Effect of phone conversations on tactical components of the driving task

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Abstract:

This paper aims at investigating how phone conversations may affect tactical control of the vehicle and decision-making. Twenty-four drivers (16 males and 8 females; mean age = 39.1; SD = 5.5) participated in an on-road experiment. They had to answer to phone calls using a hands-free kit and to maintain conversations while driving on motorway and in urban area. Results on motorway show that, during phone conversations, the drivers were less likely to overtake slower vehicles and stayed longer on the lane before moving back after overtaking manoeuvres. Some changes in speed behaviour were also observed as participants failed in adapting their speed to the limits when they changed. Driving errors were also more frequent while at the phone in urban area. Results on motorway show that while phoning, drivers tend to adapt their driving in a way to compensate for the additional attentional demand of the dual task of phoning and driving, by neglecting driving sub-tasks such as overtaking and adapting speed, etc. However, such behaviour also reveals difficulties to process all needed information to execute complex manoeuvres. Hard braking and errors in urban area occur as a consequence of these difficulties induced by phone communications.

Introduction

Many research studies have been carried out in order to assess the negative impact of phoning on the driving task at the operational level of the vehicle control, by measuring reaction times, braking time, control of the vehicle's trajectory and its dynamics (see Bruyas 2013, for a literature review). Examining a large part of these works, the meta-analysis by Horrey and Wickens (2006) and by Caird et al. (2008) indisputably show that drivers' response time increases when they use the mobile phone at the wheel. The possibility that drivers compensate for this increase in response times by reducing their speed does not meet such an agreement. According to Caird et al.'s meta-analysis, drivers who use a hand-held phone would reduce their speed more than those who use a hands-free one.

In this framework, only few researches focused on more tactical aspects of driving or decision-making. According to Michon’s hierarchical driving model (1985), at the tactical level of driving drivers have to make decisions about actions that are about to be executed, such as for example changing lane, overtaking, adapting speed, or giving the way to other vehicles. The first study which focused on these aspects of the driving was conducted by Brown et al. (1969) who showed that misjudgements were much more numerous during phases of phone communication. Later, Anttila and Luoma (2005) observed modifications in the way distracted drivers interact with other road users. For these authors, carrying out an auditory task increases unnecessary hesitations

before intersections and induces an increase in dangerous behaviour, as well as in inappropriate behaviour towards vulnerable road users. Other authors have investigated lane changes in simulated driving conditions such as Cooper et al. (2009) and Beede and Kass (2006). Their results show that the number of lane changes is significantly lower during phone conversations. Mobile phone use would also affects drivers more in situations requiring complex decision making, such as turning left (across traffic), than in situations where decision making is more simple, such as stopping at a red light (Cooper et al. 2003).

The present experiment has been designed in order to contribute to this question on how phone conversations may affect tactical control of the driving, and the driver's ability to make a decision. It was part of a larger study included in the INTERACTION European project (2009-2012). The project aimed at analysing drivers' use of in-vehicle technologies such as cruise control, speed limiter, navigation system and mobile phone by carrying out naturalistic and experimental on-road observations. The paper will focus on one part of the experimental observations, which concerns mobile phone impact on the driving.

Method

Participants

Twenty-four drivers aged from 30 to 50 years (16 males and 8 females; mean age = 39.1; SD = 5.5) participated in the experiment. All of them had a driving license and reported driving at least 2000 km per month. A compensation of 150 EUR was paid for their participation to this part of the experiment. The research protocol was approved by the ethic committee of IFSTTAR (French Institute of Science and Technology for Transport, Development and Networks).

Driving environment

Participants drove one of the equipped cars available for the INTERACTION project. As a part of the study was investigating Cruise Control use, each driver was given a car where the device was similar to the one generally used. Three types of car were available: Renault Clio Estate, Peugeot 207 SW and Peugeot 308. Car equipment consisted in sensors which allowed for getting vehicle acceleration, position, actions on pedals and commands and four cameras getting road view, dashboard, driver's face and driver's feet.

Each driver had to drive two times with an interval of two weeks in-between on a same predefined route. To avoid traffic jam during commuting period, experiments always occurred during the week from 9:30 to 11:30 am or from 14:00 to 16:00 pm. In order to compare their driving behaviour with and without phoning, they had to answer to phone calls only during one drive, same sections of the other one being analysed without phoning. The order in which the phone call occurred was counterbalanced across participants.

