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Mobile telephone simulator study

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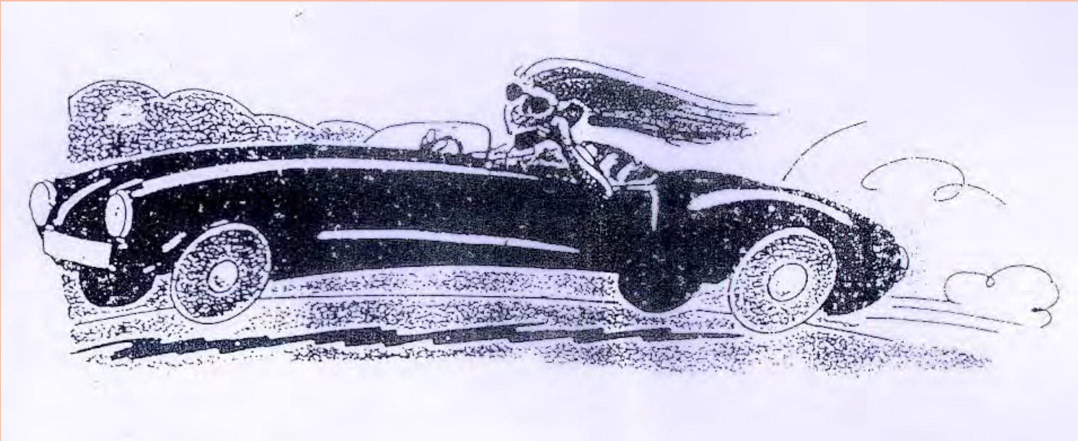

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Abstract

The study consists of four separate experiments conducted in the VTI driving simulator. The common theme was to investigate how driver behaviour and traffic safety are influenced when the driver attends to another technical device while driving.

The experiments were concerned with handsfree or handheld mobile phone conversation and dialling, receiving mobile phone SMS messages and watching a DVD film (the latter two being minor pilot experiments). In three of the experiments (mobile phone conversation, SMS, DVD) the participants drove a route which led through urban and rural environments, ranging from 90 km/h rural to 50 km/h urban environments. The urban environments differed in complexity (three levels). The driving distance was about 70 km. The dialling experiment used a rural environment with a speed limit of 110 km/h. The driving distance was about 15 km.

In the main experiment dealing with mobile phone conversation, a number of driving performance measures were analysed: driving speed, variation in lateral position, deceleration, brake reaction time, headway, time to collision, etc. PDT (Peripheral Detection Task) was used as a measure of mental workload.

Mobile phone conversation was found demanding in terms of mental workload. It also had effects on driving. Most effects were quite similar for the two phone modes (handsfree, handheld). Impaired reaction time performance was demonstrated in one of the situations for handheld mode. However, effects were found which could be interpreted as attempts to compensate for the increased workload caused by the mobile phone conversation: speed was reduced (more so for handheld than for handsfree mode), and time and distance headway increased. In spite of these compensatory behaviours, mental workload was still markedly increased by phone use.

In the SMS experiment the participants braked later in one situation when reading the SMS message. No other effects were found in this minor experiment.

In the DVD experiment, mental workload increased when watching the film, although this was compensated for to some extent by the increased distance headway to a lead vehicle. No compensation in terms of reduced driving speed, however, was apparent in this experiment.

In the dialling experiment negative effects on traffic safety were evident from the larger variance of lateral car position during the dialling task for the handsfree phone mode. The mental workload also increased with the dialling task. Compensation in terms of reduced driving speed was apparent for both phone modes.

Other aspects of mobile phone use while driving still remain to be analysed in more detail, such as starting or finishing a call, looking for a phone number to dial, mishaps like dropping the phone, etc.

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Referat

Studien består av fyra separata experiment utförda i VTI:s personbilssimulator. Det gemensamma temat var att undersöka hur körbeteendet och trafiksäkerheten påverkas när föraren ägnar sig åt annan teknisk utrustning under färd.

Experimenten gällde samtal och uppringning med handsfree eller handhållen mobiltelefon, mottagande av SMS-meddelanden på mobiltelefonen samt att se på en DVD-film (de två sistnämnda små pilotstudier). I tre av experimenten (samtal med mobiltelefon, SMS, DVD) körde deltagarna en rutt som ledde genom landsbygd och tätort i trafikmiljöer som varierade från 90-väg på landsbygd till 50-väg i tätort. Tätortsmiljöerna varierade i komplexitet (tre nivåer). Körsträckan var ca 70 km. Uppringningsexperimentet använde sig av en landsväg med hastighetsbegränsningen 110 km/h. Körsträckan var ca 15 km.

I huvudförsöket som gällde samtal med mobiltelefon analyserades att antal mått på körprestation: hastighet, sidolägesvariation, deceleration, bromsreaktionstid, tidlucka (time headway), följeavstånd (distance headway), tid till kollision, etc. PDT (Peripheral Detection Task) användes som mått på mental belastning.

Samtal med mobiltelefon visade sig ge ökad mental belastning, men hade även effekter på körprestationen. De flesta effekterna var likartade för handsfree och handhållen telefon. Försämrad reaktionstid visades i en av trafiksituationerna för handhållen telefon. Emellertid erhölls även resultat som kan tolkas som försök att kompensera för den ökade belastningen av samtalet: hastigheten reducerades (mer för handhållen än för handsfree telefon) och tidluckan och följeavståndet blev större. Trots dessa kompensatoriska beteenden var den mentala belastningen märkbart påverkad av telefonsamtalet.

I SMS-experimentet erhölls en enda effekt; deltagarna bromsade senare i en trafiksituation när de läste SMS-meddelandet.

I DVD-experimentet ökade den mentala belastningen när man tittade på filmen, även om viss kompensation förelåg genom att följeavståndet till framförvarande fordon ökade. Ingen kompensation i termer av minskad hastighet erhölls dock i detta experiment.

I uppringningsexperimentet erhölls negativa effekter ur trafiksäkerhetssynpunkt genom ökad sidolägesvariation för handsfree telefon. Den mentala belastningen ökade även av uppringningen. Kompensation i form av sänkt hastighet erhölls för såväl handsfree som handhållen telefon.

Andra aspekter av mobiltelefonanvändning under färd återstår att analyseras mer detaljerat, såsom effekter av att påbörja eller avsluta ett samtal, av att leta efter ett telefonnummer, av missöden som att tappa telefonen, etc.

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The study was headed by a project team from VTI comprising Katja Vogel, Albert Kircher, Lena Nilsson and Anne Bolling. The study was planned by the VTI team in close co-operation with Christopher Patten and Ruggero Ceci of the Swedish National Road Administration.

Mats Lidström of VTI was the creator of the visual system used in the driving simulator trials, and Håkan Jansson of VTI developed the computer programs for the trials. Leif Lantto, VTI, installed all the technical devices needed in this study in the simulator.

The experimental trials were run by Beatrice Söderström, Janet Yakoub, Albert Kircher, Anne Bolling and Katja Vogel, all from VTI. The trials were carried out during November and December 2002.

The main part of the data analysis was performed by Jan Törnros, VTI. Therese Malmström of the Swedish National Road Administration and Albert Kircher, VTI, also took part in the data analysis.

Albert Kircher, Katja Vogel and Jan Törnros were responsible for writing the report. Gunilla Sjöberg, VTI, has edited the report.

I wish to thank everyone who took part in this study.

Linköping in June 2004

Anne Bolling
Project leader

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Mobile telephone simulator study

by Albert Kircher, Katja Vogel, Jan Törnros, Anne Bolling, Lena Nilsson, Christopher Patten[*], Therese Malmström[*] and Ruggero Ceci[*]

Summary

The study consists of four separate experiments that were conducted in the VTI driving simulator. The common theme was to investigate in which way driver behaviour and traffic safety are influenced when the driver attends to another technical device while driving.

The experiments were concerned with handsfree or handheld mobile phone conversation and dialling, receiving mobile phone SMS, and watching a DVD film (the latter two being pilot experiments). In total 66 drivers took part in the experiments: 24 in the handsfree parts (conversation, dialling), 24 in the handheld parts (conversation, dialling), 10 in the SMS experiment, and 8 in the DVD experiment.

In three of the experiments (mobile phone conversation, SMS, DVD), the participants drove a route which led through both urban and rural environments as well as through some transitional passages. The driving distance was about 70 km, and the driving time was about 1 hour and 10 minutes. The traffic environments ranged from 90 km/h rural to 50 km/h urban environment. The urban environments varied in complexity (three levels from slightly to very demanding). In each traffic environment there was an event of special interest: a car following in the 90 km/h rural environment, a motorbike entering the road in the 70 km/h rural environment, a bicycle crossing the road in the complex urban environment, a traffic light turning to red in the urban environment of medium complexity, and a bus entering the road in the urban environment of low complexity. The dialling experiment used a rural environment with a speed limit of 110 km/h, where the participants were required to dial a phone number three times. The driving distance was about 15 km.

In the main experiment dealing with mobile phone conversation a number of driving performance measures were analysed: driving speed, variation in lateral position, deceleration, brake reaction time, headway, time to collision, etc. PDT (Peripheral Detection Task) was used as a measure of mental workload. A number of subjective measures were also analysed. Fewer analyses were made in the other experiments.

Mobile phone conversation experiment

The phone task was a combined calculation and memory task which was experienced as demanding. The main result was that mental workload as measured by PDT (Peripheral Detection Task) – reaction time and missed signals – increased with mobile phone conversation for both handheld and handsfree modes in all traffic environments and in all events. The effects were very similar for the two phone modes.

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Lateral control of the vehicle was affected by phone conversation. The lateral position variance decreased for both handsfree and handheld modes. Maximal lateral acceleration decreased for handsfree mode and similar tendencies also appeared partly for the handheld mode. The effects might be interpreted as attempts to compensate for the increased workload. An alternative interpretation is that the decreased lateral position variance is an effect of increased driver alertness. Other explanations seem plausible, however. It might be related to the reduced driving speed, or might be an effect of the steering becoming less prioritised during the phone conversation.

Speed was also affected by phone use. It was reduced for both phone modes in two traffic situations: the rural environment with the highest speed limit (90 km/h) and the urban environment with the highest complexity. Speed was also reduced in the handheld phone mode in two other traffic environments. Although the speed-reducing effect was not significantly different for the two phone modes for any of the traffic situations analysed separately, the speed reduction across all studied traffic environments was different for the two phone modes – it was greater for handheld phone mode. The speed reduction is assumed to be an attempt to compensate for the increased workload caused by the phone conversation. Speed variance across all analysed traffic environments was influenced – it decreased – for handsfree mode only.

Longitudinal interaction with other vehicles was also affected by phone conversation. The brake reaction time in the bus event increased for handheld phone mode. No similar effects were found, however, for the other events that required a reaction from the driver, a result which may be related to reduced speeds in these situations when being engaged in phone conversation, thus giving the driver more time to react to prevent a collision. Minimum time headway and minimum distance headway, measures of longitudinal risk margin, increased as an effect of phone use for both phone modes, a result that can also be interpreted as a compensatory behaviour.

In spite of the attempts to compensate for the increased workload caused by the mobile phone conversation (speed reduction, headway increase), mental workload was still markedly increased by phone use. It is reasonable to assume that the increased mental workload caused by the phone conversation would have negative effects from a traffic safety perspective in terms of reduced readiness to respond should a risky situation suddenly arise. To what extent the reduced speed and/or increased headway would compensate for the reduced readiness is unclear.

Questionnaire answers did not reveal any differences in perceived effort between the handsfree and handheld phone modes, an outcome which supports the results for PDT data showing no difference between the two modes. The opinion of the participants was, however, far more positive towards handsfree phone use than handheld phone use. The subjective driving performance was also rated lower for handheld than for handsfree mode.

SMS experiment

In the SMS pilot experiment the participants read and answered short questions delivered as SMS messages. Brake reaction times in four situations were analysed. The brake reaction time when a motorbike entered the rural road from the right was more than 35% longer when the driver was reading the SMS.

