To call or not to call—That is the question (while driving)

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**Abstract**

We studied whether decisions to engage in cell phone conversation while driving and the consequences of such decisions are related to the driver's age, to the road conditions (demands of the driving task), and to the driver's role in initiating the phone call (i.e., the driver as caller vs. as receiver). Two experiments were performed in a driving simulator in which driver age, road conditions and phone conversation, as a secondary task, were manipulated. Engagement in cell phone conversations, performance in the driving and the conversation tasks, and subjective effort assessment were recorded. In general, drivers were more willing to accept incoming calls than to initiate calls. In addition, older and younger drivers were more susceptible to the deleterious effects of phone conversations while driving than middle aged/experienced drivers. While older drivers were aware of this susceptibility by showing sensitivity to road conditions before deciding whether to engage in a call or not, young drivers showed no such sensitivity. The results can guide the development of young driver training programs and point at the need to develop context-aware management systems of in-vehicle cell phone conversations.

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1. Introduction

The evidence for the distracting effects of cell phones is overwhelming. Hundreds of studies have already examined this distraction and these findings have been published in scientific journals and several international scientific conferences (e.g., Regan et al., 2008). In general, these studies concluded that the use of cell phone while driving impairs driving performance, causes drivers to miss traffic signs, raises response time to unexpected events, and reduces situation awareness (Burns et al., 2002; Strayer and Drews, 2007; Lee, 2007; Lesch and Hancock, 2004; Kass et al., 2007) and ultimately increases crash injuries (Redelmeier and Tibshirani, 1997; McEvoy et al., 2005).

Over time the awareness of cell phone hazards filtered down to the public and greater and greater proportions of the drivers acknowledged that engaging in a cell phone conversation while driving is dangerous. In an interesting study performed by Lerner and Boyd (2005) subjects drove in real traffic conditions and were asked at predetermined locations to what extent they would be willing to engage in various (potentially distracting) activities at these locations. The results revealed that on a scale from 1 (absolutely not willing) to 10 (very willing without any concern) the mean rating for willing to make and receive a cell phone conversation was somewhat affected by the complexity of the driving demands, but was about the same for initiating a call as for answering one – with a score of slightly under 7. There was also a strong age effect, where the average level of willingness decreased with age. Over the past few years, public education campaigns, media reports, and law proposals to restrict the use of cell phones while driving, have increased the motoring public's awareness that using the phone while driving is dangerous. Paradoxically, however, these measures have not had much of an impact on reported use. For example a November 2011 poll of a representative sample of the U.S. adult population by the Harris group (Harris Interactive, 2011) showed that although 47% of the respondents considered talking on a hand held phone "very risky" and 24% felt the same about hands free phones, nearly 60% of the drivers used hand held phones while driving and 43% used hands-free phones while driving.

While the use of cell phones compromises the safety of all drivers, the effect on young and on old drivers appears to be greater. In addition to the fact that their driving is characterized by risk-taking behaviors (Mayhew et al., 2006), young drivers may also lack spare attentional capacity when they are engaged in vehicle control (Lee, 2007) and the ability to anticipate and manage hazards (Borowsky et al., 2010; Lee, 2007). Another factor that puts young drivers in greater risk is their high confidence in their ability to perform dual tasks. Thus, Lerner et al. (2008) found that despite their lack of experience, young drivers believed they can perform dual tasks while driving better than their parents. The detrimental effect of cell phone use on older drivers is also higher (Shinar et al., 2005; Langford and Koppel, 2006), but these drivers – in general are less likely to use the phone while driving (Lerner and Boyd, 2005).

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The decision to use a cell phone while driving is a voluntary decision, which is probably influenced by various considerations. The driver’s perception of his/her driving skills and abilities to combine driving with handling a phone conversation may affect the driver’s decision to do so. This is despite the fact that drivers are aware of the mental effort caused by combining driving and conversation (Shinar, 2007). Unfortunately, drivers do not always behave in accordance with this knowledge, as shown by Horrey and Lesch (2009), who found that even when drivers were aware of the road demands, they did not tend to postpone their phone calls.

The primary aim of this study is to explore drivers’ decisions to engage in phone calls while driving. Specifically, we examine whether these decisions are related to the driver’s age, to the road conditions (demands of the driving task), and to the driver’s role in initiating the phone call (i.e. the driver as caller vs. as receiver). For this purpose we conducted two studies in which driver age, road conditions, and phone conversation were manipulated.

2. Study 1

2.1. Method

2.1.1. Sample

Thirty-eight drivers participated in the study. They included 16 young/inexperienced drivers under the age of 20 (M = 18, SD = 0.44), 18 experienced drivers 24–30 (M = 26.4, SD = 1.92) with at least 7 years of driving experience, and 4 older drivers (65+ years old). The inclusion of the older drivers in this experiment was to see if they can handle the dual task of driving and using the cell phone prior to conducting experiment 2; therefore, their data were not analyzed.

2.1.2. Apparatus

A Systems Technology Co. STISIM driving simulator incorporated into a Rover sedan was used with a 3 m × 3 m screen, situated 3 meters in front of the driver’s eyes. The screen allowed a 40° horizontal field of view on a 1:1 scale. The simulator sampled the driving performance at 2 Hz.

For the phone task we used a hands-free cell phone with a touch screen placed to the right side of the steering wheel (see Fig. 1). Hands-free conversations were conducted via a microphone installed above the windshield and the car’s speakers. The cell phone was programmed with Labview program to receive inputs from the driver and from the driving simulator.

2.1.3. Phone tasks

The experiment employed two phone tasks: responding to incoming calls, and initiating calls. For incoming calls the participants answered the call by pressing the “Send” button on the touch screen and then engage in a conversation. For the outgoing calls the participants initiated the calls by keying in any 10 digit number and pressing the “Send” button on the touch screen. The phone tasks were similar to those used in other studies (e.g. Shinar et al., 2005). Each phone call included three arithmetic problems, consisting of the basic four operations on five single-digit numbers; e.g. [(3 × 3 + 7)/8] × 9 = ? The numbers in each problem were presented at the rate of 1 per 2 s.

2.1.4. Incentives

Participants were paid $5 to participate in the study as a token appreciation for their participation. In addition, a simple monetary system was used to stress that, as in real-world driving situations, the experimental context includes benefits (in the case of making a conversation) and costs (in the case of unsafe driving behavior). Hence, we paid each participant an additional 75 cents for each correct answer on the arithmetic problems and fined him or her with 35 cents for every driving violation (e.g. lane crossing) or accident. The incentives scheme is also in line with findings (Camerer and Hogarth, 1999) that modest monetary incentives are effective where effort increases performance (but not where the task is too easy or where it is too difficult to improve performance).

2.1.5. Driving scenarios

Each participant drove over three different scenarios: a mostly straight two-lane open road without any traffic, a four-lane road with heavy traffic (two in each direction), and a two-lane winding road. The difficulty levels of the three simulated roads were pretested in a pilot study with 12 experienced drivers without a cell phone task. The objective and subjective difficulty levels of the three roads were statistically verified with significant differences among all three road scenarios (using Scheffe pot hoc tests for performance measures and Wilcoxon signed-ranks test for the subjective measure). In terms of driver behavior, on the straight open road average speed was highest (51 mph), and speed variance was lowest (2.8 mph); on the winding road average speed was the lowest (40 mph), and speed variance was the highest (SD = 10.2 mph). In terms of rated difficulty on a scale of 1–10, the easy road was rated as 1.4, the heavy traffic road was rated as 2.2, and the winding road was rated as 2.8. Note that for this evaluation the drivers did not have to time-share the driving with any distracting task.

