Two Types of Cell Phone Conversation Have Differential Effect on Driving

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Abstract. It has been demonstrated that cell-phone conversations impair driving performance. However, it is unclear whether the difficulty of naturalistic phone conversations can modulate driving performance. The present study used a simulator to investigate whether the cognitive load of phone conversations (non-conversation, multiple choice and open question conversations) influence highway driving performance. The results showed cell phone conversations with open questions led to most aggressive driving with highest speeds and shallowest braking. Furthermore, open question conversations led to the smallest route deviations. These results suggested that a drivers' capability for monitoring speed and making manoeuvre decreases as the difficulty of a phone conversation increases. The implications of this study for driving safety are discussed.

Keywords: Driving, Cell phone, Naturalistic conversations, Simulator, Open questions, Multiple choices.

1 Introduction

It is widely accepted that cell phone conversation has a negative impact on driving performance in terms of slower reaction time to immediate events [1, 3, 4, 8], higher variation in accelerator pedal position, slower and more variable speed, and higher level of workload [16]. Cell phone conversations also exposes drivers to higher risk of accidents [20]. Based on cell phone billing records, studies found a fourfold increase in the risk of car crash associated with phone use irrespective of the age and gender of the drivers [13].

Cell phone interference is mainly due to the cognitive load imposed by generating language rather than listening comprehension or repeating words. For example, a study showed that the costs of cell-phone conversations are not due to dual-task costs associated with listening to verbal contents or speaking words [21]. In addition, many studies also showed that cell phone interference is not due to manual operation of phones. Phone conversations, regardless of phone type (handheld and hands-free), have negative impacts on performance especially in detecting brief events [8, 9]. Handheld and hands-free phones produced similar RT decrements [3]. Regardless of the causes of cell phone interference on driving, a study showed that the driving

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impairment associated with cell phone conversations was comparable to that of drunken driving [20].

Other cognitive tasks, such as word tasks [21] and mathematics games [14], also interfere with driving. Studies have found that driving performance generally turns worse as the cognitive tasks become more difficult [2, 14, 17]. However, it is still unknown whether these results can be generalized to the effect of cell-phone conversations on driving.

Several studies examined whether the difficulty of cell phone conversations can modulate the driving performance [5, 11, 16, 19]. For example, a study manipulated the difficulty of conversations by using two sets of conversational topics rated by pilot testing as easy and difficult conversations, but failed to find any difference in driving performance between the easy and difficult conversations [16]. Another study assigned straightforward topics such as personal background and hobbies to the "simple" conversation condition, and topics that required more thought, such as mathematical calculation or logical reasoning, were considered as the ''complex'' conversations condition [11]. Again, Liu (2003) did not find differences in driving performance between the ''simple'' and "complex'' conversation conditions. It is still unknown why the difficulty of cell phone conversations does not modulate driving performance. A possible explanation is that complex conversations do not necessarily make participants engage in more demanding cognitive processing. Another possibility is that the content of different topics in conversations varied dramatically, so that participants' familiarity with those topics varied and their willingness to talk about various topics was also affected. These confounding variables might mask the effect of the difficulty of conversations.

What might make the situation worse is that people are overconfident with their driving performance. They are not fully aware of the potential risk associated with cell phone conversations while driving. A study showed that many drivers may not be aware of their decreased driving performance when using cell-phones [10]. Female drivers especially tended to have a greater discrepancy between the perception of their own driving performance and their actual performance.

The current study was designed to examine whether the difficulty of conversations might influence driving performance. A review paper indicated the use of driving simulator provides the most effective and most ethical method of the influence of mobile phone use on driving performance [7]. So in this study, two sets of naturalistic conversation questions, which were similar in length and addressing the exactly same set of topics, were presented via a hand-free cell phone to drivers who were driving on a high fidelity diving simulator. One set was comprised of multiple choice questions with two options, and the other set was comprised of open questions concerning the same set of topics as those in the multiple choice questions. Although the content was the same for both sets of questions, the open questions provided wider and more in depth information and required more cognitive processing than do the multiple choice questions [6, 15]. Participants had to come up options first for the open questions in relative to the multiple choices questions. Thus we expected the open questions to impose a higher cognitive load on drivers and impair their driving performance relative to multiple choice questions.