Route duration was about one hour and a half each time. The course was long enough to make possible the use of the different devices under investigation in the INTERACTION project. The present paper will only focus on the phone sections.

The global route was composed of various driving environments, but phone calls occurred always in the same places: in a specific section of motorway and in a specific section of urban area. The motorway section (9 km) included two consecutive segments. The first one was a stretch of two lanes limited to 110 km/h and the second one was a 3 to 4 lane stretch limited to 130 km/h. The urban section (4.5 km) included 5 intersections with traffic lights (1 turn left and 4 straight on) and 2 roundabouts (1 turn right and 1 straight on).

Indications of the directions to follow were given when needed by an experimenter seating in the car on the right side of the driver. No specific instruction was given to the drivers; except to drive safely and to respect the rules of the road, and to answer when they could if the phone was ringing. For safety reason, participants were told that they could postpone the call if needed or even not answer it. They were also given the possibility to interrupt the conversation if they felt the necessity to do it.

Phone conversation

Drivers answered the phone calls using a hands-free kit. Phone calls were composed of several blocks of five short questions involving various aspects of a natural conversation: description of places or objects, sentence repetitions, questions true or not, logical problems, lists of words to produce.

Data analysis

Different variables were used to estimate the effect of conversations on the driving task:

- On motorway:
    - Mean drivers' speed was registered for the 2 portions of motorway under different speed limits (110 km/h vs. 130 km/h) in order to investigate how drivers adapt their speed according to the road environment. The drivers got speed information from the speedometer (no navigation system was used in this part of the experiment), but real speed of the car (from GPS sensor) was registered and analysed.
    - Lane change frequency corresponds to the number of time a driver changed lane per minute.
    - Time spent on the different lanes correspond to the per cent of total time a driver spent on the right, central or left lanes of the motorway. Per cents of times were used instead of actual times because time duration spent on each section differed from drivers to drivers.
    - Time spent on left or central lane before moving back corresponds to the time a driver spent on these lanes without overtaking any slower vehicle, or after having doing so. In these cases and according to the French legislation, the driver should move back to a lane on the right.
- In urban areas:
    - Hard braking number corresponds to the mean number of decelerations greater than 0.2g made per driver.
    - Driving errors such as forgetting to turn the indicator on before turning or in roundabout, taking the wrong way, or running a traffic light have

been collected while phoning and without. Making at least one of these errors have been compared with or without phoning.

A repeated measures experimental design has been used. For speed data, assumption of normality (tested by Kolmogorov-Smirnov) was met, allowing for ANOVAs analyses. For the other variables not normally distributed, non-parametric statistics were used for significance testing (unilateral Wilcoxon tests). Statistical analyses were conducted with SPSS and a significance threshold of .05 was accepted ($p < .05$).

Results

Phone conversation duration

All drivers were used to telephone while driving. Nearly all of them declared that they would have answered the phone in situations like those under investigation. Only 3 of them said they might have avoided it in such circumstances and 2 especially in the urban area. However, no drivers decided not to answer, to postpone or to interrupt the conversation, although they were given this possibility.

The mean duration of phone calls on motorway was about 4 minutes (mean duration = 242 seconds; SD = 20.30) with a minimum of 175 seconds and a maximum of 272 seconds, depending on the speed of the drivers and the time they took to finish their last sentence. The mean duration of phone calls in urban area was about 6 minutes (mean duration = 349 seconds; SD = 45.18), with a minimum of 271 seconds and a maximum of 439 seconds.

Driver speed on motorway

As the motorway section was composed of two stretches of different speed limit, a repeated measure ANOVA was conducted with two factors: phone (with and without) and speed limit (110 and 130 km/h). As traffic intensity may have strong influence on drivers' speed, analyses were conducted excluding data collected under strong traffic. Strong traffic periods were defined as periods when the traffic was such that driving behaviour was constrained by other vehicles, in a way that drivers were not free to modify and/or to adapt their speed. Only few periods were considered as such: 3.9% of all the data; 2.5% of phone data & 5.3% of without phone data. No traffic jam ever occurred in this road section.

The fact registered speed appeared to be somewhat under speed limits could be partly explained because drivers got speed information from the speedometer while real speed of the car was collected, as differences between GPS speed and speedometer-speed are generally recorded.

