Mobile phone use while cycling

De Waard, D.; Schepers, P.; Ormel, W.; Brookhuis, K.A.

Published in:
Ergonomics

DOI:
10.1080/00140130903381180

De Waard, D., Schepers, P., Ormel, W., & Brookhuis, K.A. (2010). Mobile phone use while cycling: incidence and effects on behaviour and safety. *Ergonomics, 53,* 30-42.

Abstract

The effects of mobile phone use on cycling behaviour were studied. In Study 1 the prevalence of mobile phone use while cycling was assessed. In Groningen 2.2 % of cyclists were observed talking on their phone and 0.6 % were text messaging or entering a phone number. In Study 2 accident involved cyclists responded to a questionnaire. Only 0.5 % stated to be operating their phone at the time of the accident. In Study 3 participants operated a phone while cycling. The content of conversation was manipulated, and participants had to enter a text message. Data were compared with just cycling and cycling while listening to music. Telephoning coincided with reduced speed, reduced peripheral vision, and increased risk and mental effort ratings. Text messaging had the largest negative impact on performance. Higher mental workload and lower speed may account for the relatively low number of people calling involved in accidents.

Mobile phone use while cycling: incidence and effects on behaviour and safety

Dick de Waard[1*], Paul Schepers[2], Wieke Ormel[3], & Karel Brookhuis[1,4]

[1]University of Groningen
Faculty of Behavioural and Social Sciences
Experimental and Work Psychology
Grote Kruisstraat 2/1
9712 TS Groningen
The Netherlands
tel: +31 50 3636761, +31 50 3636472
d.de.waard@rug.nl, k.a.brookhuis@rug.nl

[2]Ministry of Transport, Public Works, and Water Management
PO Box 5044
2600 GA Delft
The Netherlands
paul.schepers@rws.nl

[3]Consumer Safety Institute
PO Box 75169
1070 AD Amsterdam
The Netherlands
W.Ormel@veiligheid.nl

[4]Delft University of Technology
Faculty of Technology, Policy and Management
P.O.Box 5015
2600 GA Delft
The Netherlands

[*]Corresponding author

Statement of relevance

Although perhaps mainly restricted to flat countries with a large proportion of cyclists, mobile phone use while cycling has increased and may be a threat to traffic safety, similar to phone use while driving a car. In this study the extent of the problem was assessed by observing the proportion of cyclists using mobile phones, sending questionnaires to accident involved cyclists, and an experimental study on the effects of mobile phone use while cycling.

Abstract

The effects of mobile phone use on cycling behaviour were studied. In Study 1 the prevalence of mobile phone use while cycling was assessed. In Groningen 2.2 % of cyclists were observed talking on their phone and 0.6 % were text messaging or entering a phone number. In Study 2 accident involved cyclists responded to a questionnaire. Only 0.5 % stated that they were operating their phone at the time of the accident. In Study 3 participants operated a phone while cycling. The content of conversation was manipulated, and participants also had to enter a text message. Data were compared with just cycling and cycling while listening to music. Telephoning coincided with reduced speed, reduced peripheral vision performance, and increased risk and mental effort ratings. Text messaging had the largest negative impact on cycling performance. Higher mental workload and lower speed may account for the relatively low number of people calling involved in accidents.

1. Introduction

Many studies have been conducted on the effects of mobile phones on car driving performance (e.g., Brookhuis et al., 1991, McKnight, & McKnight, 1993, Redelmeier & Tibshirani, 1997). Caird et al. (2008) concluded on the basis of a meta-analysis that phone use, both hands-free and handheld, increases reaction time. Moreover, drivers do not compensate significantly by increasing headway or by reducing speed. Other effects that have been found are that the processing of foveal information while talking on a phone is reduced (Strayer, Drews, & Johnston, 2003), that Situation Awareness significantly drops (Parkes & Hooijmeijer, 2000), and that drivers make riskier decisions during demanding tasks such as weaving and left turns when taking part in a phone conversation (Cooper et al., 2003).

Deteriorated driving performance has been found to be the result of the cognitive demands of a telephone conversation. Strayer and Johnston (2001) compared holding a phone in the hand, shadowing and speaking with effects of a word-generation variant of the shadowing task. They found that in particular diverting attention to a secondary demanding task affected driving performance negatively. Harbluk et al. (2007) performed an on-the road study, and found that when participants performed a demanding cognitive task, peripheral looking time, and glances at traffic lights decreased. The fact that high mental demand reduces the area of the visual field has been described before (e.g., Rantanen & Goldberg, 1999) and this is a clear risk with respect to missing relevant information from the periphery. In car driving performance of secondary tasks has been shown to lead to visual tunnelling (Engström et al., 2005, Reimer, 2009).

Drivers can compensate for high secondary task demands by slowing down. Although this effect has occasionally been reported (e.g., De Waard, Hernández-Gress, & Brookhuis, et al., 2001, Rakauskas, Gugerty, & Ward, 2004), Caird et al. (2008) on the basis of their meta-analysis, concluded that drivers do not tend to slow down considerably. Other ways of compensating for negative effects could be to make a phone call at a location where the effects are limited. Brookhuis et al. (1991) found no negative effects of telephoning when driving on a quiet motorway and actually found a slight improvement in lateral position control when drivers operated a phone compared with just driving. Walsh et al. (2008) also report an effect of location. They found that automobile drivers were more inclined to use a phone when stationary waiting for traffic lights than when driving at 100 km/h. However, Walsh et al. (2008) also stated that the intention to text message was mainly influenced by perceived risk of apprehension, and not by the risk of being involved in an accident. Another important factor is that if drivers initiate a phone call they can decide to delay it, but the moment and location when drivers are called by someone else is beyond their control.

As previously stated, most studies have focussed on mobile phone use while driving a car. However, a few studies have been performed on the effects of mobile phone use while walking and crossing streets. Nasar et al. (2008) reported unsafe behaviour, and reduced situation awareness for pedestrians conversing on a mobile phone. In a study on walking speed Finnis & Walton (2008) found no effect of listening to music or using a mobile phone on speed, although they admit that their sample was rather small.

At the beginning of 2006 a member of the Dutch House of Representatives asked about the risks of using a mobile phone while cycling, and it became clear that no studies have been published on this subject. The relevance of having more information on the effects of mobile phone use on driving may be useful in countries with high proportion of cyclists. In Europe that is mainly the Netherlands, Belgium, Denmark, Sweden, and parts of Germany. In 2007, 34% of all trips up to 7.5 km in the Netherlands were made by bicycle (Ministry of Transport, Public Works, and Water Management, 2009). While it is illegal to operate a handheld mobile phone while cycling in Belgium and Germany (§ 23 Abs. 1 a StVO, see e.g. ADAC, 2008), in the Netherlands it is allowed. Exact figures about casualties as a result of operating a phone while cycling or driving are not available, as these data are not registered in the police accident records. The past decade, the total number of fatalities among cyclists remained stable at around 200 per year, about a quarter of the total number of traffic fatalities in 2006. Per 100 million km travelled, the rate of fatalities for cyclists in the Netherlands is lower than in other countries. This could be due to the relatively high level of cycling in the Netherlands, as accident risks for cyclists are actually lower in countries with higher bicycle use (Ministry of Transport, Public Works, and Water Management, 2009).

