EFFECTS OF TEXTING ON DRIVING BEHAVIOUR OF YOUNG DRIVERS IN URBAN TRAFFIC. RESULTS OF A SIMULATOR-BASED STUDY.

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ABSTRACT
Problem: In 2012 34% of Belgian car drivers indicated to have sent, over the last year, at least once a text message while driving and 50% indicated to have read at least once a text message while driving (Meesmann & Boets, 2014). *Method*: The aim of the current study was to evaluate the effect of reading and writing text messages on the driving behaviour and safety of young drivers. The effects of the texting were examined in combination with unexpected incidents while driving. The study builds on and partially mirrors a driving simulator study of Yannis et al. (2013). They concluded that texting leads to a significant decrease of mean speed and to a significant increase of reaction time which in turn leads to an increased accident risk. The participants were recruited through driving schools. In total, 38 young (candidate) drivers ready for or just after their practical driving exam participated. They conducted four scenarios in the driving simulator (StiSim3). A between-subjects study design was used including four texting conditions (reading, reading-control, writing, and writing-control). Five paired sample t-tests compared reading with reading-control and writing with writing-control for the following dependent variables. First, detection of and reaction to hazards were calculated from hazard-onset to throttle release and brake press, respectively. The total number of crashes with hazards was calculated per condition. Standard deviation of the lateral lane position (SDLP) and speed were calculated from straight road segments not including traffic lights or hazards. *Results*: Results indicated that compared to the reading-control condition, reading significantly delayed detection of and reaction to hazards. No significant effects were found for detection and reaction for the writing condition. The total number of crashes and SDLP were not significantly influenced by reading or writing. Finally, it was found that when compared to their respective control conditions both reading and writing significantly lowered the speed.

KEYWORDS
Simulator; texting; young (candidate-) drivers, speed, reaction time, detection time, crash

INTRODUCTION

A recent nationally representative behavioural measurement of the Belgian Road Safety Institute aimed at gathering information on the prevalence of distractive behavior behind the wheel indicated that at any given moment and place 1,2% of the drivers are ‘handling’ a telephone (Riguelle & Roynard, 2014). Internationally, texting while driving is receiving increased attention (Caird et al., 2014). A striking result that emerged from a nationally representative survey of car drivers conducted in 2012, was that 34% of Belgian car drivers had, over the last year, sent at least once a text message while driving. This result was in contrast to the fact that 90% of these drivers at the same time indicated to find this behaviour unacceptable. Moreover, 50% reported to have read at least once a text message while driving over the last year (Meesmann & Boets, 2014). This self-reported frequency of texting decreases steadily with increasing age, as also found in other research (Thulin & Gustafsson, 2004; Hosking et al., 2007; Telstra, 2003). Recent foreign survey studies show that 25-35% of car drivers read and 14-30% send a text message regularly (SWOV, 2013). These figures are worrying as texting while driving is considered a threat to safety (Caird et al., 2014, He et al., 2014)

The negative effects of reading or writing text messages while driving are not much doubted, as it is evident that this behavior leads to several types of distraction at the same time (visual, physical, cognitive). It requires attention and eye focus away from the traffic situation as well as fine-motoric actions. Due to this, this behaviour is considered as even more hazardous than calling with a mobile phone. The exact impact of texting on road accidents is nevertheless not easily identified because the use of mobile phones at the time of a crash is rarely recorded by the police. The main information of risks and effects of texting on driving derives from studies like naturalistic driving and simulator studies. A recent meta-analysis of such studies revealed that "texting and driving generally produce large odds ratios for safety related events" (Caird et al., 2013). The authors concluded that texting has moderate to big effects on reaction time, lateral control, longitudinal control and eye movements. From this literature it's clear that more studies examined sending text messages than reading text messages.

A raising issue is the degree to which young drivers are affected by this impact. As the survey results show, young drivers seem to be more willing to text than older drivers, although young drivers may be more vulnerable to the negative effects of limited attention due to their lack of (or lower) driving experience. In addition, young drivers usually overestimate their driving abilities (Yannis et al., 2013). Studies in Belgium are missing altogether.

Simulator studies are often used for measuring the influence of texting on driving performance and safety. Driving simulators allow collecting large amounts of data – which would be difficult to collect in real traffic conditions –under safe circumstances. Moreover, simulator study designs allow multiple test conditions including risky driving situations (Papantoniou et al, 2013). Although a risk for driving simulator sickness exists which might influence the results, these symptoms are mainly found in elderly drivers (Mackrous et al., 2014).