A significant effect of the phone was shown [$F(1,23) = 6.385$, $p = 0.019$)]. Participants drove significantly slower while at the phone than without phoning (Figure 1). As expected, a significant effect of the speed limit was also shown [$F(1,23) = 218.007$, $p < 0.001$)]. Participants drove significantly faster under the 130 limit than under the 110 limit. Finally, a significant interaction between phone and speed limit was observed [$F(1,23) = 5.806$, $p = 0.024$)], showing a greater effect of the

speed in the 130 section than in the 110 one. Pair comparisons with Bonferroni tests did not show any difference between phone and without for the 110 speed limit section, while the difference was significant in the 130 section ($p < 0.05$).

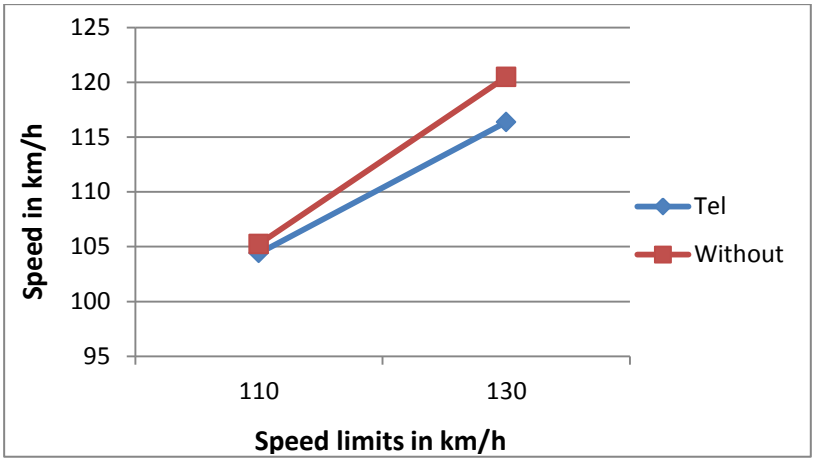

Figure 1 **Drivers' mean speed with and without phoning according to the speed limits on motorway**

Lane changes and lane position on motorway

As traffic intensity may also have an influence on behavior such as changing lane, here again analyses were conducted excluding data collected under strong traffic. Significant difference was found in terms of lane change frequency [KW, z = -2.798; $p = 0.003$)]. Drivers were less likely to change lane during phone calls than without phoning (cf. Table 1).

Concerning the time spent by the drivers on the different lanes, statistics failed to show a difference between time duration spent in the right or central lanes with or without phoning (cf. Table 1). However, drivers tend to spend less time in the left lane when they were phoning than when they were not [KW, z = -1.495; $p = 0.068$)].

Nevertheless, the time drivers spent on a central or left lane before moving back to the right, after overtaking a slower vehicle, was significantly longer while at the phone than without phoning. [KW, z = -1.943; $p = 0.026$)] (cf. Table 1).

Table 1 Mean (± Standard deviation) of lane change frequency and lane position with and without phoning under light traffic

	With phone	Without phone
Lane change frequency (Nb of lane changes per minute)	**1.19** (± 0.75)	**1.82** (± 0.80)
Time spent on left lanes (%)	9% (± 0.16)	11% (± 0.13)
Time spent on center lanes (%)	63% (± 0.22)	61% (± 0.19)
Time spent on right lanes (%)	28% (± 0.22)	28% (± 0.21)
Time spent on central or left lane before moving back (%)	**40%** (± 0.14)	**33%** (± 0.15)

Hard braking in urban area

Hard braking number was very low on motorway (only 2 occurrences), but they occurred more often in the urban area (Table 2). Number of hard braking tend to be higher in the phone condition than in the without phone condition [KW, z = -1.500; $p = 0.067$)].

Table 2 Mean number (± Standard deviation) of hard braking per driver

	With phone	Without phone
Number of hard braking per driver	**3.17** (± 1.90)	**2.63** (± 1.41)

Driving errors in urban area

Driving errors made by the drivers have been collected. Even if they were quite few, they are noteworthy in that most of them occurred in the phone condition.

- Eight of the 24 drivers forgot at least once to turn the indicator on before turning left or in roundabouts. Six of them forgot it while phoning and the two others in both with and without phoning conditions. No driver forgot it only in the without phoning condition.
- Five drivers took at least once a wrong way while at the phone and none without.
- Two other drivers run at least one amber traffic light (one run one and the other two lights) while at the phone and none without.

At the end, more than half driver (14/24 drivers) made at least one of the enumerated errors while phoning, and only 2 of them made also one error without phoning. No driver made an error only in the without phoning condition. Making at least one error occurred significantly more often while at the phone than without phoning [KW, z = -3.464; $p < 0.001$)].