2.1.6. Procedure

The participants first completed the IRB consent forms, and then drove on an empty slightly winding road for seven minutes to familiarize themselves with the simulator. Next, they read the study’s instructions and used the in-car cell phone (without driving). Drivers then rested for 5 min, and then drove while either receiving phone calls or initiating them for 20 min. They then rested again for 5 min, and then drove for another 20 min while either initiating phone calls or receiving them, rested for 5 min, and then completed the NASA-TLX task load questionnaire. The order of conversation tasks – receiving or initiating calls – (in the first or second 20 min of driving) was counterbalanced between participants. Within each conversation scenario the participants drove the three road types in a mixed, predefined order which was the same for all age groups. Within each road type identical road segments were used for outgoing and incoming calls. Following the drive on each road type the participants rated the subjective overall work load on a 0–10 scale.

2.1.7. Dependent variables

There were four types of dependent variables: engagement in phone conversation, driving performance, cell phone performance, and subjective responses. Engagement in phone conversation was measured by percentage of calls answered or initiated and by response time to incoming calls or time to initiate outgoing calls (depending on the phone task). Driving performance was assessed.

![Fig. 1. Hands-free phone simulator touch screen.](image-url)
Table 1
Percentage of calls answered and initiate by road type and age group.

<table>
<thead>
<tr>
<th>Road condition</th>
<th>Easy (%)</th>
<th>Heavy traffic (%)</th>
<th>Winding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming (answered) calls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Experienced</td>
<td>94</td>
<td>100</td>
<td>94</td>
</tr>
<tr>
<td>Outgoing (initiated) calls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Experienced</td>
<td>100</td>
<td>72</td>
<td>78</td>
</tr>
</tbody>
</table>

by average speed while dialing (outgoing calls scenario only); average speed during calls; speed variance during calls; variance of lane position during calls; and number of accidents during calls. Performance on the secondary phone task was measured in terms of the percent of participants who answered or received calls and percent of correct answers to the arithmetic problems. Subjective assessment of the various driving conditions were measured by perceived overall work load of each road condition, and by subjective task load (NASA-TLX) of the entire study.

2.2. Results

As mentioned above, the statistical analyses were performed only on the groups of young and experienced drivers.

2.2.1. Proportion of incoming and outgoing calls

The primary aim of this research was to compare the driver groups in terms of the decision of whether to speak on a cell phone while driving. As can be seen in Table 1, young drivers answered all incoming calls and initiated all possible outgoing calls. Experienced drivers were more selective: they answered 96% of the incoming calls and initiated only 83.3% of possible calls.

Using 95% confidence interval, the difference between the overall proportions of answered and initiated calls was not statistically significant (CI = –0.002 to 0.13). However, while young drivers answered and initiated 100% of all calls, the proportion of calls initiated by experienced drivers was significantly lower than the proportion of calls answered by them (95% CI = 0.002, 0.25).

2.2.2. Analysis of the effects of incoming calls on the phone and driving performance

This subsection presents analyses of the study's dependent measures during the incoming calls scenario.

2.2.2.1. Response time to calls. Response times were calculated as the time interval from the phone's first ring until the driver touched the answer button and are shown in Table 2. As noted above, the experienced drivers answered 96% of the calls, and the young drivers answered all calls. To normalize their distribution, response times were transformed using natural logarithm. A two-way (road type and age group) unbalanced mixed design ANOVA with repeated measures (on the road type) was conducted on the transformed dependent variable. The results revealed only a significant effect of road type (F(2, 32.50) = 5.00, p = 0.013). Post hoc Scheffe tests showed a significant difference in response times between the heavy traffic way (M = 4.65 s) and the winding road (M = 5.69 s).

2.2.2.2. Average speed during incoming calls. Due to size differences between the groups and the fact that not all participants answered all calls, an unbalanced mixed design ANOVA was conducted to analyze the effects of age group, road condition and cell phone conversation on the average speed. Significant main effects were found for road condition (p < 0.001) and cell phone conversation (p = 0.036). There was no age group main effect or any interaction effects. Scheffe Post hoc tests showed that the participants were slowest on the winding road (M = 38.2 mph) and fastest on the easy road (M = 50.8 mph), with the speed on the heavy traffic road in between (46.6 mph) (p < 0.05). The participants drove slightly slower during the conversation (M = 44.8 mph) than when not conversing (M = 45.7 mph).

2.2.2.3. Speed variance during incoming calls. Natural logarithm transformation was performed on the standard deviations of the participants' speed. The effects of road type, age group and the presence or absence of conversation were tested with unbalanced mixed design ANOVA. The analysis revealed significant main effects of road type (F(2, 30.40) = 30.84, p < 0.001) and age group (F(1, 35.82) = 4.63, p = 0.038). There were no conversation or interaction effects.

Speed variance of the experienced drivers was significantly lower (average SD = 4.46) than for the young group (average SD = 4.84). Scheffe post hoc tests indicated that the participants' speed variance was lowest on the easy road (average SD = 2.06), which was significantly different than the variance in the heavy traffic (average SD = 4.08) and on the winding road (average SD = 7.8).

2.2.2.4. Variance of lane position during incoming calls. The standard deviations of the participants' mean lane position were transformed using natural logarithms. The effects of road type, age group and the presence or absence of conversation were tested with unbalanced mixed design ANOVA. Because the heavy traffic road was a four-lane road and drivers were allowed to change lanes, this condition was excluded from the analysis. The analysis revealed significant main effect of road type (F(1, 31.06) = 29.77, p < 0.001), with smaller variance in the easy road (average SD of lane position = 1.03) compared to the winding road (average SD of lane position = 1.39). A conversation main effect (F(1, 29.55) = 8.44, p = 0.007) revealed a slightly lower variance during conversations (M = 1.89) than during driving without conversations (M = 2.02). There were no age group main effect or interaction effects.

2.2.2.5. Number of accidents during incoming calls. Overall there were only 3 accidents during the incoming calls scenario, all of them on the winding road, 2 by experienced drivers under the no-conversation condition. Two of the accidents resulted from collisions with other vehicles and one resulted from veering off the road.

2.2.2.6. Percentage of correct answers in the incoming calls scenario. Each phone conversation task consisted of three arithmetic problems. The average percentages of correct answers by age group and road condition are presented in Table 3.Logistic regression with repeated measures showed no significant main or interaction effects of road type or age group on the number of correct answers.

2.2.2.7. Perceived road difficulty during the incoming calls scenario. This analysis was done only when a conversation took place (32
cases in the easy road condition, 32 cases in the heavy traffic condition, and 33 cases in the winding road). A repeated measures ANOVA revealed that road condition had a significant main effect ($F(2, 28.15) = 13.047, p < 0.001$). There was no age group or interaction effect. Scheffe post hoc tests showed that participants rated the easy road as easier ($M = 2.44$) relative to the heavy traffic condition ($M = 3.73$). The winding road was evaluated almost as difficult as the heavy traffic road ($M = 3.66$), but it was not significantly different than the easy road.

### 2.2.3. Analyses of the effects of outgoing calls on the phone and driving performance

#### 2.2.3.1. Engagement in calls. Call initiation time. Call initiation time is defined as the time interval between the experimenter’s indication that the driver can initiate a call and the time when the driver started dialing. Call initiation times were transformed using natural logarithm. An unbalanced mixed (road type and age group) ANOVA on the transformed dependent variable, showed significant main effect of road condition ($F(2, 30.68) = 21.48, p < 0.001$), and interaction with age group ($F(2, 30.67) = 3.62, p = 0.039$). The interaction was due to a marginally significant difference between the age groups on the winding road ($p = 0.06$). Experienced drivers took longer ($M = 13.8$ s) to initiate calls on that road than young drivers ($M = 8.5$ s).

**Dialing time.** Dialing time was defined as the interval between the first time a participant touched the keypad and the time he or she pressed the “SEND” button, provided that the call was successful. There were no significant main or interaction effects of road type and age group on dialing time.