There are several important differences between driving a car and riding a bicycle that may affect interference between phone use and task performance. Firstly there is a difference in motor requirements as riding a bicycle requires kinaesthetic control (e.g., Wierda & Brookhuis, 1991). Under favourable circumstances and at a sufficiently high speed, a bike is self-stable and ridable without hands on the handlebars. Crosswinds, lorry slipstreams, gusts of wind, bumps and holes in the road surface and involuntary low speeds determine the stability and hence the space required to manoeuvre and effort needed for steering. Below a speed of about 12 km/h, instability increases and the rider has to apply more torque to the handlebars to remain upright (CROW, 2007). Riding at low speed and making a sharp turn require more physical effort for cyclists than for car drivers. The task of processing visual information while cycling is eased by a low speed compared to car drivers. Also, the infrastructure for cyclists is designed for lower speeds. Some cycle lanes in the Netherlands are only 1m wide with a kerb at one side and motorised traffic at the other side. Cyclists also have to deal with bollards that are put in the middle of cycle tracks to prevent cars from entering. Besides infrastructure differences, there are also differences between drivers and cyclists in the use of auditory cues—cyclist can hear cars approaching. This is important with regard to conversing over the phone and also applies when listening to music. Another important difference between cycling and driving a car is that for driving a car extensive training and a driving licence are required. There is also a difference in vulnerability. Cyclists, even if they wear a helmet and other protective gear (the use of a bicycle helmet is rare and not obligatory in the Netherlands), are far less protected than car drivers. Any decline in task performance may therefore have a larger impact on cyclists than on car drivers. Since cycling and driving differ in many ways, the present research seeks to determine the safety effects of mobile phone use while cycling.

On the basis of results found with car drivers and pedestrians, it is expected that the use of a mobile phone while cycling will cause larger steering deviations, decrease peripheral vision detection, and coincide with increased mental effort. As a result of deteriorated performance and vulnerability it is expected that the rate of mobile phone use among accident involved cyclists will be higher than the incidence of mobile phone use among cyclists in the general Dutch population.

Three studies are presented in this paper, an observation study focussing on the incidence of phone use while cycling, a survey focussing on cyclists involved in accidents, and an experimental study in which phone use while cycling was manipulated. Texting and listening to music were also included in the three studies.

2.1 Study 1: Observation

The incidence of mobile phone use while cycling was observed in the city of Groningen by street counts. In 2008 Groningen had about 180 000 inhabitants, including a large student population (45 000). The bicycle is a popular means of transport, thanks to the student population and a traffic programme that discourages cars to enter the city centre. In Groningen 45% of all trips less than 7.5 km are made by bicycle, compared with 34% in other large Dutch cities (Fietsersbond, 2008).

2.1.1 Locations Study 1

In the city of Groningen three locations that varied in traffic intensity and priority regulations were selected for the observations:

- The busy central railway station area, at a junction regulated by a traffic light
- A busy city centre location, at a junction where cyclists did not have right-of-way
- A quiet location on a wide road through a park without cars but many bicycles, with no junction

The quiet location was included to see if cyclists delay (initiating) phone calls to a moment when traffic is less demanding.

2.1.2 Procedure Study 1

At all three locations five students of the Department of Psychology recorded passing bicycles on video during the month of May 2008. Recordings were made for two hours per location (total time six hours). At the two busy locations cyclists were recorded for one hour in the morning (10-11 am) and one hour in the afternoon (5-6 pm). Cyclists were observed on working days, during dry weather. At the quiet location cyclists were only observed two times between 5 and 6 pm (as hardly any cyclists passed off-peak hours observations were limited to rush hours at this location). The time periods and locations were selected to see if there was a difference in phone use by time of day and location. If, for example, in-ear earphones were visible during recording this was added as an auditory comment to facilitate scoring later. All recordings were analysed off-line from the video, i.e. all cyclists travelling in one direction were scored and classified using the parameters listed in Table 1.

>> Table 1 about here <<

2.1.3 Results Study 1

A total of 2138 cyclists were observed and scored on displayed behaviour from the videos. Forty-seven percent were male, and 53% female. The large student population was reflected in the classified age groups; as a majority (70%) were classified as between 15 and 30 years of age, 25% between 30 and 50, 1% younger than 15, and 4% older than 50. In Table 2 the observations are split between the three locations and two times-of-day. In Table 3 the behaviour of cyclists over all locations and times of day is shown. Most cyclists were just riding their bicycle, but 2.8 % were observed to be operating a mobile phone. In Table 3 in, the ‘weighted for age’ column, the results are weighted for age group by comparing them with the Dutch Mobility Study (survey on the travel behaviour of the Dutch population, SWOV, 2009, see appendix). This was done to enable comparisons between studies as the sample deviates from the Dutch cycling population. Weighted for age, 1.5 % of cyclists observed were operating a mobile phone. This figure is close to the results of a count by the Dutch Ministry of Transport in Rotterdam in May 2006, during one day (from 8 am – 5 pm), at a busy cycle track leading into the city centre. Out of 2021 cyclists, 32 (1.6 %) were operating their mobile phone to converse or text message. No characteristics like age or sex were scored, but given that Rotterdam has a relatively smaller proportion of students compared with Groningen, the sample was likely more representative of the Dutch cyclist population in general (Schepers, 2006).

>> Tables 2, and 3 about here.

As the number of cyclists operating a mobile phone was limited at all locations (Table 2), for the main analyses all locations and times-of-day were taken together. In Table 4 the number of hands cyclists had on their handlebars is shown. As people operating a phone need one hand to hold the phone, the fact that they steer more frequently with one or with no hands is not a surprise. The 4.2 % who were talking on the phone and holding the handlebars with two hands obviously used a head set. None of the cyclists that were texting had more than one hand on the handlebars.

>>> Table 4 about here <<<

An effect of gender was found on 'number of hands on the handlebars' (χ^2,$_{N=2136,\ df=1}$ = 17.3, p=0.026); more men (1.2%) rode with zero hands on the handlebars than women (0.3%), but more women rode with one hand on the handlebars than men (12.7 opposed to 11.3 %). Most cyclists observed rode with two hands on the handlebars (87.1% of the women and 87.5% of the men).

Only very few conflicts were observed. A conflict was operationalised as a situation where either the observed cyclist or another traffic participant had to change speed or course to avoid an accident. One of the phoning cyclists (i.e. 2 %) had a conflict with others. Of the non-phoning cyclists in 0.3% of the conditions (i.e. 6 persons) a conflict was observed. This difference is not significant (Fisher's Exact test, NS). With respect to compliance to rules, the only effect found was that cyclists listening to music disobeyed traffic rules more frequently see Table 5.

>>> Insert Table 5 about here <<<

2.2 Study 2: Questionnaire sent to cyclists involved in bicycle accidents

2.2.1 Method Study 2

Consument en Veiligheid ("Consumer Safety Institute") performed a (retrospective) questionnaire study. Questionnaires were sent to cyclists who had had an accident with their bicycle and were treated at an Emergency Care Department. These victims were retrieved from LIS (Letsel Informatie Systeem; Dutch Injury Surveillance System). LIS records statistics of people treated by Emergency Care Departments in a selection of hospitals in the Netherlands, following an accident, violence or self-inflicted injury. The selection of hospitals is a representative sample of the general and university hospitals in the Netherlands with a continuously staffed Emergency Care Department. Thirteen hospitals spread over the Netherlands participated in this study. Two months after the bicycle accident questionnaires were sent to the victims. Between February and June 2008, 2975 questionnaires were sent, and 1156 (39%) were returned. A total of 1142 could be used for analyses. Of these victims 16 % were hospitalised after treatment at the Emergency Care Department. In this paper only results with respect to the questions about mobile phone use are reported (other questions were about characteristics of the accident, injury, and changes in behaviour after the accident). The age distribution of respondents is likely to differ from the age distribution of Dutch cyclists. Older cyclists are more vulnerable and more likely to be treated at the Emergency Care Department or hospitalised than young cyclists. Conversely, children are more likely to have less severe bicycle accidents. Again results are also displayed weighted for age group by comparing them with the Dutch Mobility Study (see appendix), to enable a comparison with the results of Study 1, the observation study.