Questionnaire answers showed that the participants had a negative opinion of sending SMS messages from mobile phones in cars, but were more positive to receiving SMS.

The strategy for reading the SMS varied: some participants took the phone as soon as the SMS message arrived and read it, while others waited until they were in a less demanding situation to read the SMS (for example after a crossing). The strategy for reading the SMS is probably very important in terms of traffic safety, for example if the driver waits and takes the phone after a complex situation, or if he or she feels urged to read the message as soon it arrives regardless of the prevailing traffic situation.

DVD experiment

In the DVD pilot experiment the participants were required to watch part of a DVD film (lasting 40 min) and observe certain events which appeared in the film.

It was found that watching the DVD film increased the mental workload of the drivers in most traffic environments.

Longitudinal control was affected by watching the DVD movie. Speed variance over the whole route decreased as an effect of watching the film, thus the participants kept to a more constant speed. The mean speed did not, however, show any effects as a result of watching the DVD film.

Some effects were also found for longitudinal interaction with other vehicles. The mean distance headway and the minimal distance headway in the car following event increased when watching the film, which could be interpreted as a compensatory behaviour.

Questionnaire answers did not reveal any difference between the experienced mental effort when driving while watching the film and driving with the DVD player off. The participants had a very negative opinion about watching films when driving. The participants also reported that they drove worse when watching the DVD movie.

Dialling experiment

In the dialling experiment, the participants were requested to dial a nine-digit phone number on three occasions.

Mental workload increased when dialling a phone number.

Lateral and longitudinal control were affected by dialling. Lateral position variance increased in the handsfree mode, and a similar (non-significant) trend appeared in the handheld mode. In direct comparison between the two modes, however, no difference in lateral position variance was apparent. The result is an indication of reduced safety.

Conclusions

Mobile phone conversation while driving caused increased mental workload.

Drivers tried to compensate for the increased workload caused by phone conversation by slowing down and increasing the headway to a lead vehicle in car following. The decreased lateral deviation might also be interpreted as attempts to compensate.

The dialling part of a mobile phone call appeared to be more critical from a safety point of view. Even though drivers tried to compensate for the increased workload by slowing down, their lateral position variance increased.

Handsfree and handheld mobile phone use had similar effects on driving performance.

Receiving SMS messages while driving had major negative effects on brake reaction time in the motorbike situation. The effects of a short SMS message from a safety point of view are, however, expected to depend to a significant extent on the strategy used for reading the message.

Watching a DVD movie while driving caused increased mental workload. Drivers tried to compensate for this by increasing the headway to a lead vehicle in car following. There was, however, no tendency to compensate by speed reduction, in spite of the fact that DVD received the highest effort ratings of the studied devices.

The present study concentrated on the analysis of effects of mobile phone conversation on driving. Effects of dialling were studied in a driving session of short duration. Other aspects of mobile phone use while driving, such as starting or finishing a call, looking for a phone number to dial, mishaps like dropping the phone, etc. still remain to be analysed in more detail. A mobile phone with a screen showing black-and-white still images was used. There are, however, newer more advanced types of mobile phone on the market with the capacity to transmit moving images in colour. The risk of interference with the driving task may well increase further with these new phones. This issue would also require detailed study.

The SMS and DVD experiments were pilot studies. These should be followed up by more extensive studies, enabling a more comprehensive analysis of effects of relevance to traffic safety.

Körsimulatorstudie – mobiltelefon

av Albert Kircher, Katja Vogel, Jan Törnros, Anne Bolling, Lena Nilsson, Christopher Patten*, Therese Malmström* och Ruggero Ceci*

Sammanfattning

Studien består av fyra separata experiment utförda i VTI:s personbilssimulator. Det gemensamma temat var att undersöka hur körbeteendet och trafiksäkerheten påverkas när föraren ägnar sig åt annan teknisk utrustning under färd.

Experimenten gällde samtal och uppringning med handsfree eller handhållen mobiltelefon, mottagande av SMS-meddelanden på mobiltelefonen samt att se på en DVD-film (de två sistnämnda små pilotstudier). Totalt 66 personer deltog i experimenten: 24 i handsfree-delarna (samtal, uppringning), 24 i handhållen-delarna (samtal, uppringning), 10 i SMS-experimentet och 8 i DVD-experimentet.

I tre av experimenten (samtal med mobiltelefon, SMS, DVD) körde deltagarna en rutt som ledde genom både tätort och landsbygd samt genom några övergångspassager. Körsträckan var ca 70 km, och körtiden var omkring 1 tim 10 min. Trafikmiljöerna varierade från 90-väg på landsbygd till 50-väg i tätort. Tätortsmiljöerna varierade i komplexitet (tre nivåer). I varje trafikmiljö inträffade en händelse av specifikt intresse: en följesituation (car following) på 90-väg i landsbygdsmiljö, en motorcykel som svänger in på en 70-väg i landsbygdsmiljö, en cykel som korsar vägen i den komplexa tätortsmiljön, en trafiksignal som slår om till rött i tätortsmiljön av medelhög komplexitet samt en buss som svänger ut i tätortsmiljön med låg komplexitet. Uppringningsexperimentet använde sig av en landsväg med hastighetsbegränsningen 110 km/h, där deltagarna slog ett telefonnummer tre gånger under färd. Körsträckan var ca 15 km.

I huvudförsöket som gällde samtal med mobiltelefon analyserades ett antal körprestationsmått: hastighet, sidolägesvariation, deceleration, bromsreaktionstid, tidlucka (time headway), följeavstånd (distance headway), tid till kollision, etc. PDT (Peripheral Detection Task) användes som mått på mental belastning. Ett antal subjektiva mått analyserades även. Färre analyser gjordes för övriga experiment.

Experimentet angående samtal med mobiltelefon

Telefonuppgiften var en kombinerad additions- och minnesuppgift som upplevdes krävande.

Huvudresultatet var att den mentala belastningen mätt med PDT (Peripheral Detection Task) – reaktionstid och missade signaler – ökade som en effekt av telefonsamtalet för såväl handhållen som handsfree telefon i samtliga trafikmiljöer och för samtliga händelser. Effekterna var mycket likartade för handhållen och handsfree telefon.

Lateral kontroll av fordonet påverkades av telefonsamtalet. Sidolägesvariationen minskade för såväl handsfree som handhållen telefon. Maximala sidoaccelerationen minskade för handsfree telefon och liknande tendenser erhölls delvis för handhållen telefon. Effekterna kan tolkas som försök att kompensera för den ökade mentala belastningen. En alternativ tolkning kan vara att den minskade

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sidolägesvariationen är en effekt av ökad vakenhet. Andra förklaringar är också tänkbara. Effekten kan vara relaterad till den minskade hastigheten eller att styrningen blir mindre prioriterad under samtalet.

Hastigheten påverkades av samtalet. Den minskade för såväl handhållen som handsfree telefon i två trafiksituationer: på 90-väg i landsbygdsmiljö och i tätortsmiljön med den största komplexiteten. Hastigheten minskade även för handhållen telefon i två andra trafikmiljöer. Även om den hastighetsreducerande effekten inte var olika för de två telefonslagen för någon av trafiksituationerna när dessa analyserades separat, var hastighetsminskningen över samtliga trafikmiljöer olika för de två telefonslagen – den var större för handhållen telefon.

Hastighetsminskningen antas vara ett försök att kompensera för den ökade mentala belastningen orsakad av samtalet. Hastighetsvariationen över samtliga analyserade trafikmiljöer påverkades – den minskade – endast för handsfree telefon.

Longitudinell interaktion med andra fordon påverkades även av telefonsamtalet. Bromsreaktionstiden vid busshändelsen ökade för handhållen telefon. Inga liknande effekter erhölls dock för övriga händelser som krävde en reaktion från föraren, ett resultat som kan vara relaterat till minskad hastighet i dessa situationer under samtalet, vilket skulle ge föraren mer tid att hinna reagera för att undvika kollision. Tidluckan (time headway) och följeavståndet (distance headway), mått på longitudinell riskmarginal (risk margin), ökade som effekt av samtalet för såväl handsfree som handhållen telefon, ett resultat som också kan tolkas som ett kompensatoriskt beteende.

Trots försöken att kompensera för den ökade mentala belastningen orsakad av telefonsamtalet (hastighetsminskning, ökad tidlucka och följeavstånd), ökade den mentala belastningen påtagligt som en effekt av samtalet. Det är rimligt att anta att den ökade mentala belastningen orsakad av samtalet skulle ha negativa effekter trafiksäkerhetsmässigt i termer av minskad beredskap att reagera om en riskabel situation plötsligt skulle inträffa. I vilken utsträckning den minskade hastigheten och/eller den ökade tidluckan eller följeavståndet skulle kompensera för den minskade beredskapen är oklart.

Svaren på frågeformulären gav inga skillnader mellan handsfree och handhållen telefon, ett resultat som stöder resultaten för PDT-data, som inte visade några skillnader mellan handsfree och handhållen telefon. Deltagarnas åsikter var dock betydligt mer positiva för handsfree än för handhållen telefon. Den upplevda körprestationen bedömdes också vara sämre för handhållen än för handsfree telefon.

SMS-experimentet

I pilotförsöket med SMS läste och besvarade deltagarna korta frågor i form av SMS-meddelanden. Bromsreaktionstiden i fyra situationer analyserades. Bromsreaktionstiden när en motorcykel svängde in på landsvägen från höger var mer än 35 % längre då föraren läste ett SMS.

Svaren på frågeformulär visade att deltagarna hade en negativ inställning till att sända SMS-meddelanden från mobiltelefoner i bilar, men var mer positiva till att ta emot SMS-meddelanden.

Strategin för att läsa ett SMS varierade: vissa deltagare tog telefonen så snart meddelandet anlände och läste det, medan andra väntade tills man befann sig i en mindre krävande situation innan men läste meddelandet (t.ex. efter av korsning).

Strategin för att läsa ett SMS-meddelande är förmodligen mycket viktigt från trafiksäkerhetssynpunkt, t.ex. om man väntar med att ta telefonen tills efter en komplicerad situation eller om man känner sig manad att läsa meddelandet direkt när det anländer oavsett vilken trafiksituation man befinner sig i.

DVD-experimentet

I pilotförsöket beträffande DVD fick deltagarna se på en DVD-film (längd 40 min) och observera speciella händelser som dök upp i filmen.

Det visade sig att den mentala belastningen ökade i de flesta situationer när man tittade på filmen.

Longitudinell kontroll påverkades när man tittade på filmen. Hastighetsvariationen över hela sträckan minskade, dvs. deltagarna höll mer konstant hastighet. Medelhastigheten påverkades dock ej.

Vissa effekter erhölls även för longitudinell interaktion med andra fordon. Följeavståndet (distance headway) ökade i följesituationen när man tittade på filmen, vilket kan tolkas som ett kompensatoriskt beteende.

Svaren på frågeformulären visade inga skillnader beträffande upplevd mental ansträngning mellan när man tittade på filmen och när DVD-spelaren var avstängd. Deltagarna hade mycket negativ inställning till att titta på film medan man kör. Deltagarna rapporterade även att de körde sämre när de tittade på filmen.

Uppringningsexperimentet

I uppringningsförsöket slog deltagarna ett niosiffrigt telefonnummer vid tre tillfällen.

Den mentala belastningen ökade när man slog numret.

Lateral och longitudinell kontroll påverkades av uppringningen. Sidolägesvariationen ökade med handsfree telefon och en liknande (icke-signifikant) trend erhölls för handhållen telefon. I direkt jämförelse mellan handsfree och handhållen telefon erhölls dock ingen skillnad vad gäller sidolägesvariation. Resultatet är ett tecken på försämrad säkerhet.

Slutsatser

Samtal med mobiltelefon under körning medför ökad mental belastning.

Deltagarna försökte kompensera för den ökade mentala belastningen orsakad av samtalet genom att sakta ner och öka tidluckan och följeavståndet till framförvarande fordon i följesituationen. Den minskade sidolägesvariationen kan också tolkas som försök att kompensera.