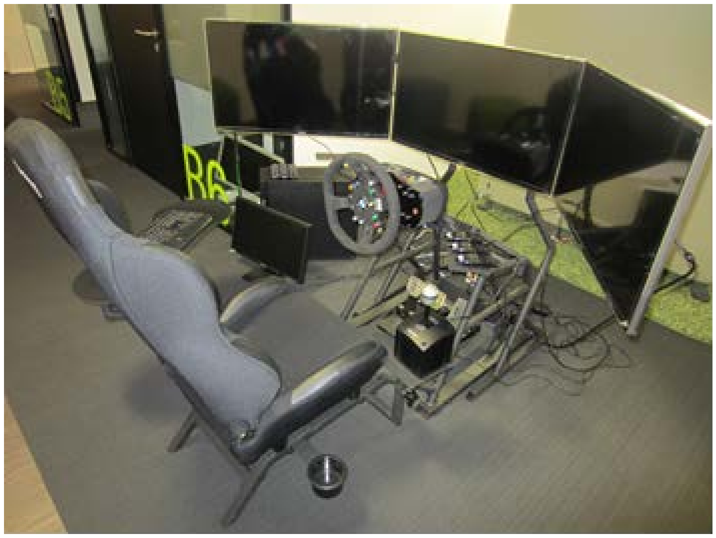
The aim of the current study was therefore to evaluate the effect of reading and writing text messages on the driving behaviour of young (candidate-) drivers during a simulated drive. The effects of the texting were examined in combination with unexpected incidents while driving. The study builds on and partially mirrors a driving simulator study of Yannis et al. (2013) where the impact of texting on the behaviour and safety of young drivers was also studied. They concluded that texting leads to a significant decrease of mean speed and to a significant increase of reaction time. This latter leads to an increased accident risk.

METHODOLOGY

The study sample consisted of 38 young (candidate-) drivers, 23 males and 15 females, with a mean age of 19,08 (SD= 2,08). Signing an informed consent form was required for inclusion in the study. Recruitment was done by six driving schools. No incentives were given.

In the procedure, the subjects first filled out a questionnaire on socio-demographic variables (age, sex, education) as well as on their driving education, driving experience, self-reported frequency of texting in general and while driving, perceived risks, expected effects of texting on driving, and opinions regarding texting and driving. All subjects were following or had followed short before the experiment driving lessons at a driving school. Most had not obtained their driving license B yet (n=23); 12 had passed the practical driver examination within the last month, and 3 subjects had their driving license B already since a longer period (respectively 3, 4 and 6 months). All of them had an own mobile phone (5 GSM; 33 smart phone). The subjects varied greatly with regard to the frequency of texting. For 'sending' there was a range of 1 to 500 messages per day (mean: 49sms/day; median: 20sms/day); for 'receiving' the range was 2 to 500 text messages per day (mean 52sms/day; median 20sms/day). Eighty-four percent (84%) indicated never to have sent a text message yet while driving. Six of the 38 (16%) candidate/novice driver participants indicated they already did. Reading text messages while driving was reported more often: 29% (n=11) said they already did it, against 71% (n=27) not. Eighty-four (84%) agreed with the opinion that 'people who text while driving, are at a higher risk to be involved in an accident'.

This was directly followed by the simulator part including first two familiarization rides and then four test rides. The simulator used in this study consists of a fixed-base set-up including a car seat, steering wheel, pedals and gear shift (current study: automatic gear shift). The software is STISIM3. Three LCD television screens are used to display the driving simulation up to 120° of visual field. The simulation is displayed as the driver's view from the inside of the car (first person perspective) and allows the participant to view the surroundings through the front and side windows as in a real car. The driving environment can also be viewed through two simulated mirrors; a rear-view mirror and driver's side mirror. Dashboard information is displayed on the middle screen (actual speed).



In the two familiarization rides (in total 10 minutes) the first aimed at exercising the technical aspects of simulated driving (steering, breaking, turning…) in a low complexity environment, the second at familiarizing with the road and traffic characteristics of the test scenarios. No specific performance measures were used to assess the driver's familiarization with the simulator before proceeding to the main experiment.