2.2.2 Results Study 2

The results are listed in Table 6. Only three respondents (0.3 %) stated that they were talking on their mobile phone at the time of the accident, and two were texting (0.2 %). All five were single vehicle accidents. Four of the victims fell from their bicycle and one hit a bollard.

Compared to the number respondents that indicated they were using a phone at the time of the accident, the number of cyclists that answered that they used the phone up to about 10 minutes before the accident is higher, 2.5 % (3.1 % if weighted for age), a proportion very close to the 2.8 % found in Study 1.

Other results were that 2.2 % (3.4 % weighted for age) of the respondents were listening to music during the accident, and that 11.4 % (12.6 % weighted for age) were talking to another cyclist.

>>> Table 6 about here <<<

2.3 Study 3: Experiment

To systematically assess the effects of using a mobile phone on cycling behaviour an experimental study was carried out.

2.3.1 Method

Twenty-four participants in the target age group, as found in Study 1, were invited to participate. They were recruited by putting messages on information boards at the University of Groningen, at the university of applied sciences, and in supermarkets. The average age of participants was 22.8 years (SD, 2.8, range 18-30), and eight were female. All participants had to indicate that they use their mobile phone while cycling.

The experiment was carried out at a quiet location north of the city of Groningen, on a 220 metre long, 1.92 metre wide cycle path. A within-subjects Latin Square randomised order design was used, in which participants completed the following six conditions:

1. Control (2): a control ride with two hands on the handlebars
2. Control (1): a control ride with one hand on the handlebars
3. Phone, easy: talking on the handheld mobile phone while performing a simple calculation task, adding 2 each time, starting from zero
4. Phone, difficult: talking on the handheld mobile phone while performing a difficult calculation task, subtracting 7 each time, starting from 846.
5. Phone, texting: entering the text “Lang zal ze leven, lang zal ze leven, lang zal ze leven in de gloria” (a Dutch birthday song).
6. MP3: listening to self-chosen music on an mp3-player

In condition 3 and 4 participants were called by the test leaders who also used a mobile phone. In those two conditions participants used a Nokia 3100 instead of their own phone (to prevent being called by accident during the experiment). In the texting conditions participants used their own phone to be sure they were used to the phone to enter text. The use of predictive texting software was allowed if participants preferred.

Participants used their own bike to avoid habituation effects. Speed was measured with a Garmin Forerunner 405 GPS watch that was attached to the handlebars. GPS data were stored every three seconds. Lateral position was scored off line, using video images that were made with a camera attached to a lamp post. With an overlay image the cycle path was divided into strips 0.19 metre wide, and the strip changes were registered (see figure 1).

>>> Figure 1 about here <<

At the end of each condition a rating of invested mental effort was required using the Rating Scale Mental Effort (RSME; Zijlstra, 1993) and a rating of perceived risk was also collected (using a copy of the RSME, but with different words used as anchor points, i.e. instead of “effort” “risk”).

During each condition task leaders unobtrusively placed two objects on the ground at changing locations along the cycle path. The objects were a printed traffic sign and a clock. After each ride the participants were asked whether they had noted anything. The number of objects mentioned and the number of objects correctly mentioned were noted. The latter included the exact time on the clock, and the correct content of the sign instead of just ‘a sign printed on paper’. Finally a questionnaire about mobile phone use was completed.

In summary, the following variables were registered or deduced:

- Speed
- SD speed (Standard Deviation of speed)
- Average lateral position
- Variation in lateral position
- Range of lateral position
- Self-reported mental effort
- Self-reported risk
- No. of objects correctly identified

The following comparisons between conditions were made:
- Control 2 vs. Control 1: effects of cycling with one hand
- Phone (Easy+ Difficult) vs. Control 1: effects of telephoning
- Phone Easy vs. Phone Difficult: effect of cognitive task
- Phone texting vs. Control 1: effect of texting
- MP3 vs. Control 2: effect of listening to music

The experiment took in total 45 minutes per participant, and each was paid € 10. Approval for the experiment by the psychological ethical committee had been obtained in advance. Approval was given provided that the participants were only allowed to cycle when there were no other traffic participants approaching or on the cycle path. Two-way radio transceiver communication between the test leaders who were standing at the beginning and end of the track preceded the decision to allow the participant to start cycling.

2.3.2 Results Study 3

The participants had on average 7.9 years experience using mobile phones (SD 1.87, range 4-12). On average they called someone 30.0 times (SD 40.2) per week, and were called 27.4 (SD 27.5) times per week. They sent 38.0 (SD 25.0) text messages weekly, and received 36.0 (SD 22.0) messages. All participants indicated that they use their phone while cycling (25 % daily, 38% weekly).

In figure 2 the average speed per condition is shown. Speed was reduced when talking on the phone ($F(1,23)=38.5$, $p < 0.001$, $\eta_p^2=0.63$), and speed was lower when performing the difficult task compared with the easy task ($F(1,23)=7.64$, $p = 0.011$, $\eta_p^2=0.25$). Texting had the largest effect on speed, a reduction of almost 3 km/h (see Table 7). No difference in speed was found between cycling with one or two hands, nor were effects of listening to music found on speed. No effects on SD speed were found.

>>> Insert Figure 2 about here <<<

Average position on the cycle path was significantly affected by texting; the average position while texting was 4.1 compared with 3.2 in the other conditions (strips indicated in Figure 1). This means that in the text messaging condition participants rode further away from the cycle path's edge.

Variation in Lane Position was assessed by calculating the number of lane strip changes. Again, only texting had a significant effect, with an average of 7.4 strip changes (see Figure 3).

>>> Insert Figure 3 about here <<<

To assess "swerving amplitude" the range of lateral position strips used was calculated. Once again only texting had a significant effect (Table 7), 3.13 strips compared with 2.82 strips during the other conditions.

In Figure 4 the number of correctly identified objects is displayed. In the difficult 'conversation' condition the fewest objects were correctly reported, with less than 10% of the participants able to report no more than one object correctly (overall effect of telephoning: Wilcoxon rank test: $Z = -2.40$, $p = 0.020$, effect of telephone task (cognitive demand): $Z = -1.84$, $p = 0.090$). Texting also affected performance negatively on this task (see Table 7).

>>> Figure 4 about here <<<

After each ride participants gave a rating of invested effort on the RSME (Figure 5), and rated perceived risk (Figure 6). Invested mental effort was highest in the high cognitive demand telephone condition ($F(1,23)=32.6$, $p < 0.001$, $\eta_p^2=0.59$, compared with the easier task), and both telephone tasks were perceived as more effortful than cycling with one hand ($F(1,23)=77.7$, $p < 0.001$, $\eta_p^2=0.77$), just as texting (Table 6). Participants also rated cycling with one hand as more effortful ($F(1,23)=7.43$, $p = 0.012$, $\eta_p^2=0.24$). Listening to an mp3-player was not judged to demand more effort.