2 Method

2.1 Participants

12 participants (6 males and 6 females) took part in the experiment for monetary compensation. Their mean age was 33.4 years old, ranging from 23 to 55 years. All participants had valid driver licenses and at least 1 year of driving experience (their mean driving history was 77.7 months). Subjects reported having normal or corrected-to-normal vision. All participants owned a cell phone, and 10 participants reported that they have used a cell phone while driving.

2.2 Instruments

Driving Simulator
An interactive cockpit driving simulator (Sim-Trainer, designed by Beijing Sunheart Inc.) was used in the present study. The simulator has a 120° view, side view mirror, dashboards and manual transmission. Participants can drive by using the steering wheel, brake and accelerator pedals.

Driving Environment
The simulated highway driving environment for the experiment was a 3-lane highway. There was a 2km-long obstruction on the highway, so that drivers had to switch lanes there. Other than those switches, participants were told to maintain their lane and speed at 50km/h all the time. There was no other traffic in order to create a simple driving environment.

Conversation Questions
There were two different types of conversation question (multiple choice and open questions), which shared the same set of topics. The multiple choice questions contained two options for the participants to choose from, and the choice was set to be obvious and easy to make, based on the results of the pilot study.

The order of the types of conversation question was counterbalanced between participants so that half of the participants answered all the multiple choice questions first, and the other half answered all the open questions first. The participants were first asked to answer multiple choice or open choice questions, then they were asked to explain why they made their choice with no more than five sentences; otherwise, the experimenter would interrupt them and move on to the next question.

Additionally, the survey collected some of participants' demographic information considered to be related to driving safety including gender, age, driving years, overall mileage, and weekly mileage.

2.3 Design

There were three conditions: non-conversation, multiple choice questions and open questions. Participants performed the same driving task for all three conditions. They first drove under the non-conversation condition without any cell phone conversation. Then they were required to drive the same route under the multiple choice questions and open questions conditions. These two conditions were counterbalanced across participants. In addition, all participants were asked to maintain the speed at 50 km/h and to stay in the lane they started with. Each condition lasted approximately 7 minutes. Since each participant drive the same route three times within half an hour, a possible practice effect is of major concern. To ameliorate this issue, participate were always required to start with the non-conversation condition. If a practice effect played an important role in driving performance, participants should have the better driving performance in two dual-task conditions (multiple choice questions and open questions) compared with the non-conversation condition. However, if driving performance in dual-task conditions is worse than the non-conversation condition, the impact of secondary task on driving might be stronger than observed results because practice effect might partially offset distracting effect of secondary task.

2.4 Procedure

Participants first drove a practice session to get used to the driving simulator and route. Participants used a Nokia C5110 cell phone with a blue-tooth headset. Participants were asked to maintain their speed at 50km/h. After the practice session, participants drove the same route with no conversation. Then they performed two more rounds of driving, each of which was assigned to either the multiple choice questions condition or open questions condition. The two conditions were counterbalanced across participants. The experimenter asked 13 questions in each condition via cell phone. Finally participants completed the subjective evaluation questionnaire.

2.5 Model for Analysis

The driving performance was evaluated by the speed maintenance performance (average speed, speed variability, average position of accelerator, accelerator position variability, average position of brake and brake position variability) and the lane keeping performance (average offset of steering wheel, variability of the offset of the steering wheel, average lateral deviation and lateral deviation variability). Repeated measures ANOVAs were conducted to test whether different types of conversation affected the speed maintenance and lane keeping.

3 Results

3.1 Speed Maintenance (Mobility)

A separate contrast analysis was conducted for each of the hypothesized effects for the speed maintenance variables.

Speed

As shown in Figure 1, types of cell phone conversation significantly influenced mean speed (F (2, 22) = 8.065, p = .002), with the fastest speed in the open question condition and the slowest speed in the non-conversation condition. Multiple comparison revealed that mean speed in the non-conversation condition was significantly slower than those in the multiple choice condition (p= .070) and the open questions condition (p = .005). The mean speed in the multiple choice questions condition was also slower than that of the open questions condition (p= .009).