Four simulator scenarios with each a length of 5,3km were developed by the University of Hasselt (Transportation Research Institute / IMOB). They all had identical environmental characteristics (urban priority road: 1x1 opposite lane, speed limit 50km/h, many buildings, trees, parked vehicles, bicycle path and sidewalk on both sides, frequent intersections and traffic lights, high traffic density) but ordered differently to avoid learning effects. We excluded curves in order to minimize the risk of simulator sickness. The traffic included busy non-intrusive road users (cars, (motor)cyclists, pedestrians) on both sides and crossing the road. Each scenario included four types of unexpected incidents triggering a reaction (brake, stop) of the subject. In order to overcome learning effects and to increase ecological validity, the nature of the unexpected incidents was altered between the scenarios (see Table 1).

Table 1: Critical events (CEs) in the 4 scenarios

	Critical event 1	Critical event 2	Critical event 3	Critical event 4
Scenario 1	pedestrian suddenly comes from behind a parked car on the right side to cross the road	car drives suddenly out of parking space on the right side of the road	sudden brake of the car driving in front to make a turn	cyclist on the right side bicycle path suddenly deviates to the left in front of the driver to make a left turn
Scenario 2	sudden brake of the car driving in front to make a turn	car drives backwards onto the road in front of the car (from the right side)	pedestrian suddenly comes from behind a parked car on the right side to cross the road	motorcyclist on the opposite lane hidden behind a big vehicle suddenly drives over the road in front of the car to make a dangerous left turn
Scenario 3	pedestrian suddenly comes from behind parked car on the right side to cross the road	car drives backwards onto the road in front of the car (from the right side)	sudden brake of the car driving in front, to make a turn right	cyclist on the opposite lane hidden behind a big vehicle suddenly drives over the road in front of

				the car to make a dangerous left turn
Scenario 4	sudden brake of the car driving in front, to make a turn right	truck drives suddenly out of parking space on the right side of the road	pedestrian suddenly comes from behind parked car on the right side to cross the road	motorcyclist on the right side cyclist path suddenly deviates to the left in front of the driver, to make a left turn

All subjects used the same touch screen smartphone (samsung galaxy) in order to overcome variations due to different provider networks and different message capacity. Familiarization with the mobile phone was also foreseen: opening a message requesting their full name and sending their name back.

The experiment used a between-subjects design including four texting conditions: reading, reading-control (no sms), writing, and writing-control (no sms). The aim was to compare experimental and control (no sms) conditions of the same scenario segment between subjects. In total, there were 16 different possible experimental texting segments (in each scenario: 2 possible reading and 2 possible writing segments). Each subject was randomly allocated to 1 experimental reading and 1 experimental writing segment in each scenario. Thus, in total, each subject got an sms task in 8 (4 reading, 4 writing) of the 16 possible conditions (segments). In the end, in each possible critical segment (16) half of the subjects had an sms task (experimental) and the other half had no sms task (control). The order of the scenarios was counterbalanced between participants as to overcome learning/order effects.

At specific, pre-defined locations in the scenarios, the researcher sent and received text messages to and from the driver. In the experimental 'reading' conditions the subjects received a text message at a specific spot in the scenario (announced by a mouse squeak by the researcher). The task was to start reading the message as soon as the sound was heard. Each subject underwent four scenarios and in each scenario one message was sent. The four received messages were a long text (including approx. 270 characters on zoo animal, fruits and vegetables, travel destinations and car brands) ending with a request to write and send back 5 examples of the respective category once they passed a certain spot in the scenario (road sign with a sun). This latter thus announced the writing task. Within each experimental reading and writing segments and within each control reading and writing segments always one unexpected incident was programmed.

Definitions of dependent variables that were derived from previous research investigating effects of distraction on driving behavior (e.g.: Cuenen et al., 2015, Engström et al., 2005, McKeever et al., 2013):

- Mean speed: mean driving speed in km/h
- SDLP: standard deviation of lateral position, which can be considered as an index of road-tracking precision (Ramaekers, 2003),
- Hazard perception:
    - Detection time: time between the first unexpected move (critical event) and the release of the gas pedal (throttle release)
    - Reaction time: time between the first unexpected move (critical event) and the push of the brake pedal
    - Crash: moment when de surface of the drivers' vehicle overlaps with the surface of any other object

The study was approved by the Ethics committee of the university hospital of Brussels.

RESULTS AND ANALYSIS

The survey results prior to the simulator rides indicated a rather big consensus among subjects with regard to *perceived* effects of texting on several driving parameters. More than 80% thought texting would 'not' lead to driving faster (84%) and would lead to slower reactions (87%). They thought less uniform about the effects on lane keeping (swinging) and distance headway.

None of the subjects suffered simulator sickness. Outlier analyses indicated that none of the subjects could be considered as consistent outliers (i.e., divergent results on multiple variables), therefore all subjects were included in the data analyses.