#### 2.2.3.2. Effects of dialing. Average speed during dialing. For participants who dialed while driving, we calculated the average speed during the dialing interval and the average speed while driving the same road segment without dialing. An unbalanced repeated measure ANOVA was conducted to analyze the effect of road condition, age group and dialing on average speed while dialing. The participants’ average speed was slower while dialing ($M = 41.03$ mph) compared to the average speed without dialing ($M = 44.97$ mph) ($F(1, 25.11) = 26.18, p < 0.001$). Significant main effects was also found for road condition ($F(2, 53.39) = 53.97, p < 0.001$). Scheffe post hoc tests ($p < 0.05$) indicate that while dialing drivers drove the fastest on the easy road ($M = 49.60$ mph), significantly slower on the heavy traffic road ($M = 43.81$ mph) and significantly slowest on the winding road ($M = 35.74$ mph).

**Speed variance while dialing.** The effects of road type, age group and dialing (yes or no) on the In-transformed standard deviations of the participants’ speed were tested with unbalanced mixed design ANOVA. The analysis reveals significant main effect of road type ($F(2, 25.55) = 8.68, p = 0.001$). Scheffe post hoc tests found that speed variance was significantly lower while dialing on the easy road (average SD = 0.9) than on the heavy traffic and the winding roads (average SD = 3.5 and average SD = 4.0, respectively).

**Variance of lane position while dialing.** The effects of road type, age group and dialing (yes or no) on the In-transformed standard deviations of the participants’ lane position were tested with unbalanced mixed design ANOVA. Because the heavy traffic road was a four-lane road and drivers were allowed to change lanes, it was excluded from the analysis. The analysis revealed significant main effects of road type ($F(1, 33.34) = 27.93, p < 0.001$), which was qualified by an interaction with age group ($F(1, 33.34) = 9.86, p = 0.004$). Independent samples t-tests revealed that the interaction stemmed from the fact that while the age groups didn’t differ on the easy road, on the winding road young drivers had a higher variance than the experienced drivers ($p = 0.005$). Dialing also had a significant main effect ($F(1, 29.84) = 6.59, p = 0.016$), with higher variance while dialing ($M = 1.14$) than while not dialing ($M = 0.98$).

**Number of accidents while dialing.** Overall, during the segments in which dialing was allowed, participants were involved in five accidents, all during dialing. Three of the accidents were collisions with other vehicles and two involved veering off the road. Three of the accidents were on the heavy traffic road and two on the winding road. Four of the accidents involved young drivers.

#### 2.2.3.3. Effects of conversations. Average speed during outgoing calls. An unbalanced repeated measure ANOVA with road condition, age group and conversation as experimental factors found that average speed was affected by road condition ($F(2, 34.75) = 123.71, p < 0.001$) and conversation ($F(1, 6.58) = 8.46, p = 0.024$). Scheffe post hoc tests revealed that the drivers drove the fastest on the easy way ($M = 50.49$ mph), significantly slower on the heavy traffic road ($M = 47.03$ mph) and slowest on the winding road ($M = 38.93$ mph). Participants also drove significantly slower during a conversation ($M = 44.52$ mph) than when not engaged in a conversation ($M = 46.44$ mph).

**Speed variance during outgoing calls.** The standard deviations of the participants’ speed were transformed using natural logarithms. The effects of road type, age group and the presence or absence of conversation were tested using unbalanced mixed design ANOVA. The analysis revealed significant main effects of road type ($F(2, 109.17) = 11.48, p < 0.001$). Scheffe post hoc tests found that the speed variance was significantly smaller in the easy road condition (average SD = 2.02) than in the other road conditions (average SD = 4.37 and 7.48 in the heavy traffic road and the winding road, respectively).

**Variance of lane position during outgoing calls.** The standard deviations of the participants’ position in the lane were transformed using natural logarithms. The effects of road type, age group and the presence or absence of conversation were tested with unbalanced mixed design ANOVA. Because the heavy traffic road was a four-lane road and drivers were allowed to change lanes, it was excluded from the analysis. The analysis revealed significant main effects of road type ($F(1, 29.36) = 11.42, p = 0.002$). Drivers maintained lane position better on the easy road (average SD = 0.94) than on the winding road (average SD = 1.16). A significant conversation main effect ($F(1, 32.61) = 4.68, p = 0.038$) was due to smaller variance during a conversation (average SD = 0.98) than the variance while not conversing average SD = 1.10. However, there was also a significant 3-way interaction ($F(1, 31.67) = 12.19, p = 0.001$). On the easy road, young drivers had higher variance during conversations than experienced drivers, but lower variance when not conversing. On the winding road, the variance was similar for both age groups during the no-conversation period, but young drivers had smaller variance during conversations.

**Number of accidents during outgoing calls.** There were only two accidents during the outgoing calls scenario, one by each age group. Both accidents were on the winding road when the drivers were not conversing, and due to veering off the road.

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Easy (%)</th>
<th>Traffic (%)</th>
<th>Winding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>89</td>
<td>85</td>
<td>87</td>
</tr>
<tr>
<td>Experienced</td>
<td>94</td>
<td>92</td>
<td>88</td>
</tr>
</tbody>
</table>

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N. Tractinsky et al. / Accident Analysis and Prevention 56 (2013) 59–70
the odds for providing correct answers. Interestingly, the experienced drivers actually improved as the road scenario became more difficult, while the young drivers retained a lower and relatively constant level of performance.

**Perceived road difficulty during the outgoing calls scenario.**

For each road type, only data from drivers who conducted conversations were analyzed (33 on the easy road, 28 on the heavy traffic road, and 30 on the winding road). An unbalanced repeated measures ANOVA revealed a main effect of road condition on driving load rating ($F(2, 25.09) = 16.69, p < 0.001$). The age group did not affect perceived difficulty – either alone as a main effect or in its interaction with the road condition. Scheffe post hoc tests showed that the participants rated the easy road ($M = 2.27$) as significantly easier than the other two road conditions ($M = 3.64$ in the heavy traffic condition and $M = 3.90$ in the winding road condition).

### 2.2.4. Subjective task load (NASA-TLX)

Kruskal–Wallis tests did not yield significant differences between age groups in the responses to the NASA-TLX questionnaire, indicating that the experimental tasks were approximately equally difficult for all groups.

### 2.3. Discussion

The results of Study 1 demonstrated the feasibility of using a single paradigm to examine the decision process in answering and eliciting calls while driving under different driving conditions. Though differences between the groups were obtained, we did not have a critical group of older drivers. Also, this study demonstrated that the younger drivers may be indifferent to the specific payoffs used, and a different one with larger penalties and lower rewards may be more appropriate. To replicate and expand the results we conducted Study 2 with older drivers and with a different payoff matrix.

### 3. Study 2

This study was conducted to replicate the findings of Study 1 and extend them to older drivers. Thus, the study methodology and analytical approach were very similar to those of Study 1, with a few minor methodological modifications, and using a different simulator that was less likely to induce simulator sickness in older drivers.

#### 3.1. Method

**3.1.1. Participants**

Three groups of drivers participated in the study: 18 experienced drivers (average age 26.4, SD = 1.76) with an average of 8.7 years of driving experience; 18 novice drivers (average age 18.3, SD = 0.74) with an average of 0.7 years of driving experience; and 18 older drivers (average age 69.8, SD = 4.2) with an average driving experience of 47.8 years. All drivers reported at least some experience of using a cell phone while driving.

**3.1.2. Instruments**

The experiment was performed with a STISIM M400 driving simulator, with three 19 in. screens providing a horizontal field of view of 150°. The participants sat on a chair facing the screens and used a Logitech Formula Force EX device as a steering wheel, and a set of pedals for the throttle and brakes. A small touch screen (identical to the one used in Study 1 (see Fig. 1), which was located to the right of the steering wheel, served as an interface to a hands-free cell phone.