Uppringning med mobiltelefon föreföll mer kritisk från trafiksäkerhetssynpunkt. Även om förarna försökte kompensera för den ökade mentala belastningen genom att sakta ner, ökade sidolägesvariationen.

Handsfree och handhållen mobiltelefon hade liknande effekter på körprestationen.

Mottagandet av SMS-meddelanden under körning hade klara negativa effekter på bromsreaktionstiden i motorcykelsituationen. Effekterna av ett kort SMS-meddelande trafiksäkerhetsmässigt kan dock förväntas till stor del bero på vilken strategi man använder för att läsa meddelandet.

Att titta på en DVD-film under körning orsakade ökad mental belastning. Förarna försökte kompensera för detta genom att öka tidluckan och följeavståndet till framförvarande fordon i följesituationen. Ingen tendens förelåg emellertid till kompensation genom hastighetsminskning, trots att tittandet på DVD-filmen gav de högsta skattningarna beträffande upplevd ansträngning av de studerade utrustningarna.

Föreliggande studie koncentrerade sig på att analysera effekter av samtal med mobiltelefon på bilkörning. Effekter av att ringa upp studerades i en körsession av kort varaktighet. Andra aspekter av mobiltelefonanvändning under körning, som att påbörja eller avsluta ett samtal, att leta efter ett telefonnummer, missöden som att tappa telefonen etc. återstår att analyseras mer i detalj. En mobiltelefon som presenterar svart-vita stillbilder användes. Det finns dock nyare, mer avancerade mobiltelefoner på marknaden som kan sända och motta rörliga bilder i färg. Risken för störande inverkan på köruppgiften kan mycket väl öka med dessa nya telefoner. Även denna frågeställning skulle kräva ett detaljerat studium.

SMS- och DVD-försöken var pilotstudier. Dessa bör följas upp med större studier som möjliggör en mer omfattande analys av effekter av relevans för trafiksäkerheten.

Abbreviations and explanations

VTI	The Swedish National Road and Transport Research Institute (Statens väg- och transportforskningsinstitut).
DVD	Digital Versatile Disc.
SMS	Short Message Service.
TTC	Time to Collision. A parameter denoting the remaining time until two objects collide when neither of the objects takes evasive action. The objects have to be on a collision course for this parameter to exist.
TH	Time Headway. The time necessary for a vehicle to reach the point where the preceding vehicle is. In the present study, however, it is defined as the time necessary for the front of the following vehicle to reach the point of the rear of the preceding vehicle. To calculate the time headway the distance between the two vehicles is divided by the speed of the following vehicle.
Distance Headway	The distance between the front part of a vehicle and the front part of the preceding vehicle. In the present study, however, distance headway denotes the distance between the rear of the preceding vehicle and the front of the following vehicle.
Handheld (HH)	When the mobile phone is held with one hand to the ear of the user.
Handsfree (HF)	A system of an external microphone and loudspeaker making it unnecessary for the user to hold the mobile phone. This allows a conversation to be held without holding the receiver. In this study, "handsfree" indicates that the telephone was placed in a holder mounted on the dashboard.
Standard Deviation (SD)	A measure of dispersion around the mean. In a normal distribution, 68% of cases fall within one SD of the mean and 95% of cases fall within 2 SD. For example, if the mean age is 45, with a standard deviation of 10, 68% of the cases would be between 35 and 55, and 95% of the cases would be between 25 and 65 in a normal distribution.
Variance	A measure of dispersion around the mean, equal to the sum of squared deviations from the mean divided by one less than the number of cases. $\sigma^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$ where *n* is the number of samples, x_i is the value of sample *i*, $\bar{x}$ is the mean of the samples, and σ^2 is the variance. *Note:* The square root of the variance is the standard deviation.

1 Introduction

1.1 Background

Mobile phones are becoming increasingly popular. Thulin and Gustafsson (2003) report that according to Swedish surveys, drivers' use of mobile phones while driving has similarly increased dramatically. In 2001, 73% of all Swedish drivers had access to a mobile phone compared to 55% in 1998. At present 85% of all car mileage is driven by drivers who have a mobile phone with them in their car. Thirty per cent of all drivers with mobile phones use them daily while driving. Thulin and Ljungblad (2001) estimated that about 2% of total driving time was done while using a mobile phone. Almost 75% of drivers' mobile phones are of the handheld type without any extra add-on equipment, and the rest are handsfree.

Mobile phones can have both positive and negative effects. They have general communication benefits, and they also provide safety benefits by enabling people to call emergency services when necessary. They may also have positive effects on driver vigilance during long monotonous drives. Moreover, travel time can be used as productive time from a professional and economic point of view.

The negative effects of mobile phone use while driving are related to the fact that a divided attention situation arises where the phone task acts as a distractor drawing attentional resources from the primary task of driving (Wickens, 1992). Negative effects may occur at the perceptual, cognitive as well as at the response execution stage of information processing, as summarised by Svenson and Patten (2003). The following summary of research findings is to a great extent comprised of selected quotations from their report.

Effects on driver information input

Graham and Carter (2001) investigated effects of "driving" and phoning on peripheral target detection in a laboratory setting. Driving and phoning caused increased detection time. Detection performance was better with a handsfree phone than with a handheld phone.

In real car driving, Zwahlen, Adams and Schwarz (1988) found that dialling an 11-digit number while driving caused prolonged eyes-off-the-road episodes.

Wikman, Nieminen and Summala (1998) investigated effects of IT equipment on the allocation of visual attention while driving on a motorway. Dialling phone numbers on a handheld phone was compared to searching for a radio station and a cassette player task. The glances were longer for the mobile phone task than for the cassette task but shorter than for the radio task.

Harbluk, Noy and Eisenman (2002) studied eye movements of drivers solving addition problems transmitted via a handsfree phone while driving on a busy city road. Drivers made fewer saccades (high-speed ballistic eye movements facilitating the exploration of the visual field) as the complexity of the phone task increased. It was also found that the time spent searching the central visual area increased, and the time spent looking at mirrors and instruments decreased, with increased complexity of the phone task.

Based on these results and results from earlier studies, Svenson and Patten (2003) conclude: When driving while talking over a mobile phone, the visual field covered decreases so that a "tunnel effect" occurs – the central area of the visual field is given more attention. Inexperienced drivers leave the attention of the central task of driving for longer periods than experienced drivers. Detection times to traffic targets typically increase and the probability of missing a target increases during a mobile phone conversation. The more demanding the conversation is, the greater the loss in reaction time and detection probability.

Effects on driver central cognitive processes

Garcia-Larrea et al. (1998) investigated to what extent the increased reaction time of a driver using a mobile phone depends on the impairment of attention and/or response sub-processes (psychomotor preparedness). They used a non-driving situation, in which the participant answered different questions while performing a reaction time task. Handheld and handsfree mobile phones were compared. The reaction time was prolonged by mobile phone use with no difference between the two modes. Stimulus induced alerting and attention allocation (as measured by P3 amplitude of event-related brain potentials) decrease was the same for both phone modes. However, the attenuation of pre-stimulus negativity was different from the control condition only when the phone was handheld. It was concluded that both the attention and response sub-processes were affected by mobile phone use and that the response readiness process is affected more in the handheld mode than in the handsfree mode.

Increased subjective workload is typically reported in simulator studies when talking over a mobile phone as compared to just driving. Alm and Nilsson (1990), using a high-fidelity driving simulator, found that self-ratings of workload increased when the drivers were using a mobile phone (handsfree) compared to a control condition. Similarly, de Waard, Hernández-Gress and Brookhuis (2001) found that the participants using a handheld mobile phone while driving in a driving simulator rated higher effort when the telephone task was added.

Burns et al. (2002) compared the effects of mobile phone conversation (handheld or handsfree) to those of alcohol corresponding to the legal limit in Britain (80 mg/100 ml) in a driving simulator study. According to mental effort ratings by the participants, driving while using a handheld phone was the most difficult. The easiest task was the normal driving without any phone conversation. The participants reported it easier to drive intoxicated than to drive while using a phone, even when it was handsfree.

Using an instrumented car driven on a motorway, Patten et al. (2003) studied the effects of using a mobile phone while driving. Effects of conversation type (simple vs. complex) and telephone mode (handheld vs. handsfree) were compared to baseline conditions. A peripheral detection task (PDT) was employed to gauge mental workload. The results were that the PDT reaction times increased when conversing, but no benefit of handsfree units over handheld units was found. The content of the conversation was far more important: the more difficult and complex the conversation, the greater the increase of PDT reaction time.

All other identified field studies that measure mental workload have found increased workload when using a mobile phone – the more complex the task the greater the workload (Parkes, Fairclough and Ashby, 1993; Brookhuis, de Vries and de Waard, 1991; Tokunaga et al., 2001).

Svenson and Patten (2003) conclude: Talking over a mobile phone requires additional energetic resources and many studies have shown this as increases in physiological and subjective measures reflecting changes in mental workload.

The increase in mental workload may interfere with driving tasks that also make significant demands on the driver's information processing abilities, such as remembering when to turn, or the monitoring of the distance to the car in front (Alm and Nilsson, 2001).

Effects on driver psychomotor output

Briem and Hedman (1995) used a tracking task to investigate the effects of conversing over a handsfree mobile phone ("simple" or "difficult") compared to tuning a radio. It was found that the radio task affected the lateral position variance as did the psychomotor processes of receiving and ending phone calls. Driving without an extra task was performed with less lateral position variance and "collision errors". Phone conversations gave values between the two extremes with the difficult conversation producing most lateral variance and errors.

Strayer and Johnston (2001) used a computer display and a joystick control of a tracking task. They tested the effects of speaking over handheld and handsfree phones. No difference between the two phone modes on tracking performance was found. However, the reaction time to "traffic events" increased when the participants had a phone conversation. A more complex conversation task caused more tracking errors than a simple conversation.

Graham and Carter (2001) cited earlier, also used a tracking task to investigate how different mobile phone designs affected "driving" (e.g. tracking) and attention (e.g. detection of stimuli on the PC screen). The phones had different interfaces: standard button phone ("manual"), speech recognition with auditory feedback, or auditory feedback plus a visual display. It was found that tracking performance was impaired and that the manual condition was worse than the other phone conditions.

Some simulator studies have been conducted investigating effects of mobile phone use on driver behaviour. California Highway Patrol (1987) published a study where effects of dialling a phone number while driving was investigated. It was found that dialling interfered with the drivers' ability to follow the road in an optimal manner. The telephone task interfered more than the task of tuning a radio. The negative impact of the dialling task was more severe when the phone was mounted between the driver's and the passenger's seat than when being mounted on the dashboard.

Alm and Nilsson (1990) used an advanced driving simulator to study the effect of using a handsfree phone mounted on the dashboard. A button had to be pressed to receive a call. The participants solved memory and decision problems. When driving the simulator the participants were asked to press the brake when a red square sign appeared next to the road. The results showed that when the driving task was easy (driving on a rather straight road), the phone conversation increased the brake reaction time and caused a reduction in speed level, but when the driving task was hard (driving on a very curvy road) no such differences emerged. This somewhat surprising result was interpreted by the authors in terms of different attention priorities – in the hard driving condition, the driving (including detection of a brake signal) was supposed to take up relatively more attention resources and the mobile task relatively less. The detection of the red signal is associated with the driving task and therefore detected just as well by the driver when s/he is talking on the phone as when not doing so. The lateral position, however, was affected by a phone call in both the easy and hard conditions: the participants drove closer to the side of the road with the phone task. No difference was found, however, for the variation in lateral position.

Using the same driving simulator but with more traffic, Alm and Nilsson (1995) studied the effects of problem solving given in a handsfree mobile phone on brake reaction time, headway and lateral position. The participants were repeatedly forced into a car following situation where they had to respond to a sudden braking of a heavy vehicle in front of the participant's car. The results showed that the brake reaction times increased when they were phoning compared to a control condition (no phoning). It further turned out that the prolonged reaction times were not compensated for by choice of slower speed and/or longer headway distance. The average minimum headway was also shorter when they were phoning than when they were not.