Risk ratings (Figure 6) partly showed a similar pattern: with the effects of telephoning ($F(1,23)=95.3$, $p < 0.001$, $\eta_p^2=0.81$), of difficulty of the secondary task ($F(1,23)=10.8$, $p = 0.003$, $\eta_p^2=0.32$), and of cycling with one or two hands on the handlebars ($F(1,23)=11.3$, $p = 0.003$, $\eta_p^2=0.33$). Risk rating for texting was highest, and listening to an mp3 player was also rated as more risky than cycling with two hands on the handlebars ($F(1,23)=11.1$, $p = 0.003$, $\eta_p^2=0.33$).

>>> Figure 5 about here <<<
>>> Figure 6 about here <<<
>>> Table 7 about here <<<

At the end of the experiment participants completed a brief questionnaire about mobile phone use while cycling. Almost all (88%) said they initiate calls while cycling, 54% are called at least a few times each week while they are riding their bicycle, and 83 % send text messages while cycling. A similar percentage, 84%, listens at least a few times a week to music while cycling.

When asked whether the location where they are cycling plays a role in initiating a call or not, 77 % answered it plays no role. For sending a text message only 33 % said location played no role. Seventy-one percent reported that they read texts messages while riding their bicycle.

Of the participants 42 % reported experiencing a dangerous situation when they were cycling and talking on their phone and 38 % while they were texting. Sixty-three percent had observed dangerous situations where cyclists were talking on their mobile phones and, 46 % observed critical situations with cyclists who were texting.

3 Discussion

3.1 Mobile phone use and cycling performance

The current study indicates that mobile phone use compromises cycling performance. The main effects as shown in Study 3 were increased feelings of invested mental effort, risk, and speed compensation was also observed. When sending text messages participants needed more lateral space and chose a position that allowed for that; further away from the road's edge. The fact that participants did not need more lateral space during a phone conversation might be due to the fact that they maintained a speed well above 15 km/h. Above 12 km/h and in normal weather conditions a bicycle is easy to stabilise without much effort (CROW, 2006). The increased lateral space used by participants while texting may have been caused by an awareness of the cyclist that he or she had to focus on a small screen with their eyes off the road, and therefore they may have increased lateral margins. However, the fact that the experiment was performed on a cycle path may have affected these results; once cyclists share the road with cars and Heavy Goods Vehicles the situation may well be different. On the other hand, if they also swerve more in conditions where other vehicles are present and cycle further away from the lane's edge and kerb, then this may create a serious safety risk. Another clear result was that cyclists missed more objects, both when they were talking on the phone, and when they were texting. This indicates that their peripheral view, and perhaps even Situation Awareness, is reduced. The results seem to support findings on visual tunnelling as found in car driving (Reimer, 2009). Overall, reduced speed and increased lane keeping variation (for texting) are effects that are consistent with high visual demand effects found in car driving (Engström et al, 2005. The effects for texting actually may have been mitigated as objects were put on ground, and gaze is directed (more) downwards while entering text. Future research could shed more light on the issues if focused on vision and kinaesthetic control for cycling.

Texting not only produced the largest effects, but the overall impression is that texting is also perceived as the most dangerous condition that was included, even considering that participants cyclists slowed down as much as 3 km/h. The text messaging condition received the highest risk ratings, and participants said that only for sending messages the location where they cycle plays a role. The effects of listening to music are limited, with the exception of an increase in perceived risk. Apparently cyclists do have the idea that they might miss important auditory cues. The results suggest that the difference in performance is due to the active engagement in the phone conversation. These results are consistent with studies on driving, listening to a radio, and mobile phone use. Reaction time increased while conversing over a mobile phone, whereas it did not increase while listening to the radio (Consiglio et al., 2003; Stayer & Johnston, 2001).

Although the counting secondary task used in Study 3 could be criticized as being very artificial, the task's cognitive demand is continuous and consistent for all, and the output is quantifiable (e.g., Brookhuis et al., 1991, Haigney & Westerman, 2001). A limitation of the experiment was that conditions were only completed if there was no other traffic present, a prerequisite for obtaining clearance by the ethical committee. The absence of traffic may have affected the results, but it is impossible to say how and in which direction.

3.2 Mobile phone use and accident risk

The results of Study 3 show that cycling performance is compromised by mobile phone use, but the results of Study 1 and 2 do not show that this leads to an increased risk of cycling accidents. The prevalence of mobile phone use among victims of cycling accidents was not found to be higher than among cyclists observed on the road. It is possible that the actual share of victims who use a phone during a cycling accident is higher than what was found in Study 2 (0.5 % weighted for age), due to socially desirable answers. However, as anonymity was guaranteed in Study 2 we think that it is not very likely that the actual prevalence of mobile phone use among cycling accident victims is higher than the prevalence among cyclists participating in traffic. The effects of mobile phone use while cycling are clear; cyclists slow down and experience more mental effort and risk. Perhaps this higher mental workload plays an important role in the relative low number of people who had an accident while calling.

In Study 1 only 2.8 % (1.5 % weighted for age) of the cyclists observed across all three sites were found to be operating a mobile phone (phoning or texting). The highest percentage was found at the busiest location. Compared with the US study on pedestrians (Nasar et al., 2008), these are low frequencies. Nasar and colleagues had a smaller sample (N=127), but 19% of pedestrians observed used a mobile phone and 24% were listening to music. In the Dutch cyclists sample 7.7 % were observed listening to music.

The percentages observed in the present study seem to give a good impression of mobile phone use while cycling. The percentages also correspond with an earlier count by the Dutch Ministry of Transport where 1.6% of the cyclists along a cycle track in the city of Rotterdam were found to operate their mobile phone while cycling (Schepers, 2006).

Considering that only 0.5 % of the cycling accidents victims stated that they were operating their mobile phone, one could ask the question whether the low share is a result of socially desirable answers. Another possibility is that mobile phone use has a distracting effect up to several minutes after a phone conversation. Cyclists may be lost in thought after a conversation and therefore have an increased risk for several minutes (e.g., Neyens & Boyle, 2007). Redelmeier & Tibshirani (1997) used in their case-control-study an interval of 10 minutes before accidents to determine the relative risk of mobile phone use while driving. Of all cycling accidents victims, 2.5 % stated that they used the phone up to about 10 minutes before the accident (3.1 % weighted for age). We do not know how many of the cyclists observed in Study 1 who were not using the mobile phone when they passed the video camera had used the phone up to 10 minutes before. It would be interesting to study the effects of internal distraction by using a case-control-design.

A remarkable finding is that cyclists who had had an accident more frequently reported that they were talking to a fellow biker at the time of the accident compared with the overall observed percentage of talking cyclists in traffic. In research on driving it is reported that conversations with passengers are self-paced in contrast to phone conversations and that during phone conversations more driving errors are committed (Drews et al., 2008). Research by Crundall, Bains, Chapman, and Underwood (2005) demonstrated that the normal in-car conversations were suppressed while driving on the most demanding urban roads. Consiglio et al. (2003) found that conversing with a passenger increased reaction time, but not as much as phoning did. The present research does not allow conclusions to be drawn about the effects of conversations with a fellow cyclist, as talking to another cyclist was not a condition in Study 3. Balance or vision problems may arise as cyclists turn their head to look at their companion cyclist. Other factors may play a role if cyclists indeed run a higher risk of a cycling accident while talking to a fellow rider. Contrary to a car driver who shares the same vehicle with the passenger, a cyclist and conversation partner ride side by side. This may result in accidents, for instance a collision with the fellow cyclist, or kerb.