### 3.1.3. Scenarios, road conditions, tasks and incentives

The experiment employed two phone scenarios. In the first scenario phone calls were initiated by the experimenter and the participants had to answer the call to engage in a conversation. Answering the call was made by pressing a “Send” button on the touch screen. In the second scenario the participants were instructed that they can make a call. The instruction was given automatically to all participants at the same point on the road. It was up to them to decide then when to initiate the call. Initiating a call required dialing any 10 digits and pressing the “Call” button on the touch screen. The participants were allowed to make one call or answer one call within each road segment.

Three road conditions identical to the ones used in Study 1 were used in this study: an intercity road with light traffic (easy), an intercity road with heavy traffic (medium), and a winding road (difficult).

Similar to Study 1, the drivers were requested to solve 3 simple mathematics problems during the calls. The problems included a sequence of single-digit numbers and operations, e.g. $(3 \times 3 + 7)/8 \times 2 = ?$ The problems were pre-recorded, with an interval of 2 s between each number. The participant’s answer to each problem was then recorded.

The participants were paid $5 for their participation in the study. To simulate a context that includes costs and benefits for making or not making a call, which are usually present when people decide on whether to make cell phones while driving, we used compensations and fines. Thus, for a correct answer the participants earned $0.5; for any driving violation (e.g. lane crossing) they were fined $0.5, and in the case of an accident they were fined $1.25. The change in the incentive scheme from that used in Study 1 was due to the fact that in Study 1 young drivers answered all calls. We therefore lowered the rewards for correct answers and increased the penalties for violations and accidents.

#### 3.1.4. Experimental design and procedure

To acquaint themselves with the simulator, participants started the session with a 7-min drive, which included equal portions of the three road types. They then read the experimental instructions and experimented with the cell phone touch screen. Next, the participants were assigned randomly to two groups which were counter-balanced in terms of scenario order. Participants in one of the groups drove the three road conditions under the incoming calls scenario first, and then drove the three road conditions again under the outgoing calls scenario. Within each scenario, the order of the roads was randomized. In the incoming calls scenario each road condition was divided to two equal parts. In one part the experimenter phoned the participants, who had to decide whether or not to answer the call and engage in a conversation. The call was initiated automatically for all participants at the same point on the road. In the other part of that road condition the participants were not interrupted by calls. This provided a controlled no-calls segment for each road type. The order of the control-call segment was counter-balanced between participants. In the outgoing calls scenario, the participants were signaled automatically at the same point on the road that they can make a call. Following each road type in each scenario, the participants rated the road difficulty on a 0–10 (Not Difficult–Very Difficult) scale. Following each scenario, they filled out a 6-item NASA-TLX work load questionnaire.

### Table 4

<table>
<thead>
<tr>
<th>Road Condition</th>
<th>Easy (%)</th>
<th>Traffic (%)</th>
<th>Winding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>85</td>
<td>82</td>
<td>85</td>
</tr>
<tr>
<td>Experienced</td>
<td>88</td>
<td>94</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 5
Percentage of calls answered and initiated by road type and age group.

<table>
<thead>
<tr>
<th>Road condition</th>
<th>Easy (%)</th>
<th>Heavy traffic (%)</th>
<th>Winding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incoming (answered) calls</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Experienced</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Elderly</td>
<td>94</td>
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<td>Overall</td>
<td>98</td>
<td>94</td>
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<td>Outgoing (initiated) calls</td>
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<tr>
<td>Young</td>
<td>83</td>
<td>100</td>
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<td>Experienced</td>
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<tr>
<td>Elderly</td>
<td>50</td>
<td>55</td>
<td>50</td>
</tr>
<tr>
<td>Overall</td>
<td>70</td>
<td>83</td>
<td>77</td>
</tr>
</tbody>
</table>

3.1.5. Dependent variables
As in Study 1, we measured the same four types of dependent variables: engagement in phone conversation, driving performance, cell phone performance, and subjective responses.

3.2. Results

3.2.1. Proportion of incoming and outgoing calls by the three age groups
The primary aim of this study was to compare the driver groups in terms of their decisions to engage or not engage in a cell phone conversation while driving. Overall, for all participants combined, it was possible to engage in 54 calls in each road condition (within each of the cell phone scenarios), for a total of 162 incoming calls and 162 outgoing calls. Of those, 148 of the incoming calls were answered (91.4%) and 125 calls were initiated (77.2%). Using 95% confidence intervals the difference between these proportions was statistically significant (CI = 0.064–0.219). Table 5 breaks down the percentage of calls (answered and initiated) at each road condition by each age group. It can be seen that the experienced and the young drivers answered all incoming calls regardless of the driving demands. Older drivers answered fewer calls, and the percent answered declined with the increasing difficulty of the drive. Similarly, in the outgoing calls condition, young drivers made almost all of the potential calls while experienced and elderly drivers were engaged in fewer calls. The difference between the proportion of initiated and answered calls for the young drivers was not significant (95% CI = −0.005 to 0.11). It was significant, however, for the experienced drivers (95% CI = 0.05–0.24) and for the elderly drivers (95% CI = 0.04–0.39).

Next, we compared the proportion of calls initiated by the drivers in the different age groups. Older drivers initiated significantly fewer calls than the experienced drivers (95% CI = 0.16, 0.51) and the young drivers (95% CI = 0.24, 0.61). Young and experienced drivers did not differ significantly from each other in the number of initiated calls (95% CI = −0.01, 0.08).

Surprisingly, fewer calls were initiated in the easy road condition relative to the other road conditions. However, none of the paired comparisons between the percentages of calls initiated in the different road conditions was statistically significant.

3.2.2. Analyses of dependent measures during incoming calls
This subsection presents analyses of the effects of the scenarios in the incoming calls on the driving performance and the performance measures on the phone task.

3.2.2.1. Response time to calls. Response time was calculated for answered calls (100% for young and experienced drivers, 74% for elderly drivers) as the time interval from the phone’s first ring until the driver touched the answer button. Fig. 2 presents the average time to answer a phone call for each age groups and road type.

Response times were transformed using natural logarithm. A two-way (road type and age group) unbalanced ANOVA with repeated measures was conducted on the transformed dependent variable. The results revealed significant effects of road type (F(2, 69.20) = 5.10, p = 0.09) and age group (F(2, 50.93) = 4.75, p = 0.013). The interaction between road type and age group was also significant (F(4, 68.61) = 3.01, p = 0.024), showing that young and experienced drivers responded faster to the ring than older drivers, and their response times are unaffected by the road conditions, while older drivers’ responses were much slower while driving on a winding road.

3.2.2.2. Average speed during incoming calls. Fig. 3 presents the drivers’ average speed on the same road segments with and without the phone task.

Due to the fact that not all participants answered all calls, an unbalanced, mixed design ANOVA was conducted to analyze the effects of age group, road condition and cell phone conversation on the average speed. The analysis revealed significant main effects of conversation (F(1, 135.68) = 15.75, p < 0.001), road type (F(2, 77.189) = 178.79, p < 0.001), and age group (F(2, 50.396) = 9.37, p < 0.001). There were no interaction effects.

In all conditions drivers from all age groups drove consistently slower when engaged in the phone conversation, by an average of 2 mph (42.3 vs. 44.2 mph). Post hoc Scheffe tests showed that the participants drove slower on the winding road (M = 37.5 mph) and fastest on the easy road (M = 50.7 mph). The speed in the heavy traffic (42.9 mph) was in between the other road types (p < 0.05). The elderly drivers drove slower (40.9 mph) than the other two groups (45.2 mph and 45.3 mph for the young and experienced groups, respectively).