In a simulator study by Reed and Green (1999) the participants made mobile phone calls on a handheld phone. The standard deviation of lateral position was greater when phoning compared to a control condition (no phoning). The mean lateral speed was also greater in the phone condition, indicating fewer and greater movements with the steering wheel when phoning. The standard deviation of driving speed also increased as an effect of phoning.

Haigney, Taylor and Westerman (2000) also used a driving simulator and found that using a mobile phone (handheld or handsfree) was associated with reduced speed and reduced standard deviation of accelerator-pedal travel. The lateral control of the car was also poorer with a handheld phone.

Strayer et al. (2002) studied the effects of mobile phone conversation on driving in a driving simulator. The results showed that talking over the phone (handsfree) increased brake reaction time in a car following situation, in both a low traffic density and a high traffic density condition.

De Waard, Hernández-Gress and Brookhuis (2001) investigated the effects on driving of using a handheld phone, answering and searching for a telephone number on a list clipped on the dashboard. The variation in lateral position increased as an effect of the phone task. The amplitude of the steering-wheel movements increased and the standard deviation almost doubled as an effect of the phone task.

Salvucci and Macuga (2002) also found the standard deviation of lateral position increased as an effect of phone use including dialling.

Fuse et al. (2001) studied the effect of different phases in using a mobile phone while driving. Looking at the phone when picking it up delayed brake reaction time. The number of participants was, however, small and the results would have to be validated in other studies.

Burns et al. (2002), comparing the effects of mobile phone conversations to those of alcohol intoxication, investigated effects on driving performance. The drivers slowed down when talking on the handheld phone compared to the other conditions (handsfree, alcohol, control). The standard deviation of speed and speed error measures indicated that the drivers had the poorest speed control when using the handheld phone. The standard deviation of lateral position was, however, worst in the alcohol condition. Reaction times to warning signs at the roadside were slower for drivers using a handheld phone in comparison to when they had consumed alcohol or compared to the control condition. Drivers were slower when they had consumed alcohol than when they had no distractions. The drivers also missed more target signs when they were using a phone compared to the control condition. Handsfree also had more misses than alcohol. The phone conditions also scored worst for false alarms.

Parkes and Hooijmeijer (2001) used rural road driving in a simulator with mobile phone conversations that consisted of answering numerical and verbal memory as well as arithmetic and verbal reasoning. One of the findings was that when phoning the drivers did not adapt to the speed limit as quickly as when not using the phone.

A number of field or track studies using real cars have also been conducted. Zwahlen, Adams and Schwarz (1988) cited above, found that dialling a phone number while driving caused increased lateral deviation. Technical solutions, such as voice controlled dialling or the use of "short numbers", were suggested in order to minimise the negative effects of dialling.

Parkes, Fairclough and Ashby (1993) had their participants drive on a motorway under moderate traffic conditions where calls were received on a handsfree mobile phone. The telephone conversations involved mental arithmetic and memory problems. No effects were found on driver behaviour in terms of speed, lane change or accelerator operations, in spite of increased self-reported subjective workload in the phoning condition.

Brookhuis, de Vries and de Waard (1991) investigated the effects of using a mobile phone while driving on a quiet rural road, a busy ring road and in a town. The phone was either handheld or handsfree. The communication consisted of solving a paced serial addition task. The driving took place in real traffic and the participants were asked to follow a lead car that occasionally braked so that the brake reaction time of a participant could be measured. When phoning there was a decrease in the standard deviation of lateral position. This may indicate that telephoning increased the drivers' alertness and improved their control of the lateral position of the car. However, the reaction time of speed decrease in response to a change of speed of the lead car increased when there was a phone call. There was also a non-significant increase in reaction time to the brake signal of the lead car. The dialling of a telephone number had a marked effect on the amount and amplitude of steering-wheel movements. The authors strongly recommended that only handsfree phones with voice activated dialling systems should be allowed in cars.

Tokunaga et al. (2001) studied the reaction times of drivers using a handsfree phone while performing a car following task on a motorway. The reaction time to the onset of the brake lights of the lead car increased with increased complexity of the phone task (casual conversation or mental arithmetic).

Hancock et al. (1999) used a test track to investigate the effects of keeping an unknown phone number in memory, while driving a car. In one condition, the participants also received a phone call. The results showed that the brake response time to the change of a traffic signal (from green to red) increased when there was a phone call. The stopping distance decreased when there was a phone call, meaning that the drivers started braking later and compensated for this delay with a very intense braking reaction.

Reed and Green (1999) studied the effects of making a phone call (handheld set with visual digits on a panel), while driving on a motorway. When dialling, the participants made slightly more frequent, but much larger steering corrections than when they did not phone. The effect of this was larger standard deviations of lateral position on the road.

Lamble et al. (1999) investigated detection and braking ability in response to a lead car that started to decelerate, while the drivers were continuously dialling series of numbers on a mobile phone. At a speed of 80 km/h, the detection time performance and the time to collision performance were impaired.

Harbluk, Noy and Eisenman (2002) cited above, investigated the braking performance of their drivers while driving, driving with easy and difficult addition tasks respectively, transmitted via a handsfree mobile phone. The more complex the situation the greater the frequency of hard braking episodes. Those who changed their gaze pattern most as a result of the phone task also tended to brake harder.

Patten et al. (2003) cited above, had their drivers use a mobile phone while completing a motorway route in an instrumented car. The route was characterised by a low level of road complexity. Effects of conversation type (simple vs. complex) and telephone mode (handheld vs. handsfree) were compared to baseline conditions. It was found that the driving speed was reduced by using a handheld mobile phone, whereas no speed reduction was apparent for the handsfree mode. Conversation type did not, however, seem to have any marked effects on driving speed.

Svenson and Patten (2003) conclude: In comparison with just driving, the standard deviation of lateral position typically increases when talking on a mobile phone. For straight rural roads, however, the standard deviation has been found not to increase under some conditions. These findings concern talking over the phone, but when making a phone call in more complex traffic environments, the standard deviation of lateral position can be expected always to increase.

Driver reaction time to a speed decrease of a car in front has been found to increase, delaying a proper speed adjustment of the car by that time. As a consequence, the braking distance will increase while talking on the phone.

There is a possibility to compensate for loss of attention and control functions during a mobile phone conversation, e.g. by reducing speed and increasing headway distance to a vehicle in front. However, research indicates that compensation cannot be expected to be sufficiently strong to outweigh the decrease in driving performance accompanying a mobile phone conversation, in particular in sudden critical situations.

1.2 Issues of the present study

Although some issues have been clarified in the research literature on the effects of mobile phone use while driving, such as the importance of the content of the conversation, there still remain some issues that have not been clarified sufficiently. One such issue, which is of significant concern not least from a legislative point of view, is the distinction between handheld and handsfree mobile phones. It is often assumed that handsfree phones are to be preferred from a traffic safety point of view since the physical distraction is assumed to be less than for handheld phones. Most international legislation against the use of a mobile phone while driving also concerns handheld phones only. However, both phone modes cause cognitive distraction which may have negative consequences. More often than not, the published studies have been based on only one type of mobile phone. Where the two modes have been compared in the same study, either no difference is apparent or there is a tendency to suggest that the use of a handheld phone would interfere with the driving task more than a handsfree phone. The issue needs further study, and one of the major aims of the present study is to compare the two modes with respect to effects on measures related to traffic safety.

Another issue that needs more study is the importance of the traffic environment in which the mobile phone is used: it can be assumed that the consequences of using a mobile phone could be quite different in situations like dense and demanding traffic compared to using the phone on a straight, empty highway. Combined with the above-mentioned issue of phone mode generally, comparisons between the two phone modes were made for a number of different traffic environments. Both the negative effects of mobile phone use and attempts to compensate for the negative effects, such as speed reduction or increased headway in a car following situation, were studied.

Since dialling may be particularly critical from a traffic safety perspective, although the duration of this sub-task is probably in most cases rather short in comparison with the duration of the conversation, comparisons between the two phone modes were made in a separate experiment for this phase of mobile phone use. This experiment was, however, limited to one situation of short duration.

The reported study contained another two experiments, also linked to the mobile phone experiments. Mobile phones can be used not only for conversation: short text messages can be sent and received via SMS (Short Message Service). Finally, another device that has started appearing in cars is the DVD (Digital Versatile Disc) player. Effects of receiving SMS messages and of watching a DVD film while driving were also studied in two separate exploratory experiments.

1.3 Aims, hypotheses

The basic aim of the mobile phone conversation experiment was to investigate effects of using a mobile phone while driving, as performed in an advanced driving simulator. Comparisons in this respect were also to be made between handsfree and handheld phone modes in different environments and traffic situations. Driver behavioural/performance measures, assumed to be related to traffic safety, mental workload, and subjective effects of using the technical device, were analysed.

The main ***hypothesis*** of the study was that the use of a mobile phone while driving would influence driving performance – both lateral and longitudinal control including longitudinal interaction with other vehicles. Mental workload was also expected to be influenced by phone use. Another hypothesis was that the effects would be different for handheld mode and for handsfree mode.

In the other three experiments (dialling, SMS, DVD), the aims and hypotheses were similar, but more limited.

1.4 Method

1.4.1 Participants

The participants were volunteers who were paid for their participation. Those selected for the study had to fulfil the following requirements (self-reported):

- Good vision (and no need to change eyeglasses to read text on a mobile phone).
- No tendency for motion sickness.
- Aged between 24 and 60 years for the mobile phone conversation experiment (with two-thirds between 24 and 35 years and the remaining one-third between 36 and 60 years), and between 24 and 35 years for the SMS and DVD experiments.
- Have held a driving licence for at least 5 years and driven at least 10,000 km during the last year.
- Use a mobile phone regularly (not necessarily in the car).

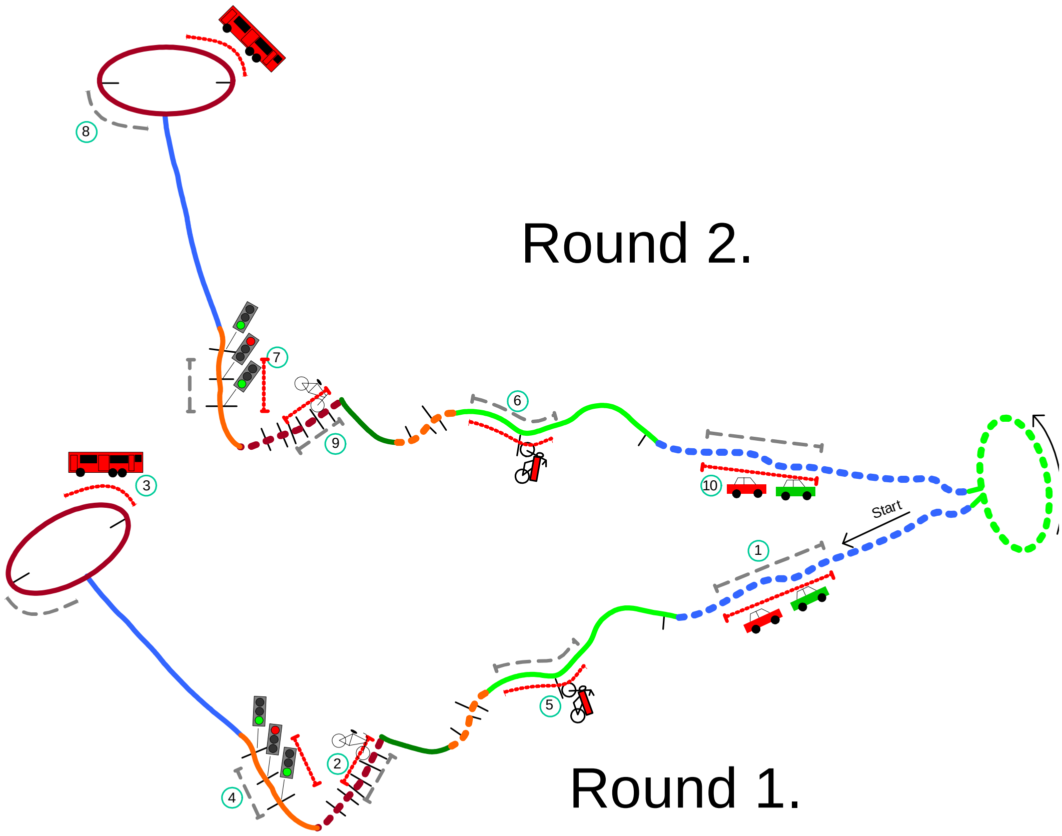
Over all the experiments in the study (mobile phone, SMS and DVD) the mean age of the participants was 32.7±8.3 years; 39 drivers were male and 27 female. The original goal was to have equal numbers of both genders – this could not be fulfilled entirely due to problems with motion sickness, especially prominent among young female participants.