Study 2 resulted in other interesting behavioural outcomes. The finding that more people listening to music run red lights of course does not imply a causal relationship, there is just a correlation between the two, it might well be that people who run red lights simply more frequently listen to music while cycling.

No compensation effects on location of use were found in Study 1: actually a larger proportion of phoning cyclists were found at the busy locations. This is in line with what the small sample of participants in Study 3 report, that for 77% location plays no role in making a phone call. For sending a text message the same percentage said location *does* play a role. Unfortunately the observed number of texting cyclists in Study 1 was too low to allow for checking this statement statistically.

For car drivers the risk of apprehension may have increased phone use while waiting for a traffic lights (Walsh et al., 2008), but this factor probably does not play an important role for Dutch cyclists, as in the Netherlands it is not illegal to use a hand held phone while cycling. Only the "general rule" that one may not endanger traffic safety applies.

Given that the accident risk does not appear to be raised by mobile phone use while cycling, few benefits would be expected from a ban on mobile phone use while cycling. The success of such a ban would also depend upon enforcement activities, which will be difficult and expensive. McCartt & Geary (2004) showed that banning of hand-held phones while driving in the USA had a temporal effect only, and after one year the percentage drivers complying with this rule was almost down to the original level. Better results might be expected from education targeted at schools, as the children there will make up the future group of cyclists phoning while riding their bicycle.

4. Conclusions

In the city of Groningen with a large student population 2.8 % of the cyclists observed were operating their mobile phone, 2.2% were talking and 0.6 % were sending a text message or operating the phone's menus. About 8 % of the cyclists were listening to music, but most cyclists (87%) were simply cycling. There were no indications that cyclists compensate for negative effects of calling by operating their phone more frequently at quiet locations, as no differences between locations of different traffic density were found.

Talking over a mobile phone while cycling does not coincide with larger steering deviations, but having a conversation, especially a demanding one, decreases the peripheral vision detection while riding a bicycle and reduces cycle speed.

Increased mental effort and risk is also reported when operating a mobile phone while cycling. Contrary to expectations these effects are not reflected in (reported) accident figures. Accident involved less frequently reported the use of a mobile phone at the time of the accident when compared with the overall observed percentage of phoning cyclists in traffic.

The largest effects were found for texting, an activity observed to be carried out by 0.6 % of cyclists. When texting cyclists need more space as they swerve more, and they cycle further away from the road's edge. However, these results were found in an experimental condition, and need to be confirmed by observation in real traffic, as there the effects are potentially very dangerous.

The effects of mobile phone use while cycling are clear. Comparable to effects found of mobile phone use while driving, effects of cognitive demand were found on speed and peripheral view. Although cyclists slow down, they still perceive more mental effort and risk. Perhaps this higher risk awareness and mental workload play an important role in the relative low number of people who had an accident while calling. Although the fact that mobile phone use is not a major contributing factor in accident statistics may also be due to a reluctance for accident involved individuals to admit that phone use may have played a role in their accident.

Acknowledgements

We'd like to thank Simon-Jan Hazenberg for analysing the GPS data, and Marije Oosterveld, Anne Visser, Timme Mulder, Wabe Bakker, and Benjamin Schäfer for taking care of all the field work! Thanks also to Marieke Timmerman for advice on statistical tests, to two anonymous reviewers who helped us to significantly improve this paper, and to Ben Lewis-Evens for a thorough final check.

References

ADAC, 2008, Retrieved 27.11.2008 from http://www.adac.de/Recht_und_Rat/verkehrsrecht/verkehrsvorschriften_deutschland/handyverbot/default.asp?ComponentID=6521

Brookhuis, K.A., De Vries, G., and De Waard, D., 1991. The effects of mobile telephoning on driving performance. *Accident Analysis and Prevention,* 23, 309-316.

Caird, J.K., Willness, C.R., Steel, P., and Scialfa, C., 2008. A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis and Prevention*, 40, 1282-1293.

Cooper, P.J., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., Siegmund, G., 2003. The impact of hands-free message reception/response on driving task performance. *Accident Analysis and Prevention,* 35, 23-35.

Consiglio, W., Driscoll, P., Witte, M., and Berg, W.P., 2003. Effect of cellular telephone conversations and other potential interface on reaction time in a braking response. *Accident Analysis and Prevention,* 35, 495-500.

CROW, 2007. *Design manual for bicycle traffic*. Ede, The Netherlands: CROW (The National Information and Technology Platform for Transport, Infrastructure and Public space).

Crundall, D., Bains, M., Chapman, P., and Underwood, G. (2005). Regulating conversation during driving: a problem for mobile telephones? *Transportation Research Part F,* 8, 197-211.

De Waard, D., Hernández-Gress, N., and Brookhuis, K.A., 2001. The feasibility of detecting phone-use related driver distraction. *International Journal of Vehicle Design*, 26, 85-95.

Drews, F.A., Pasupathi, M., and Strayer, D.L., 2008. Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied, 14*, 392-400.

Engström, J., Johansson, E., and Östlund, J., 2005. Effects of visual and cognitive load in real and simulated motorway driving. *Transportation Research Part F, 8*, 97-120.

Finnis, K.K., and Walton, D., 2008. Field observations to determine the influence of population size, location and individual factors on pedestrian walking speeds. *Ergonomics*, 51, 827-842.

Fietsersbond: Cycle Balance, december 2008. Available at http://verkenner.fietsbalans.nl

Haigney, D., and Westerman, S.J., 2001. Mobile (cellular) phone use and driving: a critical review of research methodology. *Ergonomics*, 44, 132-143.

Harbluk, J.L., Noy, Y.I., Trbovich, P.L., and Eizenman, M., 2007. An on-road assessment of cognitive distraction: impacts on drivers' visual behavior and braking performance. *Accident Analysis and Prevention*, 39, 372-379.

McCartt, A.T. & Geary, L.L., 2004. Long-term effects of New York State';s law on drivers' handheld cell phone use. *Injury Prevention*, 10, 11-15.

McKnight, A.J., McKnight, A.S., 1993. The effect of cellular phone use upon driver attention. *Accident Analysis and Prevention*, 25, 259-265.

Ministry of Transport, Public Works, and Water Management, 2009. *Cycling in the Netherlands.* The Hague, the Netherlands.

Neyens, D.M. and Boyle, L.N., 2007. The effect of distractions on the crash types of teenage drivers. *Accident Analysis and Prevention*, *39*, 206-212.

Nasar, J., Hecht, P., and Wener, R., 2008. Mobile phones, distracted attention, and pedestrian safety. *Accident Analysis and Prevention*, 40, 69-75.

Parkes, A. & Hooijmeijer, V., 2000. *The influence of the use of mobile phones on driver situation awareness*. Retrieved on 15.12.2008 from http://www-nrd.nhtsa.dot.gov/departments/nrd-13/driver-distraction/PDF/2.PDF

Rakauskas, M.E., Gugerty, L.J., and Ward, N.J., 2004. Effects of naturalistic cell phone conversations on driving performance, *Journal of Safety Research, 35*, 453- 464

Rantanen, E.M. and Goldberg, J.H., 1999. The effect of mental workload on the visual field size and shape. *Ergonomics*, 42, 816-834.

Redelmeier, D.A. and Tibshirani, R.J., 1997. Association between cellular telephone calls and motor vehicle collisions. *New England Journal of Medicine,* 336, 453-458.

Redelmeier, D.A., Tibshirani, R.J., 2001. Car phones and car crashes: some popular misconceptions. *Canadian Medical Association Journal,* 164, 1581-1582.

