothesis that cognitive demands of multitasking play a more important role in distracting drivers than manual manipulation [28, 34]. In order to understand the effects of cognitive demands on driving, researchers have looked at performance on various secondary tasks known to cause memory load in prior psychology studies. These include working memory tasks [1], mental arithmetic tasks [7] , and reasoning tasks [9]. Although not entirely representative of conversations that one may have over the phone, these tasks were used as they may replicate the cognitive demands placed on drivers while participating in more natural conversational settings. Performance on driving was reduced in all cases. We reexamine the influence of phone conversations on driving, and also explore how phone conversations are affected by driving. We compare performance across different types of conversation while driving on courses with different levels of difficulty. Also, we investigate how varying levels of attention allocation across driving and phone conversations affect performance. While others have investigated several of these factors or partial combinations, prior research has not explored the interactions in a joint manner as we do in experiments reviewed below. Strategies for interleaving secondary tasks with driving Given that people can perform two tasks concurrently [36], researchers have recently looked at opportunities to interleave secondary tasks with driving. Brumby et al. investigated how interleaving a phone dialing task with driving impacted lane keeping and the dialing time under conditions of requests to prioritize either driving or dialing [10]. Results showed that when asked to prioritize the secondary task, drivers chunk components of the secondary task and switch back to driving at chunk boundaries to maintain driving performance, and while focusing on driving, the secondary task is slowed down. In a related study, Brumby et al. showed that the fastest strategy for selecting a song on a music player while driving was to scroll in one contiguous block without returning attention to the primary task of driving. For the safest strategy, more time needs to be given to the driving task, at the cost of longer response times for the secondary task, and correspondingly longer stretches of times for the dual-task scenario [11]. The prior work suggests that, for automatized tasks like driving, it may be possible to formulate strategies to perform other tasks without significantly compromising driving. Successful dual-task scenarios will depend on the availability and requirements of cognitive resources for the secondary task in light of resource consumption by the primary task and opportunities for interleaving the two tasks. We explore performance in these scenarios by generating phone calls with different cognitive demands during driving situations of different difficulties. We probe the interaction of cognitive resources for driving and handling calls via the proxy of measuring performance on both the driving and call tasks. We reflect about the timing and nature of conversations that conflict the least with driving and propose strategies for minimizing interference. OVERVIEW OF STUDY tor, users engaged in driving a realistic route, with a realistic steering wheel, pedals, and controls. Custom software allowed researchers to design driving scenarios and log relevant parameters during driving. To simulate a hands-free phone call environment, calls were presented through a peripheral system including a loud speaker and a microphone, and calls were accepted via a button on the driving console. Experimental Design The study was designed as a 3 (driving complexity) X 3 (call type) X 3 (focus) repeated measures within subjects design. Possible effects of order were countered by blocking the factors on a fully balanced Latin square design. Users 18 people participated in our study (F= 3), recruited through a call sent out to people selected randomly from the entire employee pool of our organization. The mean age of participants was 33. 2 years, (S. D.= 8. 2) with a mean of 16. 8 years of driving experience (S. D.= 9. 41). All participants reported to be comfortable talking on the phone while driving. Driving Task Our goal was to explore if and when opportunities exist when car drivers could engage in phone conversations without reducing driving performance, to understand which conversational tasks cause the most interference with driving, and the influence of increases in driving difficulty on interference between the primary and secondary tasks. Understanding performance of driving on conversation has not been well studied. We also investigated how well users can carry out the conversation and how much they can recall afterwards. We addressed the following questions: 1. How is driving performance affected by participating in phone conversations where the driver has to interact in varying levels of engagement? How do these effects vary with changes in driving difficulty? 2. How are phone conversations influenced by concurrently driving, and how do these effects vary with changes in the levels of driving difficulty? 3. How does performance vary with requests to prioritize attention on driving, conversation, or both tasks? To answer these questions, we conducted a controlled study using a driving simulator (see Figure 1). Using the simula- Participants drove routes comprised of multiple 30s segments, each segment having either of the following three levels of complexity: simple, complex, and unexpected occurrences. An example of a simple segment is a single stretch of driving on a relatively empty road. Complex segments involve driving with many cars on a road, and requires changes of speed or lane changing. A segment with unexpected occurrences includes sudden, unexpected events, e. g., the car in front of the driver's car suddenly braking, a pedestrian stepping into the road, or an object rolling in front of the car. The segments with unexpected occurrences include time for the driver to recover and resume safe driving. Routes were about 10 minutes long. Drivers were asked to follow the route straight on, unless they saw instructions to turn left or right. Instructions appeared in large banners in the frontal view of the driver and were easy to see if drivers were looking at the road. To preserve the order of driving complexity as dictated by the Latin square design, we randomly chose segments where users would receive phone calls. Complexities were assigned to these segments according to the Latin square. Figure 1: The