Discussion and conclusion

Data from the present on-road experiment has been collected in two driving environments (motorway and urban area) with the aim of investigating tactical control of the vehicle and decision-making during phone communications.

First of all, a significant effect of phone conversation was shown on drivers' speed on motorway, as they drove significantly slower while at the phone. However, it is noteworthy that this decrease in speed did not occur in the first part of the route, which was limited to 110km/h, but in the second consecutive one under 130 km/h limit. The absence of effect in the first segment is in line with other studies using hands-free phone. According to Caird et al.'s meta-analysis (2008), reducing speed while phoning would be associated more with hand-held phone use than with hands-free phone use. The fact that distracted drivers in our experiment did not increase speed in the second segment can be interpreted in different ways. First it could be seen as indicator of an adaptive behaviour. In this situation, drivers would make the decision not to increase their speed even if they could do it when the speed limit changed, in order to reduce the driving demand. However, drivers may also have not perceived and/or not processed the speed modification while phoning, while they would have better doing so without phoning. Consequently they could not decide to adapt their speed to the speed indications, because they were not aware of the modification.

Some modifications of the driving behaviour have also been observed in terms of lane changes on motorway. Drivers spent less time on the left lanes, changed lane less frequently and kept more time before moving back to the right after overtaking slower vehicles. Cooper et al. (2009) and Beede and Kass (2006) also observed a decrease in lane change frequency in simulated driving. This could argue in favour of a decision made by distracted drivers to simplify the driving task. In such a situation, overlooking some of the peripheral driving tasks would make them more enable to devote enough attentional resources to the dual task of driving and phoning.

Results in urban area showed an increase in hard braking in response to events from the driving environment. If it is well known that drivers' response time increases while at the phone, some studies have also observed that they carry out sharp braking more often when engaged in mobile phone task (Hancock et al. 2003, Harbluk et al. 2007). In such cases, drivers would begin to press on the brake later, but compensate for this late braking by braking harder, in order to ultimately stop in time. These adjustments of braking behaviour would allow them to compensate for a reduction in visual control of the environment. In order to brake in a suitable manner, the drivers must affect a control of the environment which allows them to take all pertinent information into account. When distracted, the recognition of these elements is distorted, which delays the moment of decision-making. In this case, sharper braking compensates for this delay.

At the end, results in urban area indicated that more driving errors were made by drivers when they were phoning. Beede and Kass (2006) also showed that drivers committed a significantly higher number of violations and errors during phone conversations. As pointed out by the authors, behaviour that avoids the completion of certain tasks but in the course of which a higher number of errors and violations is recorded supports deterioration in situation awareness. In these cases, drivers no longer succeed in processing all information in the road environment. This is also what the

higher number of hard braking suggests. This reduction in situation awareness during phone communication has been observed by Gugerty et al. (2004). The authors showed that phone communication degrades various aspects of their situation awareness, including their abilities to identify, locate and respond to hazardous vehicles and to avoid accidents.

If such an experiment, as any experiment, presents certain limits, driving behaviour that has been observed here was unrestrained and management of the driving task was more or less determined by the drivers. No instruction was given in terms of speed unless respecting the traffic rules nor in terms of overtaking vehicle or not. All drivers were used to answer phone calls using a hands-free phone while driving, even if we can admit that maybe some of them would have preferred not answering to the call in urban area. However, they were given the possibility to delay, interrupt or even not answer the phone call if they felt not comfortable conversing in a particular situation and none of them found it necessary. The method allows us then to explore the impact of dual task under conditions that were not predictable, as it is often the case in simulator studies. The fact drivers were subject to natural driving conditions that could vary, make some comparisons more difficult. However, it enhanced the possibility to observe real behaviour inside the traffic and to analyse decision made by drivers without being given specific instruction.

In conclusion, keeping the same speed when it is possible to accelerate or changing lane less frequently, allow the drivers to minimize the driving demand. By avoiding the less important driving sub-tasks they allocate more attentional resources to the dual task of phoning and driving. Such behaviour could be considered as an adaptive behaviour which enhances safety, by at least mitigating the effect of the conversation on the driving. However, it could also reveal drivers' difficulties to process all needed information to execute complex manoeuvres such as overtaking in surrounding traffic, and to adapt to the modification of the driving conditions. In urban area, hard braking and errors such as running traffic lights, forgetting to put the indicator on, or taking the wrong direction would be then consequences of this deterioration of information processing, revealing lack in situation awareness.

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