Reimer, B., 2009, Cognitive Task Complexity and the Impact on Drivers' Visual Tunneling, Paper #09-2953. *Proceedings of the Transportation Research Board 88th Annual Meeting*, Washington, DC, USA: TRB.

Schepers, J.P., 2006, *Wat zijn de risico's van mobiel bellen op de fiets? [What are the risks of mobile phone use while cycling?].* Rotterdam, the Netherlands: Ministry of Transport, Public Works, and Water Management.

Strayer, D.L., and Johnston, W.A., 2001. Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science*, 12, 462-466.

Strayer, D.L., Drews, F.A., and Johnston, W.A., 2001. Cell phone-induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied*, 9, 23-32.

SWOV, 2009. *Onderzoek verplaatsingsgedrag, Mobiliteitsonderzoek Nederland*, retrieved January 14 2009 from http://www.swov.nl

Walsh, S.P., White, K.M., Hyde, M.K., and Watson, B., 2008. Dialling and driving: factors influencing intentions to use a mobile phone while driving. *Accident Analysis and Prevention,* 40, 1893-1900.

Wierda, M. and Brookhuis, K.A., 1991. Analysis of cycling skill: a cognitive approach. *Applied Cognitive Psychology*, 5, 113-122.

Zijlstra, F.R.H., 1993. *Efficiency in work behavior. A design approach for modern tools*. PhD thesis, Delft University of Technology. Delft, The Netherlands: Delft University Press.

Mobile phone use while cycling: incidence and effects on behaviour and safety

Table and figure captions

Table 1. Variables scored in observation study
Table 2. Observations per location and time of day (morning, quiet, and afternoon, busy), and the cyclists operating a telephone (either calling or text messaging)
Table 3. Observed behaviour of cyclists (N=2138)
Table 4. Number of hands on the handlebars, percentage observed cyclists (N_{max} = 2024)
Table 5. Rule compliance
Table 6. Study 2: Secondary activities at the time of the accident (N=1142)
Table 7. Study 3: Effects of Texting compared with Cycling with one hand
Figure 1. Lateral Position was scored from video: with an overlay image the cycle path was divided into strips of 0.19 metre wide
Figure 2. Average cycle speed in km/h per condition (error bars denote Standard Error). Control (2) = riding with two hands on the handlebar, Control (1) = riding with one hand on the handle bar, Phone easy = simple calculation task, Phone difficult = the difficult subtraction task, Phone texting = entering a text message, and MP3 = listening to an mp3 player or iPod
Figure 3. Average number of times the cyclists changed strips (figure 1) per condition.
Error bars indicate Standard Error.
Figure 4. Number participants that correctly identified two, one, or no objects.
Figure 5. Average rating on the Rating Scale Mental effort (RSME, Zijlstra, 1993) per condition. The scale has a range from 0 to 150. A rating of 12 coincides with the investment of “hardly any effort”, 28 = “a little effort”, 38 = “some effort”, 58 = “rather much effort”, 112 = “extreme effort”.
Figure 6. Average rating on the Risk scale (comparable with the RSME) This scale also has a range from 0 to 150. A rating of 12 coincides with the experience of “hardly any risk”, 28 = “a little risk”, 38 = “some risk”, 58 = “rather much risk”, 112 = “extreme risk”.
Appendix 1. Cyclists in the Dutch Mobility Study (Mobiliteits Onderzoek Nederland) and in the present observation Study 1, and accidents in Study 2 and weighing (correction) factor

Mobile phone use while cycling: incidence and effects on behaviour and safety
Table 1. Variables scored in observation study

Variable	**Score**
Gender	Male or female
Age	< 15, 15-30, 30-50, 50+ years of age
Secondary task	None, talking on mobile phone, text messaging (or operating menus), mp3: listening to music (earphones visible), talking to other cyclist/passenger, other
Number of hands on the handlebars	Two, one, none
Conflict	If yes: with which other traffic participant
Obeyance of rules	Red-light running, not giving right of way, impede others

Table 2. Observations per location and time of day (morning, quiet, and afternoon, busy), and the cyclists operating a telephone (either calling or text messaging)

Location	*Morning*	*Afternoon*	**Total**	**Using phone (% location)**
Railway station	167 (8 %)	352 (16 %)	519 (24 %)	8 (1.5 %)
City centre	251 (12 %)	726 (34 %)	977 (46 %)	43 (4.4 %)
Park		642 (30 %)	642 (30 %)	10 (1.6 %)
Total	418 (20 %)	1720 (80 %)	2138 (100%)	51 (4.1 %)

Table 3. Observed behaviour of cyclists (N=2138)

Observed	Observed weighted for age	
2.2 %	1.2 %	was calling with their mobile phone
0.6 %	0.3 %	was text messaging, entering a phone number, or operating the phone's menus
7.7 %	4.9 %	was listening to an mp3 player
2.3 %	4.9 %	was talking with fellow cyclists/passengers
86.6 %	88.5 %	was just cycling
0.5 %	0.3 %	"something else"

Table 4. Number of hands on the handlebars, percentage observed cyclists (N_{max} = 2024)

Hands on wheel	talking on phone *1	Text messaging *2	listening to mp3 player *3	talking *4	cycling, other
two	4.2	0.0	84.8	68.0	90.7
one	93.8	92.3	12.1	30.0	8.9
none	2.1	7.7	3.0	2.0	0.4
Effects (compared with default "cycling"):		*1 talking on phone: $\chi^2_{,N=1907, df=1} = 347$, $p < 0.001$ *2 text messaging: $\chi^2_{,N=1872, df=1} = 88$, $p < 0.001$ *3 listening to mp3 player: $\chi^2_{,N=2024, df=1} = 20.3$, $p < 0.001$ *4 talking with other cyclist: $\chi^2_{,N=1909, df=1} = 28.6$, $p < 0.001$			

Table 5. Rule compliance

Rule compliance	talking on phone *1	Text messaging *2	listening to mp3 player *3	talking *4	cycling, other
OK	97.9	100.0	91.5	100.0	97.2
Red light running	2.1	0.0	7.3	0.0	2.5
impede others	0.0	0.0	1.2	0.0	0.3
Effects (compared with default “cycling”):		*1 talking on phone: $\chi^2{}_{,N=1860,\ df=1} = 0.19$, NS *2 text messaging: $\chi^2{}_{,N=1873,\ df=1} = 0.38$, NS *3 listening to mp3 player: $\chi^2{}_{,N=2025,\ df=1} = 15.25$, $p < 0.001$ *4 talking with other cyclist: $\chi^2{}_{,N=1910,\ df=1} = 1.47$, NS			

Table 6. Study 2: Secondary activities at the time of the accident (N=1142)

Activity	**Respondents**	**Respondents weighted for age**
Talking on mobile phone (handheld)	0.3 %	0.3 %
Talking on mobile phone (hands free)	0.0 %	0.0 %
Texting	0.2 %	0.2 %
Listening to music (headphones)	1.9 %	3.0 %
Listening to music (loudspeaker)	0.3 %	0.4 %
Talking with other cyclist or passenger	11.4 %	12.6 %
Used mobile phone 10 minutes before accident	2.5 %	3.1 %