The driving simulator data was analyzed with MATLAB (MathWorks, Natick/US), statistical analyses were performed with IBM SPSS Statistics 22.0. Five paired sample t-tests compared reading to reading-control and writing to writing-control for the five dependent variables. Three dependent measures represented hazard perception. Detection of and reaction time to hazards were calculated from hazard-onset to onset throttle release and onset brake press, respectively. To account for accidental throttle releases and brake presses, the pedal onsets were determined by a 10% criteria. More specifically, considering the entire pedal range, only when the throttle was released for 10%, or the brake was pressed for 10%, they were considered as pedal onsets in response to hazard-onset. This method was adapted from Reyes & Lee (2008) where at least 9% of the total range of the brake pedal needed to be pressed in response to bicyclists. By employing a 10% criterion we were sure to completely eliminate pedal onsets based on pedal fluctuations (e.g., caused by adhering to the speed limit). To be consistent in determining pedal onsets over subjects, if the 10% criterion was already reached at hazard-onset (e.g., the throttle was released for 10% of the pedal range), a missing value was assigned to the detection and/or reaction time. Finally, it was determined whether the driver crashed onto the hazard. In case of a crash, respective detection and reaction times were assigned as missing values as we only wanted to include detection and reaction times for safe hazard handling. The standard deviation of the lateral lane position (SDLP) and speed (m/s) were calculated from straight road segments, that were similar per condition (i.e., reading/control and writing/control), not including traffic lights or hazards. Due to a randomization of road segments over the conditions, zones in the reading/control conditions consisted only of 50m, while zones for writing/control consist of 150m.

Concerning detection and reaction times in response to hazards (see table 1), results indicated that, compared to the reading-control condition, reading significantly delayed detection of and reaction to hazards. No significant effects were found for detection and reaction for the writing condition in comparison to the writing control condition.

Table 2: Paired sample t-test results for detection- and reaction-time

Variable	Mean	SD	t	p
DT_read	1.35	0.38	2.27	0.03*
DT_conread	1.18	0.31		
RT_read	2.03	0.37	2.89	0.01**
RT_conread	1.86	0.30		
DT_write	1.17	0.43	0.50	0.62
DT_conwrite	1.12	0.35		
RT_write	1.97	0.58	1.14	0.26
RT_conwrite	1.79	0.59		

The amount of crashes was not significantly influenced by reading (t= -0.37, p= 0.71, mean read= 0.47, SD read= 0.60, mean conread= 0.53, SD conread= 0.65) or writing (t= -1.00, p= 0.32, mean write= 0.34, SD write= 0.53, mean conwrite= 0.47, SD conwrite= 0.56).

Although SDLP was not influenced by reading (t= 1.57, p= 0.13, mean read= 0.05, SD read= 0.03, mean conread=0.04, SD conread= 0.02) or writing (t= 0.30, p= 0.77, mean write= 0.10, SD write= 0.05, mean conwrite= 0.10, SD conwrite= 0.03), speed was as when compared to their respective control conditions both reading (t= -3.31, p= 0.00**, mean read= 11.53, SD read= 1.25, mean conread= 12.15, SD conread= 0.84) and writing (t= -2.97, p= 0.01*, mean write= 12.19, SD write= 1.08, mean conwrite= 12.70, SD conwrite= 0.03) significantly lowered the speed.

DISCUSSION

The results of this simulator study only partly replicate the results from Yannis et al., 2013.

A uniform finding is the significant decrease in mean driving speed while reading and sending a text message, reflecting some compensation when engaged in texting. This is in line with the literature (Yannis et al., 2013; Caird et al., 2013). The meta-analysis of Caird et al. (2013) showed that speed (while sending sms) was significantly lowered in nine studies while two studies had non-significant results.

The results furthermore indicate that there was no difference on SDLP when comparing texting with free driving. This result is not in line with Caird et al. (2013) who included in their meta-analysis 13 studies measuring lateral control for sending sms, and found 23 significant and just 2 non-significant results. The scenario might have contributed to the lack of finding significant results, because a straight track without curves or turns was chosen in order to minimize the risk for simulator sickness.