STISim driving simulator. The system hosts a console with a steering wheel, turn signals, and buttons mapped o to external functions. Three 47" screens placed at roughly 45 generate a convincing impression of driving a vehicle. For consistency, segments with no phone calls were assigned difficulty levels randomly. This procedure reduced the probability that users would be able to predict phone calls on any given segment. Phone Tasks While driving, participants would occasionally receive phone calls, heralded by a traditional phone ring tone. Pressing the respond button on the console would mark the start of the conversation. The phone task was selected according to the design and launched. Participants had 30 seconds to perform the task. Phone tasks belonged to one of the three categories: assimilation, retrieval, and generation (Table 1). The categories were designed based on prior studies looking at decrements of performance in driving while drivers engage in secondary tasks (see, e. g., [34]). In distinction to the prior work, we designed the tasks so as to resemble conversations that one typically may have over the phone. For the assimilation task, the participants listened to a 1520 second news headline. The choice of this task was motivated by Strayer and Johnston's [34] book-on-tape task, where participants were instructed to listen so that they could answer post-experiment questions. For the retrieval task, participants were asked to answer two questions, similar to questions one may hear from a telemarketer. For the generation task, participants were asked to provide driving directions between two points of interest. The first two tasks were designed to exploit verbal and linguistic/semantic resources. The third task adds more explicit spatial reasoning challenges to the mix. Methodology Each call type was paired with each driving complexity, according to the Latin square design. To measure performance on the phone tasks, participants filled out a short questionnaire at the end of each route, designed to test recall of the content of the phone conversations. To reduce workload, we provided multiple choices when users were asked to select topics pertaining to the phone conversations. For each route, participants were asked to distribute their attention across the two tasks according to the following focus (focus more on driving, focus more on phone conversation, focus on both considering them to be equally important). Focus was assigned based on the Latin square. Prior studies have shown that asking users specifically to focus on one task over another in dual-task experiments involving driving can yield different outcomes [10, 21]. The experimental session lasted about 1. 5 hours. Users came back for two more sessions, where the experimental factors were varied according to the Latin square design to correct for ordering effects. In summary, each participant drove 9 routes and answered 81 phone calls over 3 sessions. Measures On arrival to the lab, participants were first guided through an informed consent process. They were then given an overview of the study. The experimenter then gave a demonstration of the controls of the driving simulator and the participant was provided with 10 minutes of practice driving to become accustomed to the system. Participants were also interrupted with practice phone calls during the practice session. Participants were then started with the study. To provide baseline data, users first performed only the phone tasks, without driving. They then went through a route of driving, without any phone interruptions. Participants then drove 3 routes where for each route they received 9 phone interruptions, 3 for each phone call type. Phone task type Assimilation (listen only) Retrieval (respond) Generation (respond) Example A 16 year old in NY recently was texting while walking and fell into an open manhole. When did you last have the oil changed in your car? Please give directions from your home to the nearest grocery. Performance for both driving and the phone tasks were measured for route segments when users were answering a phone call while driving. For driving performance, we measured the number of collisions, missed turns, and sudden braking, and driving speed while talking on the phone. We also recorded the same measures when users were driving while not engaged in a phone call, as a way of measuring baseline performance. The values were automatically recorded by the simulator. For performance on the phone task, we measured the ability to correctly identify topics in the phone conversation. As an indicator of how users attempt to modulate the conversation to ensure driving safety, we also tracked the time participants took to respond to the ringing of an incoming phone call, and analyzed the prosodic content of their utterances through measuring the mean length of silent segments. RESULTS For the baseline condition, each user provided 3 data points per phone task, totaling 9 data points per user. For the experimental condition, each user provided 3 data points for each of the (Driving complexity (3) X Call type (3) X Focus (3)) conditions, totaling 81 data points per user and a grand total of 1, 620 data points. Effects on driving Table 1: Examples of phone based task categories. The overall rates of occurrences of events characterizing driving performance (collisions, missed turns, sudden brakes etc) were low. Just as distractions do not always lead to catastrophic outcomes in real life, we saw small numbers of costly events with the simulator, similar to findings described in [34]. However, we sought to investigate the extreme cases of when such events occur, and how much they are affected by the factors (Focus, Driving complexity, and Call type) explored in this experiment. Because of the complexity of the experimental design, for each dependent fac- tor, we will analyze first the three-way interactions (if applicable), then the two-way interactions between Call type and Driving complexity for each level of Focus, and finally the effects of Call types for each level of Driving complexity. As the length of the call varied by type, we will report on the events/minute to normalize comparisons across call types. We use Î±= 0. 0125 to control for Type 1 errors. Collisions a) Call type assimilation retrieval generation A collision was recorded when the user hit a car, an object, or a pedestrian. Overall, the rate of collisions/min in the experimental conditions (with phone calls) was significantly higher than in the baseline condition (no phone calls) (t(17)= 5. 19, p