Table 7. Study 3: Effects of Texting compared with Cycling with one hand

Measure	**F**	**p**	**η_p^2**
Bicycle control			
Average Lateral position strip	F(1,22) = 21.35	<0.001	0.492
No. Strip Changes (variation)	F(1,22) = 13.73	0.001	0.384
Lat. Pos. Range	F(1,22) = 3.30	0.083	0.130
Speed	F(1,23) = 87.58	<0.001	0.792
SD Speed	F(1,23) < 1	NS	0.039
Self-report			
RSME (Effort)	F(1,23) = 31.95	<0.001	0.581
Risk-rating	F(1,23) = 95.30	<0.001	0.806
Physiology			
Heart rate	F(1,19) = 1.36	NS	0.067
SD Heart rate	F(1,19) < 1	NS	0.009
Peripheral vision	Wilcoxon Rank		
No. of objects correctly detected	Z=–2.25	0.031	

Appendix 1. Cyclists in the Dutch Mobility Study (Mobiliteits Onderzoek Nederland) and in the present observation Study 1, and accidents in Study 2 and weighing (correction) factor

Age Group	Dutch mobility study	Study 1 (street counts)	Correction factor for age (Study 1)	Study 2. Percentage accidents	Correction factor for age (Study 2)
0-14	18%	1.4 %	12.6	22.7 %	0.8
15-29	26%	69.6 %	0.4	16.9 %	1.5
30-49	25%	24.7 %	1.0	18.4 %	1.4
50+	31%	4.3 %	7.2	42.0 %	0.7

Figure 1.