The number of crashes did not differ between the experimental and control conditions. This is not in line with the source study of Yannis et al. (2013), and neither with the meta-analysis results of Caird et al. (2013) who found 2 studies with 3 significant crash related results for sending text messages. Yannis et al. (2013) found that both reading and writing text messages lead to an increased accident probability. They related this to driver distraction and delayed reaction at the moment of the incident. It should be noted here that we used a simplified design and scenario in which the number of unexpected incidents was much smaller compared to their study. Therefore, in the current study the chance for an accident was generally much smaller. The decreased mean speed of the subjects also may have added to the smaller chance for an accident with the sudden hazards, although in their study, Yannis et al. (2013) claimed that this cannot compensate for the increase in accident probability induced by texting.

Looking at the results on detection and reaction times to the hazards, the results are also not fully in line with Yannis et al. (2013) and Caird et al. (2013). Detection and reaction times are only significantly higher during reading compared to free driving. Yannis et al. (2013) concluded from their simulator study that reading and writing lead to a statistically significant increase of the mean reaction time, and they found even higher increases for sending than for reading. Caird et al. (2013) concluded from their meta-analysis that sending text messages adversely affects reaction time (8 studies: 10 significant effects, 2 non-significant for sending sms); for reading they found 1 significant and 1 non-significant result.

The self-reported data is not yet exploited in this study. It could be hypothesized that some of the reported variables are related to driving parameters, as indicated in other studies (Schlehofera et al., 2009). Further analyses taking the self-reported data into account and linking these data to the driving outcomes will enrich the results and could help interpreting them. After the experiment, the subjects were asked how they experienced it. The big majority (>85%)

indicated to experience great difficulty with the double tasking, as well as not wanting to repeat this behind the wheel. This suggests that the simulated experience of texting while driving including risky critical events may have a sensitizing effect (short term, self-reported).

Based on the current results, as well as results from previous studies (Yannis et al. 2013; Caird et al., 2013), solutions for the detrimental effects of texting on driving need to be implemented. One recent solution regards in-vehicle technology consisting of a speech-based interface removing the manual and visual distraction from the equation (He et al., 2014; Owens et al., 2011). Nevertheless, although less detrimental for driving performance than handheld text-entry, speech-based text-entry also impaired driving when compared to driving-alone (He et al., 2014; Owens et al., 2011;). This because interference by secondary activities (e.g., texting) not only occurs at the visual level but also at the cognitive level, leaving less spare attentional capacities to devote to the driving task (Ross et al., 2014).

A general drawback of this study (like in many controlled studies) concerns the decreased ecological validity due to: the use of a standard smartphone (not their own), asking the subject to start reading and writing at pre-defined spots (no space for compensation strategies taking the traffic context into account). Yannis et al. (2013) found that drivers using mobile phones with a touch screen (instead of a keyboard) had a higher probability of being involved in an accident in case of an incident.

Generally, no matter how well a simulator experiment is designed, it is rather unlikely that drivers perform exactly as they would in actual conditions (GHSA, 2011). This is due to the fact that several issues such as the feeling of speeding, rainy weather etc. cannot be fully represented, and this is a known limitation of simulator experiments (Yannis et al., 2013). Moreover this was a very simplified design and scenario.

This study allows some recommendations for future research:

- Trade-off 'realism/ecological validity' and 'statistical possibilities': the unexpected incidents in the scenarios were differed with regard to the type of the other road user as well as their sudden action in order to increase the realism of the traffic situation and to avoid too much learning effects. Due to this decision though the incidents finally appeared to be too different to make combined scores for data analysis. Therefore in the end only identical incidents could be compared to each other in a between-subjects design. Moreover, this also led to the impossibility to compare text reading and text writing conditions with each other.
- Limited number of programmed incidents led to a smaller general accident risk, which may be related to the lack of finding significant effects on crash risk.
- Minimize the need for manual actions of the test leader like time stamps. In the end there were too much errors, and this was not useable.
- Some critical incidents were less usable than others (led to many missing values). A detailed analysis of the reasons behind would be interesting.
- Future studies should include additional conditions (rural, urban, different weather conditions, day-night) to enrich the findings.
- Future distraction simulator studies should ideally also include eye-tracking, which provides additional information/interpretation (e.g. number and duration of glances to the mobile phone, or glances off the road). The meta-analysis of Caird et al. (2013) found – in six studies – eleven significant effects with regard to eye movements while sending text messages, and with regard to reading messages they found five significant results and two non-significant results.

CONCLUSIONS

The aim of the current study was to evaluate the effect of reading and writing text messages on the driving behaviour and safety of young drivers. It can be concluded that driving behaviour and safety are both affected by texting. The results of this study are partly consistent with other studies. Important lessons are learned for the conduction of (distraction related) simulator studies in future.

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