Despite the requirement for no reported tendency for motion sickness, a number of participants experienced such problems during the test session. This happened to 32 participants. When this happened, the participant was replaced by another participant who fulfilled the requirements.

1.4.2 Route

The simulated route used in the mobile phone conversation, SMS and DVD experiments involved two rounds and a connection between the rounds, as shown in Figure 1. The two rounds were completely identical (a fact that was not disclosed to the participants). Each round was driven in both directions. The total route length, including the 4,000 m stretch for connecting round one and round two, was 69,370 metres. The time needed to complete the drive was approximately one hour and 15 minutes. The route had rural and urban parts, and the speed limit ranged from 50 km/h to 90 km/h (see “Traffic environments” below). There was some traffic on the route, for example other vehicles, bicycles, a motorbike, pedestrians, busses, etc. The weather conditions were clear sky and high friction.

There were different events (“critical” situations) along the route, one in each of the five different environments (see “Events on the route” below). Each event appeared once in each of the two rounds. For each part with an event there was a similar part of the road where no event appeared. A phone call appeared at these parts in either round 1 or round 2. Data was collected for the five different environments with and without event and with and without phone call.



Distances where data was collected: ○ - ○ Sites of phone call
------ without event

.... with event

Figure 1 *Route, events and one setup of phone calls for the study used in the mobile phone conversation and SMS experiments. The same route and events were used in the DVD experiment.*

Traffic environments

Below is a description of the traffic environments used on the route. Each line code (from Figure 1 beginning at "Start") represents a traffic environment.

- Rural road 90 km/h. Curvy, 3.5 m lane width, surrounded by woods, sometimes a bit more open, some oncoming traffic.
- Rural road 70 km/h.
- Rural road 50 km/h. Lampposts, crossings with right of way, pedestrian sign.
- Rural road 70 km/h.
- Complex urban section 50 km/h. Separated lanes and separate pedestrian and cycle track, houses on both sides, car and pedestrian crossings, traffic lights, parked busses and cars, pedestrians and bicycles appear.
- Medium complex urban section 50 km/h, bus lane, few houses, traffic lights.
- Rural section 90 km/h fairly straight.

Simple urban section circular route around a residential area, side roads into the area, bus stops.

Rural road 70 km/h connecting rounds 1 and 2.

Events on the route

Car following

A car following situation was on a rural road with a speed limit of 90 km/h. Two cars driving at low speed (40 km/h) appeared in front of the driver. When the driver caught up with the cars, they accelerated and then varied their speed in a sin-function from maximally 85 to minimally 65 km/h. After approximately 2 kilometres the vehicles accelerated and left the scene. Oncoming traffic was expected to prevent overtaking.

Motorcyclist

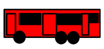
The motorbike situation occurred on a rural road with a speed limit of 70 km/h. Here a motorbike entered the main road from the right without yielding, and the drivers had to brake in order to avoid a collision.

Cyclist

The bicycle situation occurred in the urban section with high complexity and a speed limit of 50 km/h. Two seconds before the driver reached the junction the bicycle appeared and began entering from a side road to the right of the main road. The speed of the bicycle was constant. The participants were expected to stop and yield to the bicycle. If the driver did not stop, the bicycle stopped to prevent a collision.

Traffic light

The traffic light situation was on an urban section with medium complexity and a speed limit of 50 km/h. A traffic light turned from green to amber 4 seconds before the driver reached the crossing. The driver was expected to stop. If the driver did not stop the traffic light switched back to green.



Bus

The bus situation was in an urban section with low complexity and a speed limit of 50 km/h. A bus was standing at a bus stop. The bus began to indicate 4 seconds before the driver reached the bus stop, and entered the main road. Oncoming traffic made overtaking difficult, the driver was expected to stop and yield to the bus. If the driver passed the bus in any case, the bus remained at the bus stop. If the driver yielded, the bus drove at 50 km/h and stopped again at the next bus stop after approximately one kilometre. Oncoming traffic was meant to prevent the participants from overtaking the bus before it stopped at the bus stop.

1.4.3 Design

The common theme of the experiments was to investigate in what way driver behaviour is influenced when the driver attends to another technical device while driving.

The basic experimental design is shown in Figure 2 below. The experiments were concerned with mobile phone use, receiving mobile phone SMS, and watching a DVD film. The drivers who participated in the main handsfree or handheld mobile phone experiment also participated in an experiment analysing the dialling part of a mobile phone call (see Chapter 5 – Dialling experiment). As shown in Figure 2, the comparisons between *with* and *without* device were within subjects. Since only within subjects comparisons were made in the DVD and SMS experiments, a repeated measures design was used in those experiments. In the mobile phone experiments, comparisons were also made between subjects – between handsfree and handheld phone modes. Since such comparisons were included, a mixed design was used in those experiments.

Figure 2 also shows the different traffic environments in the experiments. The environments used in the phone conversation, SMS and DVD experiments ranged from 90 km/h rural environment to 50 km/h urban environment. The environments contained events which forced the driver to take some action. Urban environments of different complexities (low, medium, high) were included, according to the classification proposed by Fastenmeier (1995).

In total 66 drivers took part in the experiments: 24 in the handsfree experiments (conversation + dialling), 24 in the handheld experiments, 10 in the SMS experiment and 8 in the DVD experiment. It should be noted that the SMS and DVD experiments were more "pilot-like" in character because of the small number of participants.

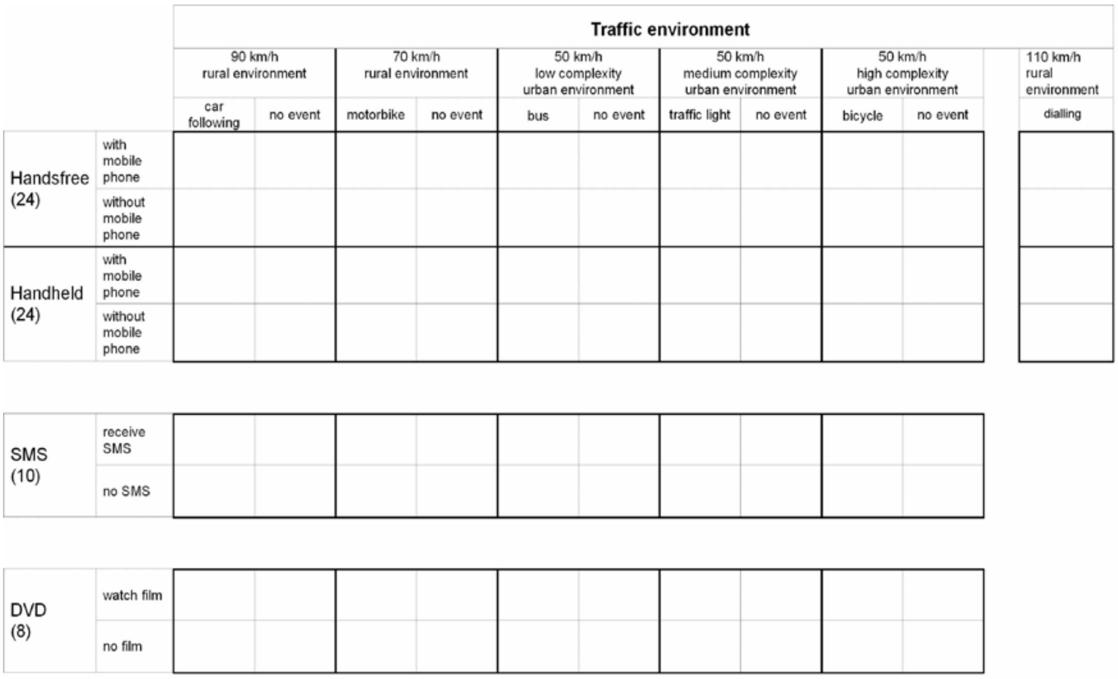


Figure 2 *Design of the four experiments (number of participants in parentheses).*

In the mobile phone conversation experiment, the participants were randomly assigned to one of two groups, which would have the phone calls in different orders. The locations of the phone calls were balanced to avoid consequences of learning effects due to the possibility of recognising the route in the second round. Figure 1 above shows these locations for half the participant group. The other half received their phone calls in the remaining with event/no event sections (line codes), as depicted in the figure. The same design was used in the SMS experiment. In the DVD experiment, half the participants watched the DVD film during the first round while the second round served as a control condition (no DVD), whereas the remaining participants received the two conditions in reverse order. In the dialling experiment a different design was used: only one drive was made during which the participant dialled a phone number. Comparisons were made between those occasions and the remaining part of the drive, serving as a control condition.

1.4.4 Driving simulator

The VTI driving simulator was used in the study (see Table 1 for technical data of the simulator). It is used to create realistic sensations in a laboratory environment, and includes:

- a cut-off vehicle cab.
- a computerised vehicle model.
- a large moving base system.
- a vibration table.
- a PC-based visual system.
- a PC-based audio system.

Table 1 *Technical data of the VTI driving simulator.*

Vibration table	
• vertical	± 5 cm
• longitudinal	± 7.5 cm
• roll	± 7°
• pitch	± 4°
Motion system	
• pitch	- 10° to + 15°
• roll	± 22°
• lateral	± 3.5 m
• max. acceleration	0.4 g
Visual system	Real time PC-based graphic projection system
• field of view	3 channels forward view 120° x 30°
• resolution	1152 x 864 pixels per channel at 60 Hz
Computer system	Computer Alpha Server 1000A
• program language	Fortran 90, C
• transport delay time	40 ms

The time delay introduced in the simulator is very short (40 ms), which is important when focusing on the control and manoeuvring aspects of driving. The noise, infra-sound and vibration levels inside the cabin corresponded to those of a modern passenger car. The car body used in this experiment was a Volvo 850 with manual gear box.

Figure 3 shows the inside of the driving simulator as used for the mobile phone conversation experiment. The mobile phone placed in the holder is visible, as well as the peripheral detection task device (PDT) used to measure mental workload (described below).

Figure 3 *Inside of the driving simulator with PDT and mobile phone visible.*

1.4.5 Effect measures

The following measures were analysed:

- Driving speed – average, variance, maximal.
- Brake reaction time to events (braking for traffic light, bus, motorbike and bicycle).
- Lateral position variance.
  Lateral position is defined as the distance between the middle line of the road and the centre of the vehicle.
- Lateral acceleration – variance, maximum.
- Longitudinal acceleration – variance, maximum.
- Time headway – minimum.
  Time Headway to a lead vehicle is defined as the elapsed time between the rear of the lead vehicle passing a point on the roadway and the front of the following vehicle passing the same point.
- Distance headway – average, variance, minimum.
  Distance Headway to a lead vehicle is defined as the distance to a lead vehicle – the distance from bumper to bumper.
- Time to collision – minimum.
  Time to Collision (TTC) is defined as the calculated time to collide into a lead vehicle.

The sampling rate was 10 Hz for all of the effect measures mentioned above.