The speed variability is shown in Figure 1b. Types of cell phone conversation significantly influenced the variability of speed (F (2, 22) = 4.585, p = .022). Multiple comparison revealed a significant difference between the non-conversation condition and the open questions condition (p = .008), but there was no other significant effect (p> .100).

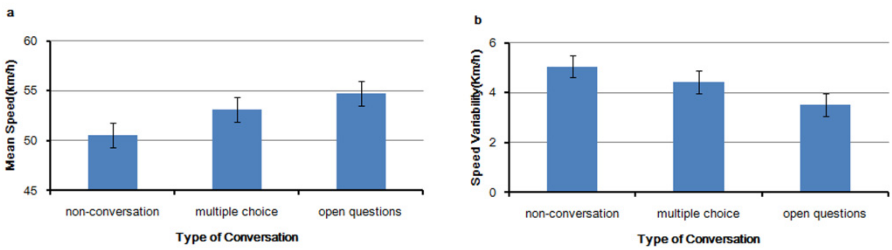

Fig. 1. Mean speed and speed variability of the three conditions. (a) Mean speed of the three conditions. (b) Speed variability of the three conditions. The error bars represent standard error.

Accelerator Position

Type of cell phone conversation did not have an effect on the mean accelerator position (F (2, 22) = 1.981, p = .162) or the variability of accelerator position (F (2, 22) = 2.707, p = .089).

Brake Position

The mean brake position is shown in Figure 2a. There is a main effect of the type of cell phone conversation on the mean brake position (F (2, 22) = 4.946, p = .017), with the shallowest brake position in the open question condition and the heaviest brake position in the non-conversation condition. Multiple comparison revealed a significant difference between the non-conversation and the open questions (p = .007), but no other significant effects (p> .140).

The mean brake position is shown in Figure 2b. There is a main effect of the type of cell phone conversation on brake position variability (F (2, 22) = 4.454, p = .024). Multiple comparison revealed a significant difference between non-conversation and the open questions (p = .020), and a marginally significant difference between non-conversation and the multiple choice questions (p = .073), but there was no significant difference between the multiple choice questions and the open questions (p = .231).

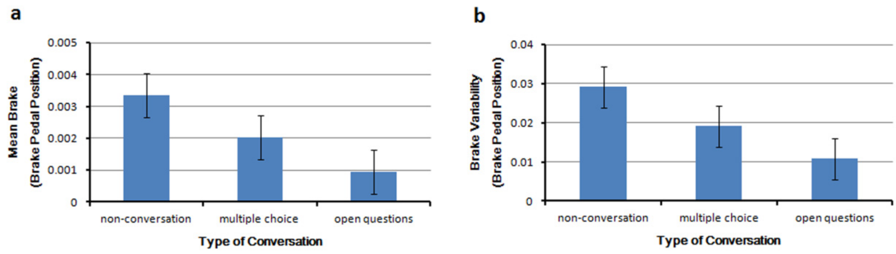

Fig. 2. Mean brake position and brake position variability of the three conditions. (a) Mean brake position of the three conditions. (b) Brake position variability of the three conditions. The error bars represent standard error.Lane position maintenance (Stability).

Deviation

The absolute deviation from route is shown as a function of conversation type in Figure 3a. The type of cell phone conversation significantly influenced the mean of the absolute deviation ($F(2, 22) = 20.971$, $p = .000$), with the smallest deviation in the open question condition and the largest deviation in the non-conversation condition. Multiple comparison revealed a significant difference between the non-conversation condition and the open question condition ($p = .000$). There was also a significant main effect on mean deviation between the non-conversation condition and the multiple choice questions condition ($p=0.009$). These results indicate that participants were more likely to deviate from the route in the non-conversation condition than in the open questions or multiple choice question condition.

The variability of absolute deviation from route is shown as a function of conversation type in Figure 3b. There was a main effect of cell phone conversation on the variability of absolute deviation ($F(2, 22) = 3.985$, $p = .033$). Multiple comparison revealed a significant difference between the non-conversation condition and the open questions condition ($p = .025$), but there were no other significant effects ($p> .100$).