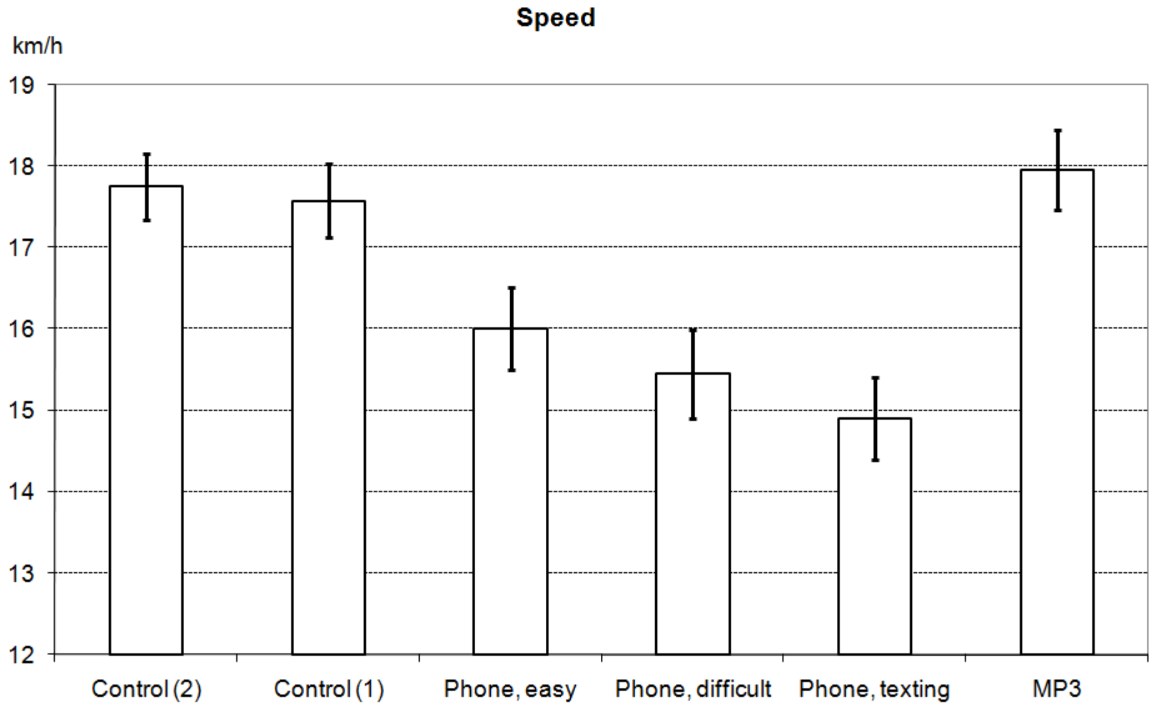

Figure 2

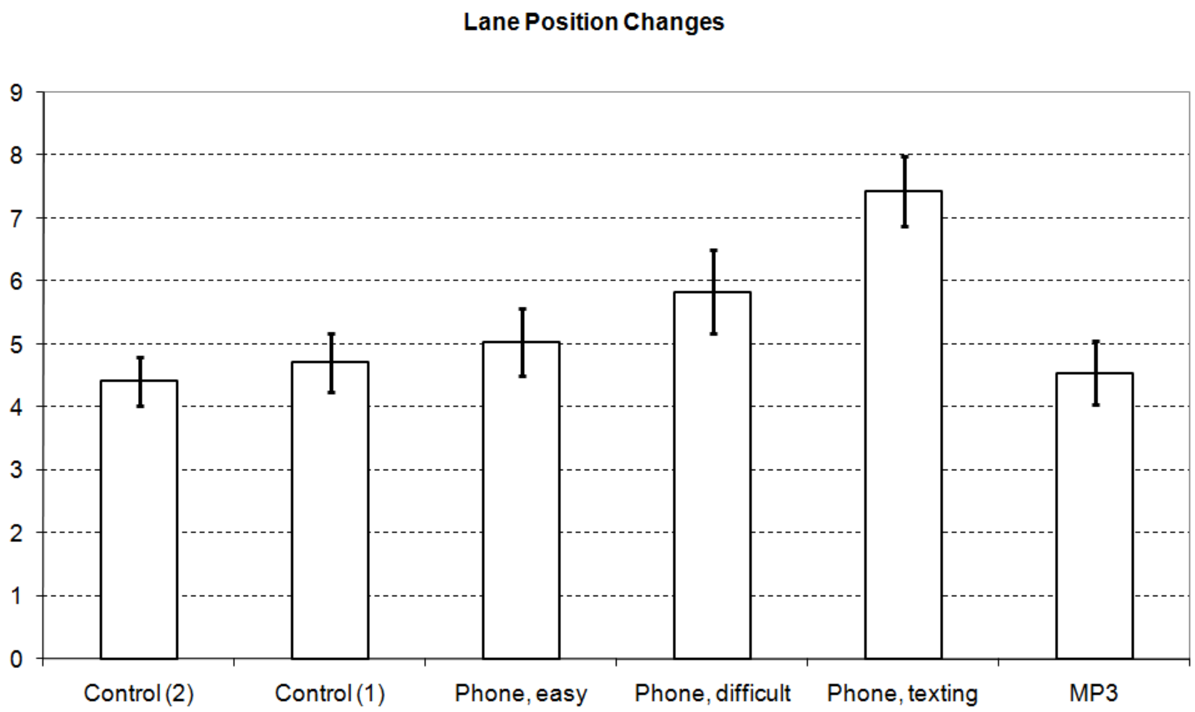

Figure 3

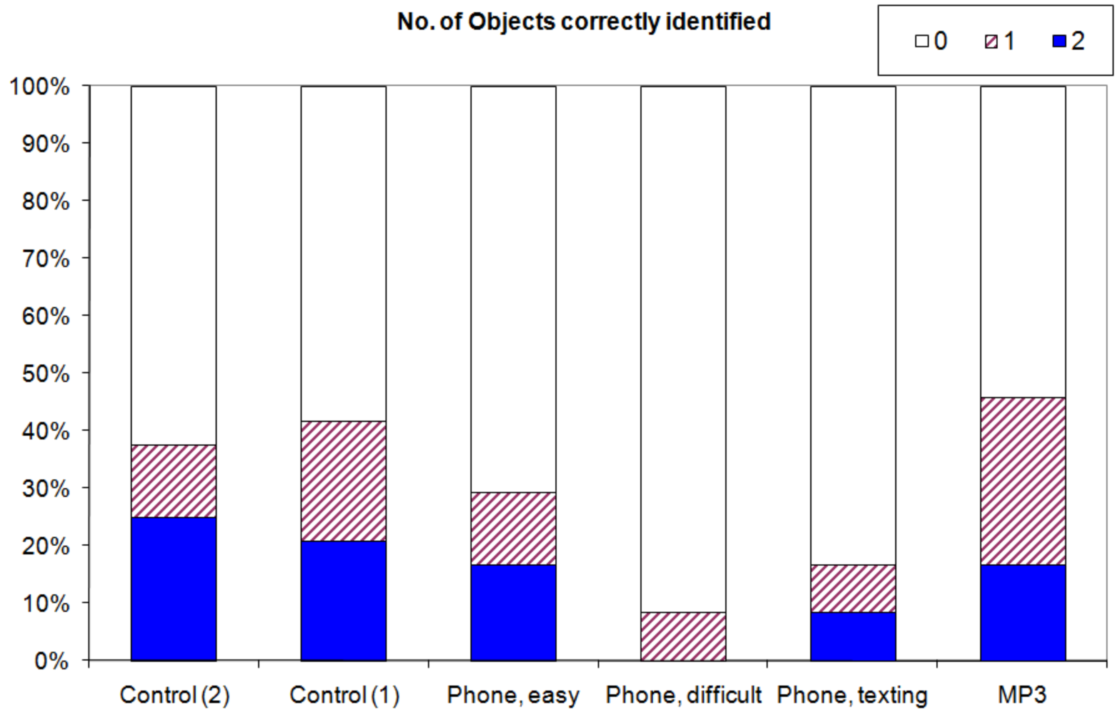

Figure 4

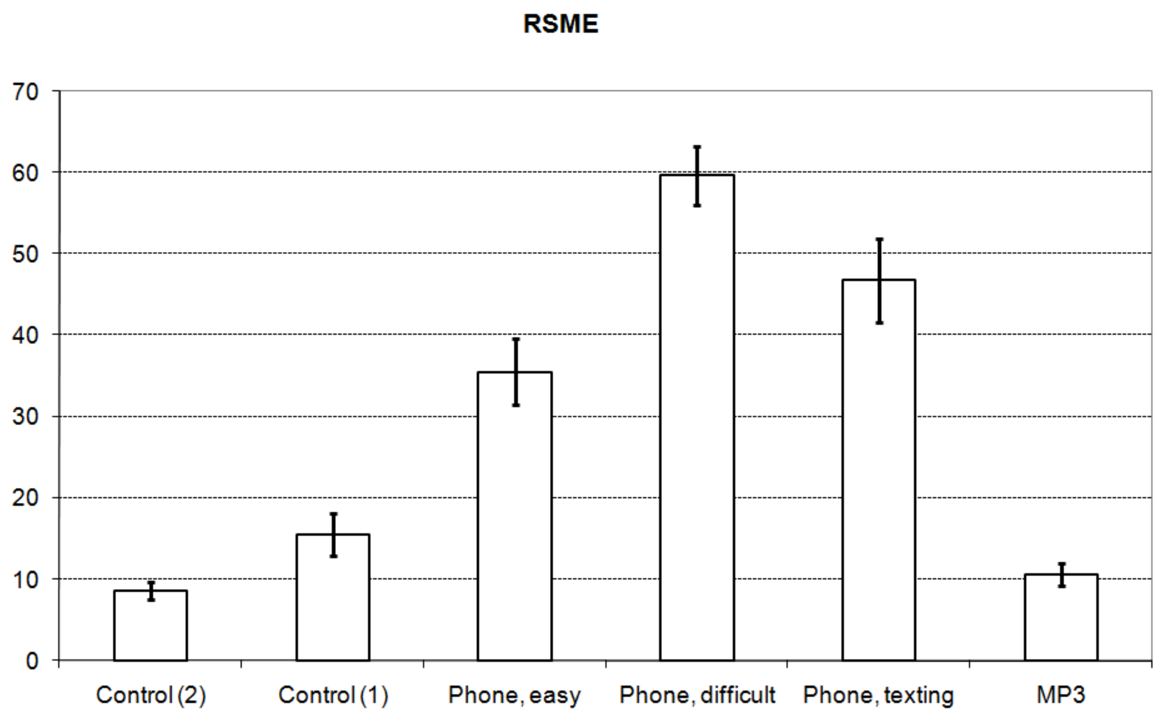

Figure 5

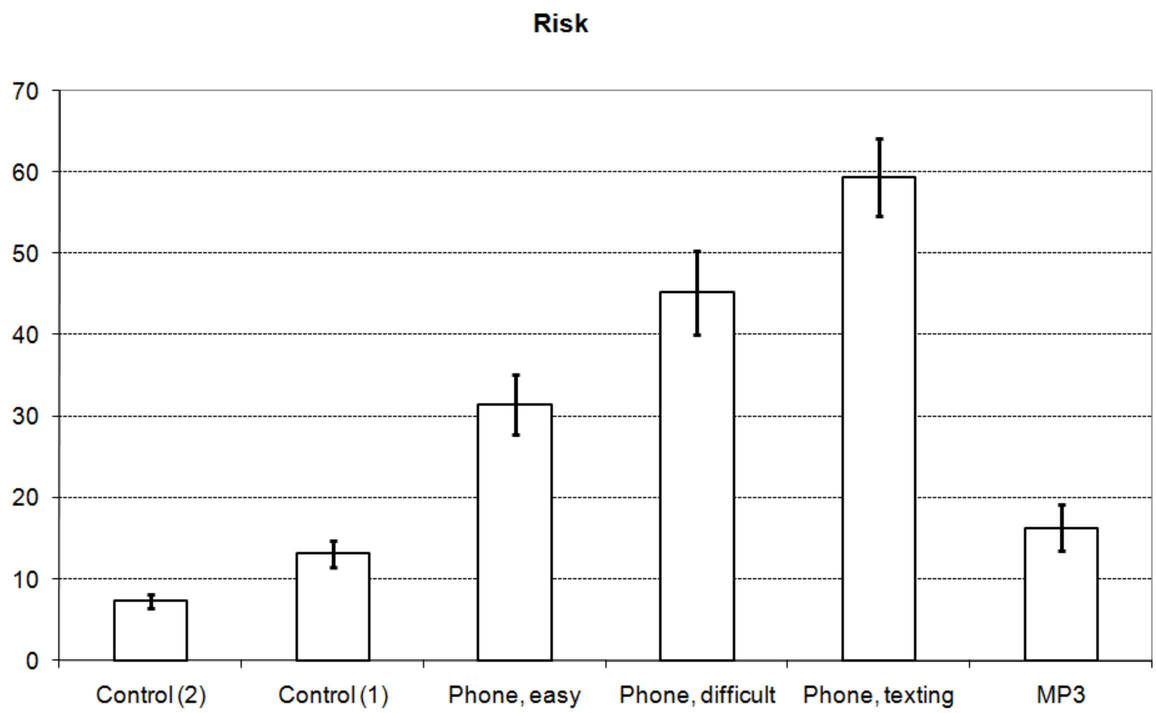

Figure 6