- Number of participants stopping at certain events.
- PDT (Peripheral Detection Task) – Reaction time to detected stimuli, Percentage missed PDT signals. PDT is a relatively new secondary task performance measure intended to gauge mental workload, whereby drivers respond to visual stimuli presented off centre of their forward view by pressing a micro switch placed on the finger. The method is based on research by van Winsum et al. at TNO (van Winsum, Martens and Herland, 1999). In the present experiment the PDT device had six red high-intensity LEDs, which were projected and reflected in the left part of the windscreen (see Figure 3). Figure 4 shows the PDT response button placed on the index finger of the left hand of a participant. This button was clicked against the steering wheel, and the drivers had the opportunity to try the PDT during a practice drive session. An LED of the PDT device was lit every 3–5 seconds (randomly). It was on for maximally two seconds, or until the driver pushed the PDT response button. The sequence of the blinks was randomised. If a driver reacted to the PDT stimulus within two seconds (maximal time the LED was on), then the reaction was scored as a "hit", and reaction time was measured. If the reaction came after two seconds, then it was scored as a "miss". The data were stored in synchronisation with the vehicle data in order to allow maximal ease of analysis. The PDT was placed so that the reflections of the LEDs were presented at a horizontal and vertical angle which approximates the visual angle that corresponds to a pedestrian or some roadside signs, as recommended by van Winsum et al. (1999).

Figure 4 *PDT response button.*

Other collected data were the results of the phone task (how many correct additions), the results of the SMS and the DVD task, demographic data and data from the questionnaires (described below).

After the drive the participants in the mobile phone conversation experiment answered a demographic questionnaire (age, gender, time driving licence held, car mileage), and another one concerned with the drive (Appendices 0, 0). In short, the questions were:

- Mental effort (scale used: RSME – Rating Scale Mental Effort) for a critical situation and for the whole route. The RSME (Zijlstra and Van Dorn, 1985) subjective workload scale is a simple paper-and-pencil instrument that requires participants to indicate workload on a continuous unidimensional scale (for the RSME paper form see Figure 5 below). The official scale is sized such that 150 equals 150 mm from origin to top.
- Opinion about mobile phone use in cars (separate for handsfree and handheld).
- Own mobile phone use in cars (type and frequency).
- Effort in completing the drive.
- Preference for handsfree or handheld phone.
- Concentration on phone or on driving.
- Influence of mobile phone on speed, lateral position and headway.
- Opinion about driving "quality" with mobile phone.
- Experienced motion sickness.

In the SMS and DVD experiments similar questions were asked when relevant, referring to SMS and DVD instead of to a mobile phone (Appendices 10.2.3, 10.2.4). The questions asked in the dialling study were partly different as shown in Chapter 5.3 Introduction.

The results of the questionnaires are reported separately for each of the four experiments in the appertaining results section.

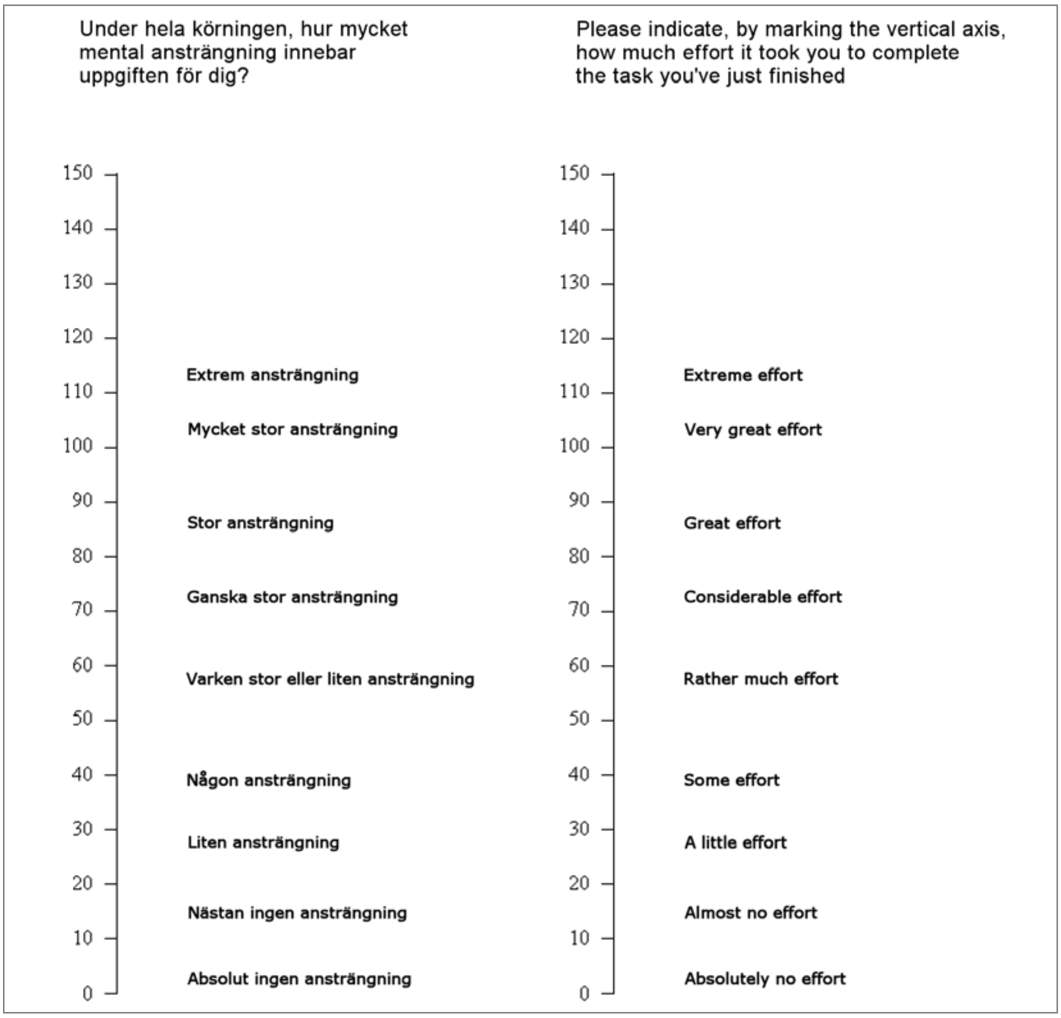


Figure 5 *RSME scale in Swedish and English. The Swedish form was used in the experiments.*

1.4.6 Procedure

The procedure for the mobile phone users was the following: Upon arriving at the driving simulator facility the participant was introduced to the simulator. The participant was presented a written instruction (Appendix 10.1.1 or 10.1.2) explaining the driving and phone tasks. The instruction was to drive as s/he would do in real traffic under the same conditions. The phone task (adding consecutive numbers) was explained by the test leader and practised. The participant then entered the simulator for a practice drive where the phone task was also practised. The test leader summarised the task (to drive as one would do in real driving, and to deal with the phone task as instructed). Then the main test drive (handsfree or handheld) took place. After the test drive the participant left the simulator to fill in a questionnaire (Appendix 10.2.1 or 10.2.2). The test leader then gave instructions for the dialling session (drive as one would do in real driving under the same conditions, dial when instructed to do so). The Dialling session then followed. The test session ended with filling in another questionnaire (Appendix 10.2.5).

The participants in the SMS and DVD experiments followed the same schedule, although somewhat shorter since only one test drive was performed.

The written instructions are shown in Appendices 10.1.3 and 10.1.4, and the questionnaires in Appendices 10.2.3 and 10.2.4.

1.4.7 Statistical analyses

Data were analysed with t-tests, variance analysis or with non-parametric test methods (Wilcoxon Signed Ranks Test for related samples and the Mann-Whitney U test for independent samples). A significance level of .05 was adopted for the significance tests. SPSS 11 was used as statistical package for the analyses.

2 Mobile phone experiment

2.1 Participants

Forty-eight participants took part in the experiment, 24 in the handsfree part and 24 in the handheld part.

In the handsfree part there were 12 males and 12 females. Sixteen participants were between 24 and 34 years of age and the remaining eight were between 42 and 52. The mean age was 35.1±9.4 years. The drivers had held a driving licence for 16.8±9.4 years.

In the handheld part there were 14 males and 10 females. Sixteen participants were between 24 and 35 years of age and the remaining eight were between 36 and 54. The mean age was 33.2±8.7 years. The drivers had held a driving licence for 14.8±8.4 years.

2.2 Design

Each participant received ten phone calls, five on the first round and five on the second. Five of the phone calls came while an event was occurring, and five came during a control situation (no event in a similar environment). Since every event and non-event occurred twice, it was possible to sample data from each both with and without a phone call present.

Each of the phone calls lasted approximately one minute. Since the handsfree mobile phone part had the same settings, it was possible to compare handsfree and handheld mobile phone use.

2.3 Phone task

The following requirements were specified for the choice of mobile phone:

1. No flip cover
2. “one click SMS reading”
3. Large buttons, especially the “OK” and scroll buttons
4. Large screen with good contrast and good font size

After considering a wide range of models, a Nokia 6310 was chosen (see Figure 6). The size of the phone is 129x47x17 mm, the weight 111 gram. The holder for the mobile phone was a *NOKIA HF set CARK 91*.

Figure 6 *Mobile phone used in the experiment.*

In the handsfree part the drivers used a handsfree mobile phone (thus the telephone always remained in the holder and the driver conversed via loud-speakers) while driving in the simulator. Only for accepting and ending the call did the driver have to reach over to touch the corresponding buttons on the telephone. When receiving a phone call during the experiment, the participant had to perform a calculation task.

The experiment in the handheld condition corresponded exactly to the handsfree condition experiment, the only difference being that the telephone had to be taken in the hand for use. This means that while on stand-by, the telephone was placed in a holder installed in the simulator, and when the phone rang the driver had to pick it up and hold it to his or her ear while talking. After finishing the call the telephone was put back into the holder.

The same telephone task was to be performed in both the handheld and the handsfree conditions. During the telephone conversation the participants had to add numbers to each other according to the following rules: The experimenter dictated a one-digit number, which the participant had to remember. Then the experimenter dictated the next one-digit number, which the participant also had to remember. The participant had to respond by giving the sum of the two one-digit numbers. Afterwards the experimenter dictated the next one-digit number. The participant had to respond by giving the sum of the second number of the first addition and the last one-digit number. Then the next one-digit number was dictated. Thus, the participant always had to keep the second number of the last addition in mind and add the newly dictated number to it. In other words, the two one-digit numbers dictated last had to be added after each dictated number. In Table 2 an example is provided. Whenever the participant decided not to be able to perform an addition (either because he or she had forgotten one of the numbers or for any other reason) he or she was asked to say “pass”. Then the next two one-digit numbers were dictated.

The experimenter noted whenever the participant gave a wrong answer or asked to “pass”. This way it was possible to judge the performance of the participant in the telephone task.

Table 2 *An example of the complex telephone task.*

Experimenter reads numbers:		Participant had to answer:
3		
9	→	12
1	→	10
1	→	2
9	→	10
6	→	15

2.4 Results mobile phone experiment – behavioural effects

Note: in some analyses the full sample size (24 participants) is not available because of problems with the data.

2.4.1 Analyses

The following table (Table 3) lists the analyses that were performed in the mobile phone experiment. An **x** in a cell means that the analysis was performed.