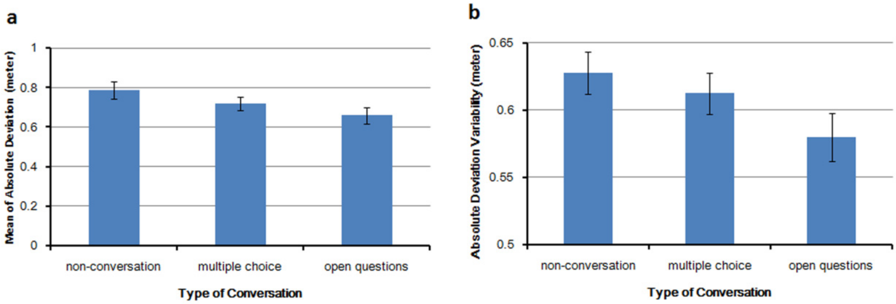

Fig. 3. Mean absolute deviation and absolute deviation variability of the three conditions. (a) Mean absolute deviation of the three conditions. (b) Absolute deviation variability of the three conditions. The error bars represent standard error.

Steering Offset

The offset of the steering wheel is shown as a function of conversation type in Figure 4a. Type of cell phone conversation significantly influenced mean steering offset ($F(2, 22) = 8.216$, $p = .002$), with the smallest steering offset in the open question condition. Multiple comparison revealed a significant difference between the non-conversation and the open questions conditions ($p = .023$) and between the multiple choice questions and the open questions ($p = .001$), but there was no significant effect between the non-conversation and the multiple choice questions conditions ($p = .631$). The variability of steering offset is also shown as a function of conversation type in Figure 4b. There was a main effect of phone conversation type on the steering offset variability ($F(2, 22) = 6.374$, $p < .001$). Multiple comparison revealed a significant difference between the non-conversation and the open questions conditions ($p = .027$) and between the multiple choice questions and the open questions ($p = .004$), but there was no significant effect between the non-conversation and the multiple choice questions conditions ($p = .510$). These results indicate that participants were least likely to make manoeuvres in the open questions condition.

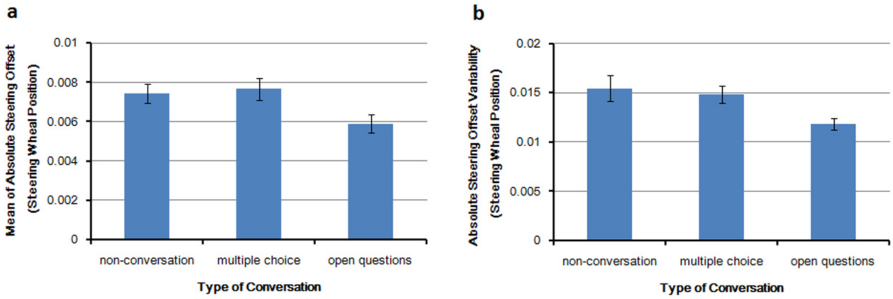

Fig. 4. Mean absolute steering offset and absolute steering offset variability of the three conditions. (a) Mean absolute steering offset of the three conditions. (b) Absolute steering offset variability of the three conditions. The error bars represent standard error.

3.2 Subjective Evaluation

Twenty out of twenty-four pilot participants (83.3%) rated the open questions more difficult than the multiple choice questions. Other three participants reported that two kinds of conversation questions were equally difficult. Only one participant rated the open questions easier than the multiple choice questions. These difficulty ratings were made when the pilot participants were not driving, and thus focused exclusively on the conversation task.

Participants evaluated the distracting effect of phone conversations on a seven-point scale ranging from “absolutely no disturbance” to “serious disturbance”. The distracting effects of the two kinds of questions are listed in Figure 5. Participants rated the open questions condition (mean ± SE: 4.92 ± .50) much more distracting than the multiple choice questions condition (mean ± SE: 3.58 ± .45), and the difference was significant ($t(11) = 2.402$, $p = .035$).