Fig. 2. Average response time to a phone call depending on age group and road type.

Fig. 3. Average speed during incoming call and without distraction by road condition and age group.
3.2.2.3. Speed variance during incoming calls. The standard deviations of the participants’ speed were transformed using natural logarithms. The effects of road type, age group, and the presence or absence of conversation were tested with unbalanced mixed design ANOVA. The analysis revealed significant main effects of conversation ($F(1, 73.22) = 19.38, p < 0.001$), road type ($F(2, 105.38) = 77.12, p < 0.001$), and age group ($F(2, 62.60) = 4.84, p = 0.011$). There were no interaction effects.

During a conversation the participants had a harder time maintaining constant speed (average SD = 7.20) relative to the no-conversation condition (average SD = 5.81). Scheffe post hoc tests indicate that the participants’ speed variance in the heavy traffic road (average SD = 6.23) was significantly higher than their speed variance in the easy road (average SD = 4.31) and significantly lower than their speed variance in the winding road (average SD = 9.45). Speed variance was significantly different between the experienced group, who drove most consistently, speed-wise (average SD = 5.5), and the young group, who drove least consistently (average SD = 7.4). The elderly group did not differ significantly from the other groups (average SD = 6.7).

3.2.2.4. Variance of lane position during incoming calls. The standard deviations of the participants’ position in the lane were transformed using natural logarithms. The effects of road type, age group, and the presence or absence of conversation were tested with unbalanced mixed design ANOVA. Because the heavy traffic road was a four-lane road and drivers were allowed to change lanes, it was excluded from the analysis. The analysis revealed significant main effect of road type ($F(1, 46.94) = 53.80, p < 0.001$), with smaller variance in the easy road (average SD of lane position = 1.35) than on the winding road (average SD of lane position = 1.88). The age–group effect was marginally significant [$p = 0.06$] with experienced drivers maintaining their position best followed by young drivers and older drivers respectively. Conversing – surprisingly – did not affect the variance of the lane position. However, the age group by conversation interaction was significant ($p = 0.046$): Older drivers were more susceptible to variance in lane position during conversations.

3.2.2.5. Number of accidents during incoming calls. Overall there were 13 accidents during the incoming calls scenario (including eleven collisions with other vehicles). While the number may be too small for statistical analysis, it is worth noting that eight of the accidents occurred while conversing on the winding road. Of these 8 accidents, 6 involved the young group and 2 the elderly group. Overall, 9 of the accidents involved young drivers.

3.2.2.6. Percentage of correct answers in the incoming calls scenario. The phone conversation task consisted of three arithmetic problems. The average percentage of correct answers by age group and road condition is presented in Table 6. A logistic regression model showed that the only significant difference in the percent of correct answers was between the elderly drivers and the experienced and young drivers ($p = 0.008$), with the elderly doing worse than the other two groups.

Table 6

<table>
<thead>
<tr>
<th></th>
<th>Easy (%)</th>
<th>Traffic (%)</th>
<th>Winding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>79</td>
<td>76</td>
<td>74</td>
</tr>
<tr>
<td>Experienced</td>
<td>91</td>
<td>95</td>
<td>97</td>
</tr>
<tr>
<td>Elderly</td>
<td>76</td>
<td>81</td>
<td>53</td>
</tr>
</tbody>
</table>

3.2.2.7. Perceived difficulty of the drive during the incoming calls scenario. An unbalanced repeated measures mixed ANOVA revealed significant main effects for road condition ($F(2, 39.367) = 9.66, p < 0.001$) and age group ($F(2, 41.554) = 3.41, p = 0.043$) on perceived drive difficulty. There was no interaction effect.

Scheffe post hoc test indicated that the young drivers rated the driving experience as significantly easier ($M = 2.31$) than the elderly and the experienced groups ($M = 3.81$ and 3.92, respectively). Participants rated the easy road as the least difficult condition ($M = 2.72$) relative to the other road conditions ($M = 3.76$ and $M = 3.92$ for the heavy traffic and the winding road, respectively). However, based on a Scheffe test there were no statistically significant differences among the three road conditions.

3.2.2.8. NASA-TLX Questionnaire for the incoming calls scenario. To test the subjective task load differences between age groups we conducted Kruskal–Wallis tests on each item in the NASA-TLX questionnaire and on the overall score. Significant effects were found only for the time demand measure ($p < 0.001$) and for the overall measure ($p = 0.02$). Marginally significant effects were found for the physical demand measure ($p = 0.054$) and the effort measure ($p = 0.055$).

A Mann–Whitney test conducted on differences between each pair of age groups, showed that the young group reported a significantly lower task load relative to the experienced group for the time demand item (mean rank = 11.8 vs. 25.3, $p < 0.05$) and for the overall measure ($M = 14.3 vs. 22.7, p = 0.017$). There was also marginally significant difference for the effort item ($M = 15.1 vs. 21.9, p = 0.05$).

Similarly, the young participants reported lower task load relative to the elderly participants for the time demand measure ($M = 12.1 vs. 24.9, p < 0.001$), for the physical demand measure ($M = 14.4 vs. 22.6, p = 0.02$), for the effort measure ($M = 14.8 vs. 22.3, p = 0.031$) and for the overall measure ($M = 14.3 vs. 22.8, p = 0.017$). The differences along the frustration measure were marginally significant ($M = 15.1 vs. 21.9, p = 0.05$).

3.2.3. Analysis of dependent variables during outgoing calls

3.2.3.1. Engagement in calls. Call initiation time. Call initiation time is defined as the time interval between the experimenter’s indication that the driver can initiate a call and the time in which the driver started dialing. Fig. 4 presents the average time to initiate a call by age group and road type.

Call initiation times were transformed using natural logarithm. An unbalanced mixed design (road type and age group) ANOVA was conducted on the transformed dependent variable, yielding significant main effects for the road condition ($F(2, 70.59) = 14.71, p < 0.001$) and the age group ($F(2, 101.23) = 4.38, p = 0.015$). There was no interaction effect.

Scheffe post hoc test showed that call initiation times on the winding road ($M = 22.86$) were significantly ($p < 0.05$) longer than the initiation times on the easy and heavy traffic roads ($M = 10.42$).

Fig. 4. Average initiation call time by age group and road type.
and 12.49, respectively). The elderly drivers ($M = 19.8$ s) took longer to initiate calls than the young and the experienced drivers ($M = 12.7$ s and $M = 13.6$, respectively).

**Dialing time.** Dialing time was defined as the interval between the first time a participant touched the keypad and the time he or she pressed the “SEND” button, provided that the call was successful. Fig. 5 presents the average dialing time for each age group in each road type.

Dialing times were transformed using natural logarithm. A two-way (road type and age group) unbalanced ANOVA with repeated measures was conducted on the transformed dependent variable, yielding significant main effects for the road condition ($F(2, 48.38) = 7.86, p = 0.001$) and the age group ($F(2, 47.60) = 10.79, p < 0.001$). There was no interaction effect.

Scheffé post hoc test showed that call dialing times on the winding road ($M = 26.8$ s) were significantly ($p < 0.05$) longer than the dialing times on the easy road ($M = 16.6$). Dialing times on the heavy traffic road ($M = 20.9$) were not significantly different than on the other two roads. Post hoc tests on differences between age groups found that the elderly group ($M = 36.3$) took significantly ($p < 0.05$) longer than the experienced group and the young group to dial a number ($M = 16.8$ and $M = 17.8$, respectively).

### 3.2.3.2. Effects of dialing

**Average speed during dialing.** For participants who dial while driving, we calculated the average speed during the dialing interval and the average speed while driving the same road segment without dialing. Eight observations – notably all from the elderly group – were omitted for the following reasons: in 4 cases the drivers pulled to the side of the road in order to dial; in 4 cases the participants dialed for so long that dialing extended into the next road segment (that was supposed to be free of cell phone conversations). Fig. 6 presents for each age group and road condition, the mean of speed differences between driving without distraction and driving while dialing.