Table 3 *Performed analyses for the handsfree or handheld mobile phone conversation experiment. The grey fields demarcate those scenes in which an event occurred.*

	A	B	C	D	E	F	G	H	I	J
	90 km/h no event	**70 km/h rural no event**	**50 km/h comple x bicycle**	**50 km/h medium traffic light**	**50 km/h simple bus**	**50 km/h simple no event**	**50 km/h medium no event**	**50 km/h comple x no event**	**70 km/h m-bike**	**90 km/h car follow**
mean speed (km/h)	X	x				x	x	x		x
speed var. (km/h)	x	x				x	x	x		x
max speed (km/h)	x	x				x	x	x		x
brake reaction time (ms)			x	x	x				x	
lat. pos. variance (cm)	x	x			x	x			x	x
lat. acc. variance (cm/s^2)	x	x			x	x			x	x
max lat. acc. (cm/s^2)	x	x			x	x			x	x
acc. variance (cm/s^2)			x	x	x				x	
min acc. (braking) (cm/s^2)			x	x	x				x	
mean dist headway (m)										x
dist headway variance (m)										x
min dist headway (m)					x					x
min time headway (s)					x					x
min TTC (s)					x					x
ss stopping at event (n)			x	x	x					
PDT reaction time (ms)	x	x	x	x	x	x	x	x	x	x
PDT miss (%)	x	x	x	x	x	x	x	x	x	x

2.4.2 Driving speed

Driving speed data were analysed for six traffic situations, one of the traffic environments with events (car following) and each of the five traffic environments without events (90 km/h rural, 70 km/h rural, 50 km/h urban complex, 50 km/h urban medium, 50 km/h urban simple).

The following comparisons were made for each of the six traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:
  a. difference between phone modes regarding effect of phone call
  b. difference between phone modes when phone was used

The result description, however, starts with an analysis of the combined result for the six traffic situations.

2.4.2.1 Average speed

The average speed at the analysed six situations combined is shown in Figure 7. Average speed was reduced by phone use for handheld mode ($t(20)=6.71$; $p<.001$), but not for handsfree mode ($t(23)=1.81$; $p>.05$). The effect of phone use was greater for handheld than for handsfree mode ($t(43)=2.47$; $p<.05$). The size of the difference was (60.43–57.74) – (60.48–59.50) = 1.7 km/h.

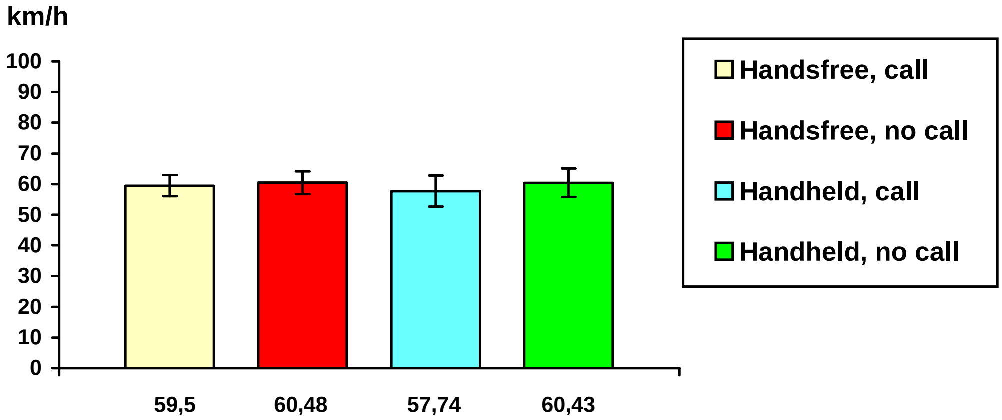


Figure 7 *Average speed at the six situations combined (± SD).*

The result for the six situations analysed separately (see below) can be summarised as follows:

Handsfree phone use caused a reduction of average speed in two situations – car following, and the complex situation without event in the urban environment.

Handheld phone use caused a reduction of average speed in four situations – car following, rural road with speed limit 90 km/h without event, the complex situation in the urban environment without event and, finally, in the urban environment of medium complexity without event.

The effect of phone use differed between phone modes in one situation - rural 70 km/h without event.

2.4.2.1.1 *90 km/h rural: car following*

The average speed at the *90 km/h rural: car following* situation is presented in Figure 8. Speed data in both conditions (with and without phone call) were obtained for all 24 participants using a handsfree phone, and for 21 participants using a handheld phone. According to performed t-tests, the speed was reduced by phone use for both phone modes ($t(23)=3.174$; $p<.05$ for handsfree, and $t(20)=2.106$; $p<.05$ for handheld). The speed differences were 2.4 km/h and 2.5 km/h respectively (Table 8).

When analysing differences between phone modes, one effect emerged. The speed was lower for the handheld phone than for the handsfree phone when using the phone ($t(45)=2.142$; $p<.05$). The difference was 3.3 km/h (Table 9).

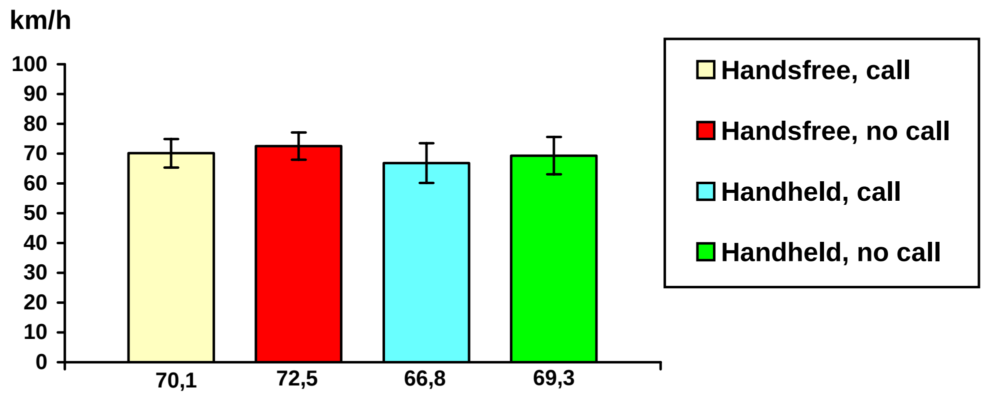


Figure 8 *Average speed at 90 km/h rural: car following (± SD).*

2.4.2.1.2 90 km/h rural: No event

The average speed at the *90 km/h rural: no event* situation is presented in Figure 9. Speed data in both conditions (with and without phone call) were obtained for all 24 participants using a handsfree phone, and for all 24 participants using a handheld phone. According to performed t-tests, the speed was reduced by handheld phone use (t(23)=3.436; p<.01). The speed difference was 5.8 km/h (Table 10).

When analysing differences between phone modes, however, no significant speed differences emerged (Table 11).

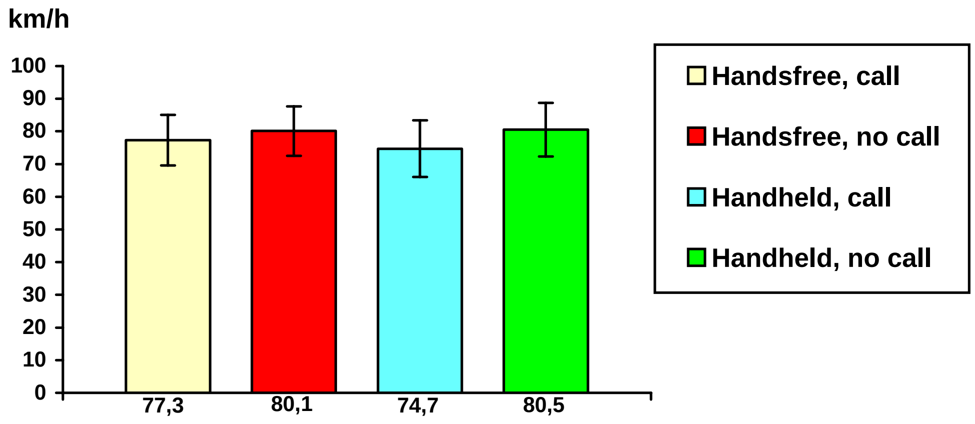


Figure 9 *Average speed at 90 km/h rural: no event (± SD).*

2.4.2.1.3 70 km/h rural: No event

The average speed at the *70 km/h rural: no event* situation is presented in Figure 10. Speed data in both conditions were obtained for all 48 participants. According to performed t-tests, the speed was not affected by phone use (Table 12).

However, a difference between phone modes was found: the effect of phone use differed (t(46)=2.657; p<.05). The difference was (67.3–65.4) – (64.4–66.6) = 4.1 km/h (Table 13).

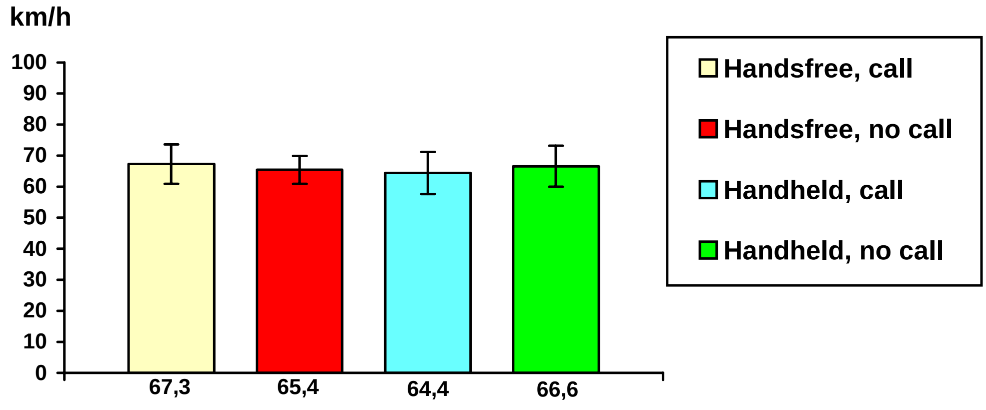


Figure 10 *Average speed at 70 km/h rural: no event (± SD).*

2.4.2.1.4 50 km/h urban complex: no event

The average speed at the *50 km/h urban complex: no event* situation is presented in Figure 11. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, the speed was reduced by phone use for both phone modes ($t(23)=3.146$; $p<.01$ for handsfree, and $t(22)=4.314$; $p<.001$ for handheld). The speed difference was 1.9 km/h for handsfree phone and 2.7 km/h for handheld phone (Table 14).

No speed differences between phone modes were found, however (Table 15).

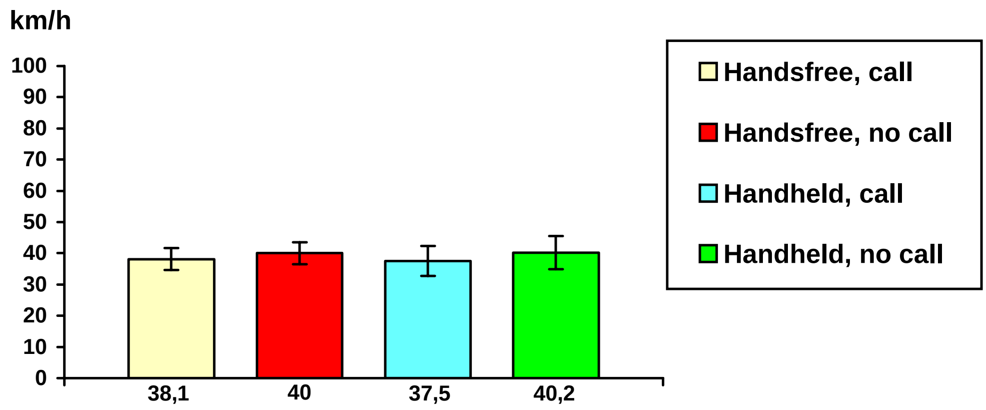


Figure 11 *Average speed at 50 km/h urban complex: no event (± SD).*

2.4.2.1.5 50 km/h urban medium: No event

The average speed at the *50 km/h urban medium: no event* situation is presented in Figure 12. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, the speed was reduced by phone use, but only for handheld phone ($t(22)=2.527$; $p<.05$). The speed reduction was 2.4 km/h (Table 16).

No difference between phone modes emerged, however (Table 17).