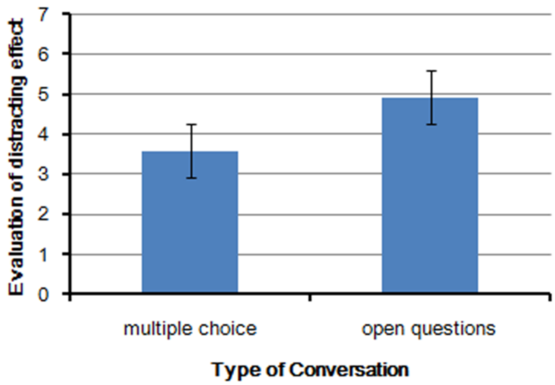

Fig. 5. The subjective evaluation of distracting effect of the conversation questions

Participants were required to evaluate their own driving performance for each of the three conversation conditions (non-conversation, multiple choice and open questions conversation) on a seven-point scale ranging from "very bad" to "very good". Their evaluation of driving performance is illustrated as a function of conversation type in Figure 6. The driving performance in the non-conversation condition was reported best (mean ± SE: 5.92 ± .34), followed by the driving performances in the multiple choice questions condition (mean ± SE: 4.50 ± .36). The participants reported that the driving performance in the open questions condition was the worst (mean ± SE: 3.75 ± .46). These subjective evaluations were submitted to a repeated measure ANOVA. There was a significant difference between the three conversation conditions, $F(2, 22) = 9.702$, $p = .001$, indicating that participants were aware of the strongest distracting effect in the open questions conversation condition.

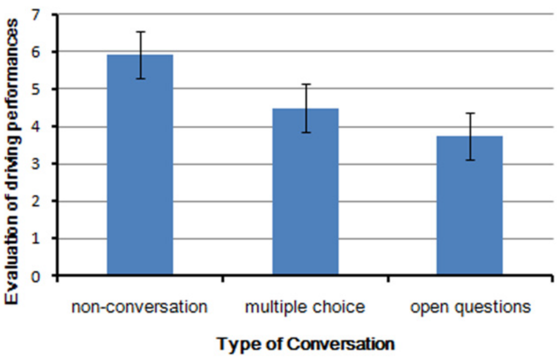

Fig. 6. The subjective evaluation of driving performance

4 Discussion

The present study replicated the classic finding of cell-phone conversation's interference with driving performance. More specifically, participants lose precise control of speed and tend to speed up when they are engaged by phone conversations. More importantly, this study clearly showed that participants tend to drive faster in the open question condition than in the multiple choice condition. In other words, phone conversations cause larger impairment in driving performance as the conversation becomes harder. This finding indicates that the difficulty of a cell-phone conversation modulates the cognitive load of the conversation, thus resulting in differential impairment on driving.

Presumably cell-phone conversation interferes with driving because the conversation engages cognitive processes which are attention consuming [18, 21]. Previous studies showed that some processes involved with cell-phone conversation, such as manual operation of cell phones, listening to verbal stimuli and repeating words, do not interfere with driving [3, 8, 9, 21]. The present results indicate that generating response options might be one of those attention-demanding processes that can interfere with driving. The present study is the first one to identify a specific cognitive process in cell-phone conversation that can interfere with driving.

The present study found that drivers speeded up when they are actively engaged in cell phone conversation. This finding was inconsistent with some previous findings that drivers slow down when they are talking on cell phones [16]. The discrepancy might be due to the task requirement of maintaining 50km/h on a traffic free highway in the present study. Since there is no traffic on the highway, participants might feel compelled to drive fast to satisfy the task demand. Thus participants depress the accelerator to almost the same extent across the three conversation conditions, but participants used the brake progressively less often as the phone conversation became harder. As a result, they were unable to monitor and control speed precisely as their attention was increasingly engaged in the cell phone conversation. In other words, the heavier load was imposed by the cell phone conversation, the faster they drove.

Participants also tended to more strictly stick to their route and to maneuver less as the conversation became harder. This further demonstrated that, when drivers are progressively engaged by conversation, they lose their ability to closely monitor their driving status. This impairment may increase their risk of having a traffic accident in more complex situations.

Drivers in the present study were able to perceive the disruptive effect of cell phone conversation on driving. However, most of them except one still reported cell phone usage in driving. Actually it is common among drivers who often feel compelled to take a phone call during driving [22]. This study indicated that drivers should try their best to avoid very complex cell phone conversations involving generating multiple options.