As can be seen in Fig. 6, there was a positive difference (meaning that speed was lower while dialing) in all road conditions and for all age groups. An unbalanced repeated measure ANOVA was conducted to analyze the effect of road condition, age group and dialing on average speed while dialing. The participants’ average speed was 6.2 mph slower while dialing ($M = 37.78$ mph) compared to the average speed without dialing ($M = 44.05$ mph) ($F(1, 136.16) = 77.86, p < 0.001$). Significant main effects were found also for road condition ($F(2, 70.0) = 107.24, p < 0.001$), and age group ($F(2, 43.94) = 5.98, p = 0.01$). The interaction between age group and road condition was also significant ($F(4, 69.08) = 5.48, p < 0.001$).

Scheffé post hoc tests ($p < 0.05$) indicated that drivers drove the fastest on the easy way ($M = 50.3$ mph), significantly slower on the heavy traffic road ($M = 41.3$ mph), and significantly slower still on the winding road ($M = 32.06$ mph). The post hoc tests among the age groups showed that the elderly group drove significantly slower ($M = 38.68$ mph) than the young and the experienced groups ($M = 42.04$ mph and 43.14, respectively).

The interaction between road condition and age group was due to the older group’s tendency to drive slower than the other groups in the relatively easier conditions (the easy road and the heavy traffic road), but just as slow as the other two groups on the winding road. Still, it is important to note, that in all three conditions older drivers also initiated considerably fewer calls than the other two groups.

**Speed variance while dialing.** The effects of road type, age group and dialing (yes or no) on the in-transformed standard deviations of the participants’ speed were tested with unbalanced mixed design ANOVA. The analysis revealed significant main effects of road type ($F(2, 88.88) = 14.82, p < 0.001$) and dialing ($F(1, 141.02) = 8.43, p = 0.004$), and marginal effect of age group ($F(2, 54.70) = 3.15, p = 0.051$). While dialing, the participants’ speed fluctuated more (average SD = 4.28) than while not dialing (average SD = 3.13). Scheffé post hoc tests show that drivers maintained speed best on the easy road (average SD = 2.65), then on the heavy traffic road (average SD = 3.73), and worst on the winding road (average SD = 4.81).

**Variance of lane position while dialing.** The effects of road type, age group and dialing (yes or no) on the in-transformed standard deviations of the participants’ lane position were tested with unbalanced mixed design ANOVA. The analysis revealed significant main effects of road type ($F(1, 59.37) = 20.67, p < 0.001$), which was qualified by a road type x age group interaction ($F(2, 57.50) = 4.15, p = 0.021$). The interaction showed that on the winding road, experienced drivers deviated from their lane position more than the other two groups.

**Number of accidents while dialing.** Overall, during the segments in which dialing was allowed, participants were involved in nine accidents (including six collisions with other vehicles). Of those, eight happened during dialing while only one happened while not dialing. Experienced drivers were involved in two accidents, older drivers in three and young drivers in four.

### 3.2.3.3. Effects of conversations

**Average speed during outgoing calls.** For the outgoing calls scenario, the mean of speed differences between driving without distraction and driving while speaking on the phone is presented in Fig. 7 for each age group and road condition.

An unbalanced mixed design repeated measure ANOVA with road condition, age group, and conversation as experimental
factors found that average speed was affected by road condition (\(F(2, 34.74) = 45.72, p < 0.001\)) and conversation (\(F(1, 36.21) = 15.70, p < 0.001\)). Participants drove significantly slower during a conversation (\(M = 44.0\) mph) compared to the no conversation condition (\(M = 46.2\) mph) under all road conditions. Scheffe post hoc tests revealed that the drivers drove the fastest on the easy way (\(M = 51.4\) mph), significantly slower on the heavy traffic road (\(M = 44.4\) mph) and the slower still on the winding road (\(M = 40.7\) mph).

**Speed variance during outgoing calls.** The standard deviations of the participants’ speed were transformed using natural logarithms. The effects of road type, age group and the presence or absence of conversation were tested using unbalanced mixed design ANOVA. The analysis reveals significant main effects of conversation (\(F(1, 99.94) = 27.83, p < 0.001\)) and road type (\(F(2, 83.15) = 43.09, p < 0.001\), an interaction of conversation and road type (\(F(2, 99.49) = 10.26, p < 0.001\)), and a 3-way interaction of all three variables (\(F(4, 97.30) = 4.59, p = 0.002\)). When not engaged in the phone task, speed variance increased for all drivers from the easy road (\(M = 3.7\) mph), to the heavy traffic road (\(M = 6.0\)), and to the winding road (\(M = 8.2\)). The 3-way interaction, illustrated in Fig. 8, indicates that during conversation the elderly drivers had the highest speed variance on the heavy traffic road and the experienced drivers had the lowest speed variance on all road types.

**Variance of lane position during outgoing calls.** The standard deviations of the participants’ position in the lane were transformed using natural logarithms. The effects of road type, age group and the presence or absence of conversation were tested with unbalanced mixed design ANOVA. Because the heavy traffic road was a four-lane road and drivers were allowed to change lanes, it was excluded from the analysis. The analysis revealed significant main effect of road type (\(F(1, 45.86) = 11.75, p < 0.001\)). Drivers maintained lane position better on the easy road (average SD = 1.30) than on the winding road (average SD = 1.64). There was also a significant conversation x age group interaction (\(F(2, 44.06) = 5.86, p = 0.006\)), showing that, for older drivers lane position variance was greatest when speaking on the phone, while for younger lane position variance was greatest when not speaking on the phone. Experienced drivers had the least variance under both conditions.

**Number of accidents during outgoing calls.** Overall, there were seven accidents during the outgoing calls scenario (including five collisions with other vehicles). Of those, 6 happened during conversations. Five of the 7 accidents involved young drivers and 2 involved old drivers.

**Percentage of correct answers in the outgoing calls scenario.** The percentage of correct answer by age group and road condition presented in Table 7. A logistic regression model showed that only the interaction between age and road condition had a significant effect on the probability (\(p = 0.006\)), with elderly drivers performing better on the heavy traffic road and young drivers performing better on the easy road and worst on the heavy traffic road.

**Perceived road difficulty during the outgoing calls scenario.** An unbalanced mixed design ANOVA revealed a significant main effect of road condition on road difficulty rating (\(F(2, 31.95) = 14.38, p < 0.001\)). There was no age group main effect or age group x road condition interaction effect. Scheffe post hoc tests found that the participants rated the easy road (\(M = 2.17\)) as significantly easier than the other two road conditions (\(M = 3.79\) in the heavy traffic condition and \(M = 3.87\) in the winding road condition).

**NASA-TLX Questionnaire for the outgoing calls scenario.** Kruskal–Wallis tests of the effect of age group on responses to the NASA-TLX questionnaire found only one significant difference — the effort item (Chi Square (df = 2) = 5.99, \(p = 0.05\)). Mann–Whitney tests found that the differences were between the younger drivers, who rated the task as less difficult compared to the experienced drivers.

### Table 7

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Easy (%)</th>
<th>Traffic (%)</th>
<th>Winding (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>93</td>
<td>64</td>
<td>79</td>
</tr>
<tr>
<td>Experienced</td>
<td>84</td>
<td>94</td>
<td>92</td>
</tr>
<tr>
<td>Elderly</td>
<td>76</td>
<td>95</td>
<td>85</td>
</tr>
</tbody>
</table>

**3.2.4. Gained benefits and perceived impairment from the cell phone conversations**

#### 3.2.4.1. Benefits.

As describe in the Method section, the cost–benefit scheme included a $0.5 bonus for each correct answer on the phone task, and $0.5 fine for any driving violation during the conversation. One way ANOVA revealed significant age group effect (\(F(2) = 6.39, p = 0.004\)). The experienced drivers gained the most under this scheme, earning on average $6.75 (SD = 2.31). The young group earned $4.15 (SD = 3.38) and the elderly group earned $3.13 (SD = 3.09).

#### 3.2.4.2. Perceived driving impairment.

At the end of the experimental session, the participants rated the degree to which their driving was impaired by the cell phone conversations on a 1 (no impairment)–10 (extreme impairment) scale. Young drivers reported the least impairment (\(M = 3.2\)), and experienced and older drivers reported higher and similar levels of impairment (\(M = 4.5\)).
and $M=4.4$, respectively). Mann–Whitney tests showed that the difference was significant ($p<0.001$).

3.2.5. Summary of results

The two studies yielded very similar and consistent results concerning the inclination of drivers to make or receive a phone call, and the actual and perceived effects of these tasks for the different groups under the different road conditions. Table 8 provides a summary of findings in the two studies.

4. Discussion

We conducted two experiments to study drivers’ decision on whether to answer and to initiate calls while driving in a simulator; their driving behavior while engaged and not engaged in the phone task; and their performance on the conversation task. Participants in the study came from three driver groups of varying experience and age, and they drove under three different road conditions. In this section we discuss the main findings of these experiments from four perspectives: drivers’ decisions to engage in phone conversations, driving performance while speaking on the phone, performance on the secondary task (the phone conversation), and subjective assessment of the driving session.

4.1. Decision to engage in a phone conversation

Two findings stand out from both experiments in terms of drivers’ willingness to engage in cell phones. First, drivers are usually more likely to answer phone calls than to initiate calls. This finding matches Walsh et al.’s (2007) finding that the most common use of cell phone while driving is answering a call. There may be a greater urgency in engaging in an incoming call as opposed to an outgoing call that can be delayed until timing (e.g., driving conditions) is more appropriate. It is possible, however, that this finding is an artifact of the experimental setting: Answering a phone call required pressing a single button. Initiating a call, on the other hand, required a more complex action (pressing 10 digits and the Send button). However, it is important to notice that these settings closely resemble one’s operations in real-world context of incoming or outgoing calls.

Second, and regardless of road conditions, young drivers are more likely to initiate calls than older more experienced drivers. Young drivers also initiate and accept calls at virtually the same rate – which is close to 100%. In contrast, experienced drivers and older drivers were both sensitive to road type when initiating calls and to the context of the calls (incoming vs. outgoing). This sensitivity was especially manifested in the behavior of the elderly drivers, who also took longer to respond to incoming calls and to initiate calls, a trend which was accentuated in the more difficult road conditions. These results are in line with earlier findings about the behavior of young and elderly drivers. Young drivers do not handle phone calls on a strategic level (i.e., taking into account road and context conditions), which puts them at a greater risk compared to more experienced drivers (Shinar et al., 2005). Older drivers, in contrast, are either highly sensitive to varying road and context conditions (Andrews and Westerman, 2012), or are more reluctant to share the driving task with other tasks, and therefore manage their incoming, and especially outgoing calls accordingly (e.g., Poyhti et al., 2005).

In fact, some of the elderly drivers in our study did not make outgoing calls at all, indicating awareness of their declining ability to multitask while driving.

4.2. Performance on the driving task

Performance measures shed more light on the participants’ decisions to engage in phone calls while driving. As in previous studies (e.g., Liu and Lee, 2006), we found that drivers drive slower when engaged in phone conversations. This effect was obtained in both scenarios (incoming and outgoing calls). In addition, during the incoming call scenario and during the dialing action, the elderly drivers drove the slowest. This finding is consistent with Horberry et al. (2006) and Bayram et al. (2005), who suggested that elderly drivers compensate for difficulty in coping with the demands of attention by reducing speed. Experienced drivers were better than younger drivers at optimizing driving performance given the changing road conditions and the need to decide on whether to engage in phone calls.

The results indicate that while young drivers more readily engaged in multitasking while driving compared to experienced drivers, they performed less consistently in terms of speed variance and involvement in accidents. The greater demands of the dialing action were manifested differently in the different age groups as a function of the driving demands. The largest difference in speed during dialing was found between the elderly drivers and the other two age groups in the heavy traffic road. Driving on this road apparently required more information processing, which made it more difficult for the elderly drivers compared to the other two age groups.

In other respects the results are consistent with previous studies that show that engaging in a phone conversation is detrimental to various driving measures such as speed and lane position maintenance and crashes (though there were too few crashes to analyze statistically). Also as found in previous studies, average speed was consistently lower while engaged in a phone task than when not (e.g., Shinar, 2007). However, it should be noted that in this study, drivers had only a short period of adaptation to driving a simulator. Longer adaptation period could have contributed to improved driving performance (Shinar et al., 2005).

4.3. Performance on the phone task

Relative to the other groups, experienced drivers performed consistently better on the secondary task in terms of percentage of correct answers to the arithmetic problems. The poorer performance of the other two groups was manifested especially in the more difficult road conditions in Study 2. Young drivers performed worst when making outgoing calls in heavy traffic conditions. Older drivers performed worst receiving incoming calls on the winding road.

The financial rewards awarded at the end of Experiment 2 represent the combined performance of drivers in both tasks. Experienced drivers received the highest pay while elderly drivers and young drivers accrued lower and similar benefits. This is despite the fact that the elderly drivers answered only about three quarters of the incoming calls and initiated only half of the potential outgoing calls. Thus, young drivers performed less efficiently on the secondary task and drove less well than the older drivers. It is important to remember, though, that in reality the costs of poor performance on the driving task (e.g., being involved in accidents) may be considerably more extreme than in the cost–benefit scheme employed in our study.

4.4. Subjective evaluations

Compared to the experienced and the older drivers, the young drivers perceived the driving conditions as easier, and reported less effortful driving. These results are consistent with previous research that found that young drivers tend to underestimate road risks (Taubman-Ben-Ari and Lotan, 2011) and to be overconfident while multitasking (Lerner et al., 2008).
Table 8
Summary of significant results.