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References

1. Beede, K.E., Kass, S.J.: Engrossed in conversation: The impact of cell phones on simulated driving performance. Accident Analysis and Prevention 38, 415–421 (2006)
2. Briem, V., Hedman, L.R.: Behavioural effects of mobile telephone use during simulated driving. Ergonomics 38, 2536–2562 (1995)
3. Caird, J.K., Willness, C.R., Steel, P., Scialfa, C.: A meta-analysis of the effects of cell phones on driver performance. Accident Analysis and Prevention 40, 1282–1293 (2008)
4. Collet, C., Guillot, A., Petit, C.: Phoning while driving I: a review of epidemiological, psychological, behavioural and physiological studies. Ergonomics 53(5), 589–601 (2010a)
5. Collet, C., Guillot, A., Petit, C.: Phoning while driving II: a review of driving conditions influence. Ergonomics 53(5), 602–616 (2010b)
6. Friborg, O., Rosenvinge, J.H.: A comparison of open-ended and closed questions in the prediction of mental health. Quality & Quantity 47(3), 1397–1411 (2013), doi:10.1007/s11135-011-9597-8
7. Haigney, D., Westerman, S.J.: Mobile (cellular) phone use and driving: a critical review of research methodology. Ergonomics 44(2), 132–143 (2001)
8. Horrey, W.J., Wickens, C.D.: Examining the Impact of Cell Phone Conversations on Driving Using Meta-Analytic Techniques. Human Factors 48(1), 196–205 (2006)
9. Ishigami, Y., Klein, Y.M.: Is a hands-free phone safer than a handheld phone? Journal of Safety Research 40, 157–164 (2009)
10. Lescha, M.F., Hancock, P.A.: Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? Accident Analysis and Prevention 36, 471–480 (2004)
11. Liu, Y.: Effects of taiwan in-vehicle cellular audio phone system on driving performance. Safety Science 41, 531–542 (2003)
12. Laberge, J., Scialfa, C., White, C., Caird, J.: The Effect of Passenger and Cellular Phone Conversations on Driver Distraction. In: Transportation Research Record, pp. 109–116. Transportation Research Board, Washington (2004)
13. Mccartt, A.T., Hellinga, L.A., Bratiman, K.A.: Cell Phones and Driving: Review of Research. Traffic Injury Prevention 7(2), 89–106 (2006)
14. McKnight, A.J., McKnight, A.S.: The effect of cellular phone use upon driver attention. Accident Analysis and Prevention 25, 259–265 (1993)
15. Miller, G.V.F., Travers, C.J.: Ethnicity and the experience of work: Job stress and satisfaction of minority ethnic teachers in the UK. International Review of Psychiatry 17(5), 317–327 (2005), doi:10.1080/09540260500238470
16. Rakauskas, M.E., Gugerty, L.J., Ward, N.J.: Effects of naturalistic cell phone conversations on driving performance. Journal of Safety Research 35, 453–464 (2004)
17. Shinar, D., Tractinsky, N., Compton, R.: Effects of Practice with Auditory Distraction in Simulated Driving. In: Transportation Research Board 81st Annual Meeting Compendium of Papers (CD-ROM), Transportation Research Board, Washington, DC (2002)
18. Strayer, D.L., Drews, F.A., Crouch, D.J., Johnston, W.A.: Why Do Cell Phone Conversations Interfere with Driving? In: Walker, W.R., Herrmann, D. (eds.) Cognitive Technology: Transforming Thought and Society. McFarland and Company Inc., Jefferson (2005)
19. Strayer, D.L., Drews, F.A.: Profiles in driver distraction: Effects of cell phone conversations on younger and older drivers. Human Factors 46, 640–649 (2004)

20. Strayer, D.L., Drews, F.A., Crouch, D.J.: A Comparison of the Cell Phone Driver and the Drunk Driver. Human Factors 48(2), 381–391 (2006)
21. Strayer, D.L., Johnston, W.A.: Driven to distraction: dual task studies of simulated driving and conversing on a cellular telephone. Psychological Science 12, 462–466 (2001)
22. Wood, C., Torkkola, K., Kundalkar, S.: Using Driver's Speech to Detect Cognitive Workload. In: 9th Conference on Speech and Computer (SPECOM 2004). International Speech Communication Association Press, France (2004)