<table>
<thead>
<tr>
<th>Incoming calls</th>
<th>Study 1 (young and experienced drivers only)</th>
<th>Study 2 (young, experienced, and elderly drivers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent calls answered</td>
<td>Young answer all calls (experienced drivers answer nearly all calls – difference not significant)</td>
<td>Young answer all calls, experienced answer slightly fewer calls Elderly answer fewest calls, depending on road condition</td>
</tr>
<tr>
<td>Response time to calls</td>
<td>Greater on winding road than on heavy traffic roads</td>
<td>Longest for the elderly, especially on the winding road</td>
</tr>
<tr>
<td>Average speed during incoming calls</td>
<td>Lower speed while conversing Lower on winding road, followed by heavy traffic road, and highest on easy road Elderly drivers slower than experienced drivers</td>
<td>Lower while conversing than when not Elderly on winding road, next on heavy traffic road, highest on easy road Elderly are slower than the young and experienced</td>
</tr>
<tr>
<td>Speed variance</td>
<td>Lower for experienced drivers than young ones Lower on easy road than on winding road</td>
<td>Lower for experienced drivers and highest for young drivers (older drivers in between) Lowest on easy road, next on heavy traffic road, and greatest on winding road Greater with conversation than without it</td>
</tr>
<tr>
<td>Lane position variance</td>
<td>Lower on easy than on winding road Lower while conversing than when not conversing</td>
<td>Lower on easy than on winding road Lower for experienced drivers relative to older drivers (young drivers in between) Higher for older drivers during conversation than when not conversing</td>
</tr>
<tr>
<td>Number of accidents (too small for analysis)</td>
<td>Total = 3. During conversations = 3, on winding roads = 3</td>
<td>Total = 13. While conversing on winding road = 8 (6 young), total young = 9. Experience are correct more often than the young and elderly Young perceive it as less difficult than the experienced and elderly</td>
</tr>
<tr>
<td>% of correct answers Perceived road difficulty (driving load)</td>
<td>n.s. Easy road is easiest, winding road next, and heavy traffic most difficult</td>
<td>Young felt less loaded than experienced and elderly drivers</td>
</tr>
<tr>
<td>NASA TLX (incoming)</td>
<td>NA</td>
<td>Study 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outgoing calls</th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>% initiated calls</td>
<td>Young initiate all possible calls</td>
<td>Young initiate almost all possible calls Elderly initiate only 50% of calls</td>
</tr>
<tr>
<td>Call initiation time</td>
<td>Longest for experienced drivers on winding road and shortest for young drivers on winding road</td>
<td>Longer on winding than on easy and heavy traffic road Longer for elderly than for young and experienced drivers</td>
</tr>
<tr>
<td>Dialing time</td>
<td>n.s.</td>
<td>Longer on winding than on easy road Longer for elderly than for young and experienced</td>
</tr>
<tr>
<td>Average Speed during dialing</td>
<td>Lower while dialing than when not Lower on winding than on heavy traffic and fastest on easy road</td>
<td>Lower while dialing than when not dialing Lower on winding than on easy road, which is lower than on easy road Lower for elderly than for young and experienced</td>
</tr>
<tr>
<td>Speed variance while dialing</td>
<td>Lower on easy road than on heavy traffic and winding road</td>
<td>Lower on easy road than on heavy traffic, which is lower than on easy road Lower for elderly than for young and experienced</td>
</tr>
<tr>
<td>Lane position variance while dialing</td>
<td>Greater when dialing than when not Greatest for young drivers on driving road, lowest for experienced drivers on winding</td>
<td>Greater for experienced drivers on winding road lowest for young and elderly drivers on winding road</td>
</tr>
<tr>
<td># of accidents while dialing</td>
<td>Overall = 5, while dialing = 5, young = 4</td>
<td>Overall = 9, while dialing = 8.</td>
</tr>
<tr>
<td>During conversation</td>
<td>Study 1</td>
<td>Study 2</td>
</tr>
<tr>
<td>Average speed during outgoing calls</td>
<td>Highest on easy road, then heavy traffic, and lowest on winding Lower when conversing than when not conversing</td>
<td>Highest on easy road, lower in heavy traffic, and slowest on winding road Lower while conversing than when not</td>
</tr>
<tr>
<td>Speed variance during outgoing calls</td>
<td>Lower on easy road than on heavy traffic and winding road</td>
<td>Greater for elderly in heavy traffic while conversing than for all other drivers while conversing Lowest for experienced drivers in all conditions</td>
</tr>
<tr>
<td>Lane position variance during outgoing calls</td>
<td>Lower on easy road than on winding road Lower while conversing than when not conversing</td>
<td>Greater on easy road than on winding road Greater for elderly while conversing than while not conversing Lowest for experienced drivers</td>
</tr>
<tr>
<td>Number of accidents during outgoing calls</td>
<td>Overall = 2, winding road = 2, no conversation = 2</td>
<td>Overall = 7, conversation = 6, young = 5</td>
</tr>
<tr>
<td>% of correct answers Perceived road difficulty (driving load)</td>
<td>Higher for experienced than for young drivers Easy road perceived as less difficult than heavy traffic and winding road</td>
<td>Highest for experienced, followed by elderly, and lowest for young drivers Easy road perceived as less difficult than heavy traffic and winding road</td>
</tr>
<tr>
<td>NASA TLX (outgoing)</td>
<td>NA</td>
<td>Greater effort felt by experienced and elderly drivers than by young drivers</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Measures</th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA TLX (overall)</td>
<td>n.s.</td>
<td>NA</td>
</tr>
<tr>
<td>Gains from calls</td>
<td>NA</td>
<td>Experienced gained the most, young drivers next, and elderly the least.</td>
</tr>
<tr>
<td>Perceived driving impairment from phone task</td>
<td>NA</td>
<td>Young drivers felt less impaired than experienced and elderly drivers</td>
</tr>
</tbody>
</table>
4.5. Study limitations

There are three limiting factors that must be acknowledged in this study. The first factor is that the two studies were conducted in driving simulators, with all of the concomitants limitations of a simulated environment. Thus, the absolute values of behavioral measures may be different than they are in real world driving. Nonetheless, the differences observed between the driver groups and the different conditions are probably valid as has been demonstrated in some validation studies, including one done on simulated driving in our laboratory (Shinar and Ronen, 2007). It is possible that driving in a simulator may be particularly difficult and artificial for older drivers, though the use of driving simulators in the study of older drivers’ behavior is quite common, and the greater difficulties that older drivers have in time sharing driving and using the phone has been established on the road as well (Shinar, 2007).

The second factor is the monetary incentives and penalties used for correct answers on the phone task and driving violations and accidents, respectively. It is very difficult to determine the real world equivalence of the rewards associated with answering and attending to a phone while driving and the subjective costs of violations and accidents. Thus, the monetary values we chose were based on previous studies (e.g. Camerer and Hogarth, 1999) and pilot testing. The third factor is the nature of the phone task. The arithmetic task used here was first used by McKnight and McKnight (1993) and since then has been used repeatedly (including in one of our previous studies; Shinar et al., 2005) as a surrogate for a cognitively demanding phone conversation.

5. Conclusions and implications

Our two studies portray a relatively consistent picture of how various factors affect drivers’ decision to engage in phone conversations while driving, and the consequences of such engagement. Thus, we found that the likelihood that drivers choose to engage in a phone conversation is higher when the call is initiated by the other party than when they feel the need to call. In the latter case, drivers are more attuned to contextual factors such as the difficulty of the road, and are less inclined to initiate calls when road conditions are more demanding. Moreover, young drivers were more eager to engage in calls and were less sensitive to road conditions when deciding whether to answer a call or to initiate one, to the extent that they initiated and responded to calls at almost any opportunity, regardless of the road and traffic conditions. Not surprisingly, young drivers were also found to underestimate road difficulty and the demands of dual task performance. Consequently, young drivers underperformed both in the primary and the secondary tasks, and were in a greater risk of being involved in accidents. In contrast to young drivers, elderly drivers appeared conscious of their information processing limitations. They were highly sensitive to the driving context and to their cognitive and motor limitations when making decisions about whether or not to engage in calls, and especially in their decisions whether or not to initiate calls.

With the proliferation of in-vehicle information technologies, and especially with the accessibility of mobile phones to virtually all drivers, drivers constantly trade-off the benefits and potential costs of using those technologies while driving. Evidently, young drivers underestimate the potential costs associated with dual tasking while driving. They may also attribute greater benefits to using those systems. Hence, of the three driver groups studied here they are the most susceptible for the deleterious effects of mobile phone use while driving.

The implication of our finding is that since the traditional approach to control risks through public education has not been very effective, other measures should be enacted to modify cell phone use while driving. These controls could be linked to smart ignitions, road-based in-vehicle informatics, licensing restrictions (e.g. as part of graduated licensing systems), and enforcement. Because, experienced drivers seem to be able to handle the dual driving-and-phone tasks better, and older drivers seem to be better judges of their limitations, the need for such measures is most pressing for the young and less experienced drivers who are already the highest risk group drivers on the road.

References


Shinar, D., Tractinsky, N., Compton, R., 2005. Effects of practice, age, and task demands, on interference from phone task while driving. Accident Analysis and Prevention 37, 315–326.