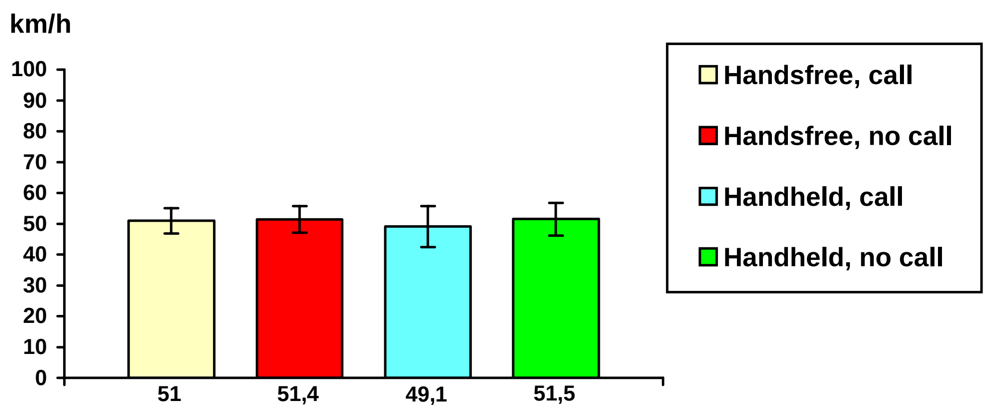


Figure 12 *Average speed at 50 km/h urban medium: no event(± SD).*

2.4.2.1.6 *50 km/h urban simple: No event*

The average speed at the *50 km/h urban simple: no event* situation is presented in Figure 13. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, the speed was not affected by phone use (Table 18).

No differences between phone modes emerged either (Table 19).

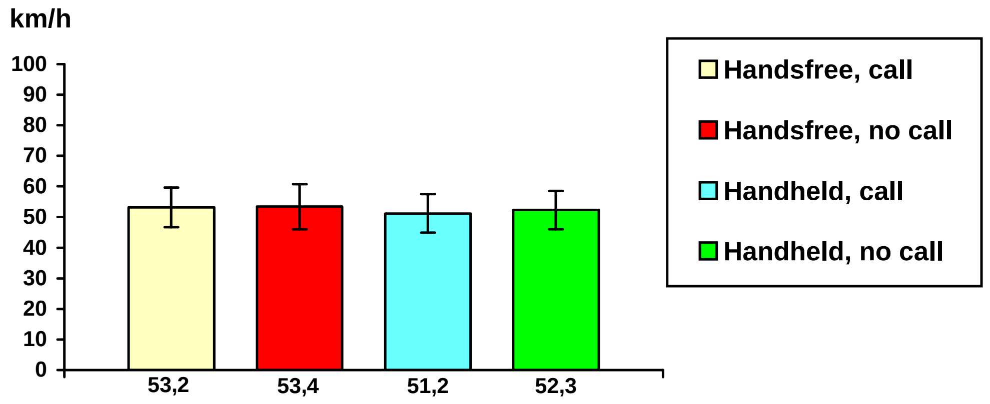


Figure 13 *Average speed at 50 km/h urban simple: no event (± SD).*

2.4.2.2 Speed variance

The average speed variance at the analysed six situations combined is shown in Figure 14. Speed variance was reduced by phone use for handsfree mode ($t(23)=2.44$; $p<.05$), but not for handheld mode ($t(20)=.87$; $p>.05$). The effect of phone use was not, however, different for the two phone modes ($t(43)=1.12$; $p>.05$).

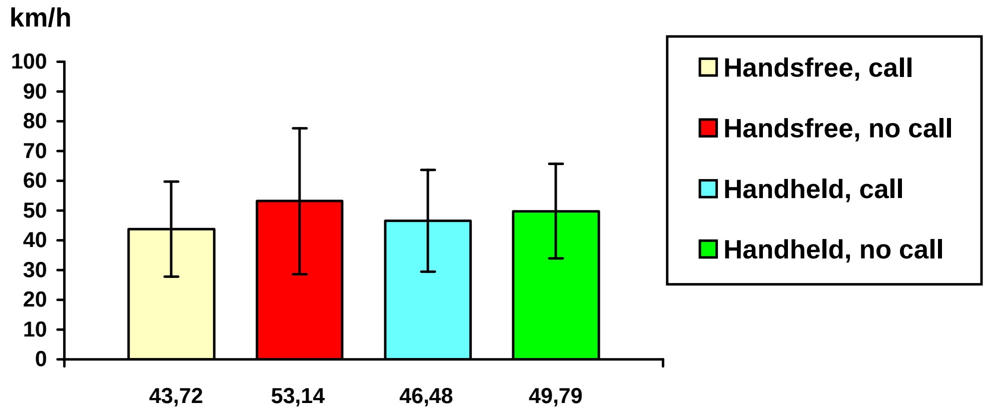


Figure 14 *Speed variance at the six situations combined (± SD).*

The result for the six situations analysed separately (see below) can be summarised as follows:

Handsfree phone use caused a reduction of speed variance in one situation – the complex situation in the urban environment without event. Handheld phone use also caused a reduction of speed variance in one situation – the car following situation in the rural environment – but caused increased speed variance in one situation - the urban environment of medium complexity without event.

2.4.2.2.1 90 km/h rural: Car following

The average intra-individual speed variance at the *90 km/h rural: car following* situation is presented in Figure 15. Speed data in both conditions were obtained for all 24 participants for handsfree phone, but limited to 21 for handheld phone. According to performed t-tests, the speed variance was reduced by handheld phone use ($t(20)=2.123$; $p<.05$) (Table 20).

No differences between phone modes emerged (Table 21).

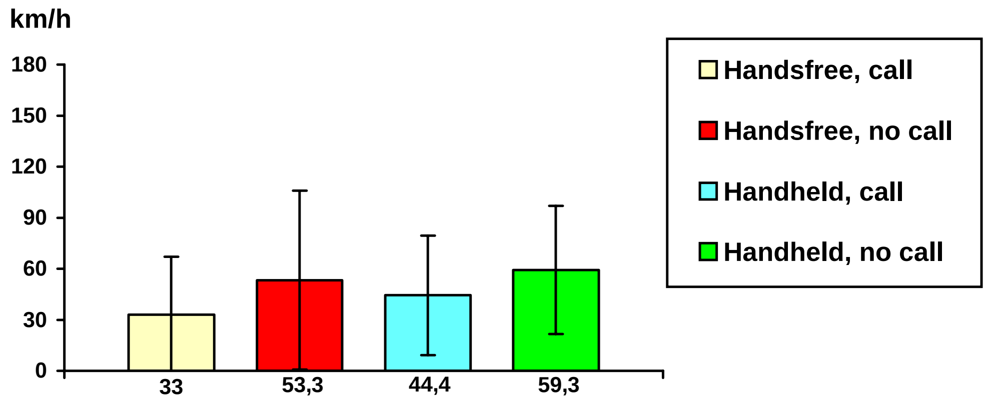


Figure 15 *Speed variance at 90 km/h rural: car following (± SD).*

2.4.2.2.2 *90 km/h rural: No event*

The average intra-individual speed variance at the *90 km/h rural: no event* situation is presented in Figure 16. Speed data in both conditions were obtained for all 48 participants. According to performed t-tests, the speed variance was not influenced by phone use (Table 22).

No differences between phone modes emerged (Table 23).

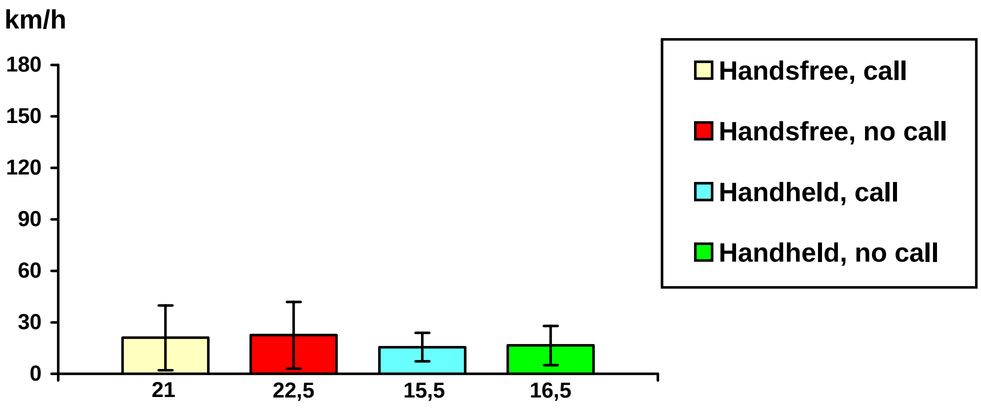


Figure 16 *Speed variance at 90 km/h rural: no event (± SD).*

2.4.2.2.3 *70 km/h rural: No event*

The average intra-individual speed variance at the *70 km/h rural: no event* situation is presented in Figure 17. Speed data in both conditions were obtained for all 48 participants. According to performed t-tests, the speed variance was not affected by phone use (Table 24).

No differences between phone modes emerged (Table 25).

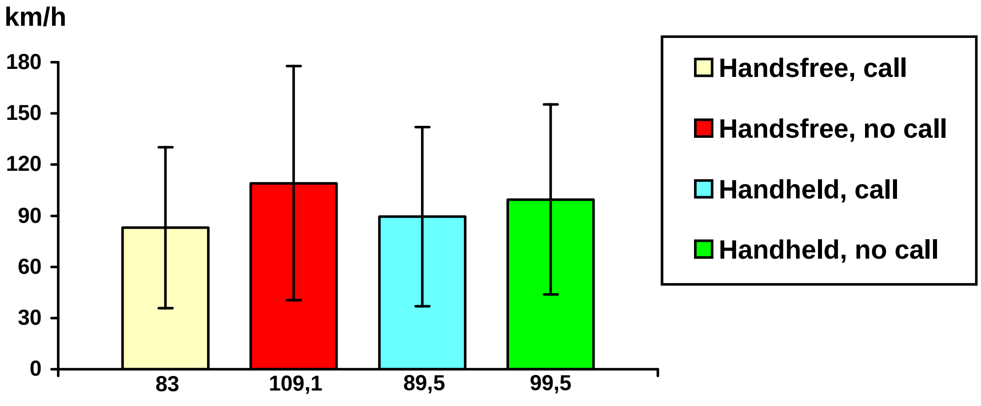


Figure 17 *Speed variance at 70 km/h rural: no event (± SD).*

2.4.2.2.4 50 km/h urban complex: no event

The average intra-individual speed variance at the *50 km/h urban complex: no event* situation is presented in Figure 18. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, speed variance was reduced by phone use, but only for handsfree phone ($t(23)=2.410$; $p<.05$) (Table 26).

No differences between phone modes emerged (Table 27).

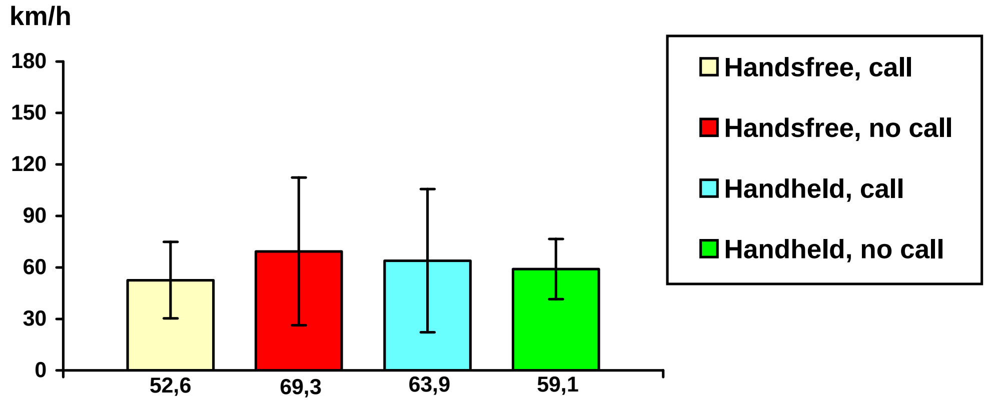


Figure 18 *Speed variance at 50 km/h urban complex: no event (± SD).*

2.4.2.2.5 50 km/h urban medium: No event

The average intra-individual speed variance at the *50 km/h urban medium: no event* situation is presented in Figure 19. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, speed variance was increased by phone use, but only for handheld phone ($t(22)=2.079$; $p<.05$) (Table 28).

However, no differences between phone modes emerged (Table 29).

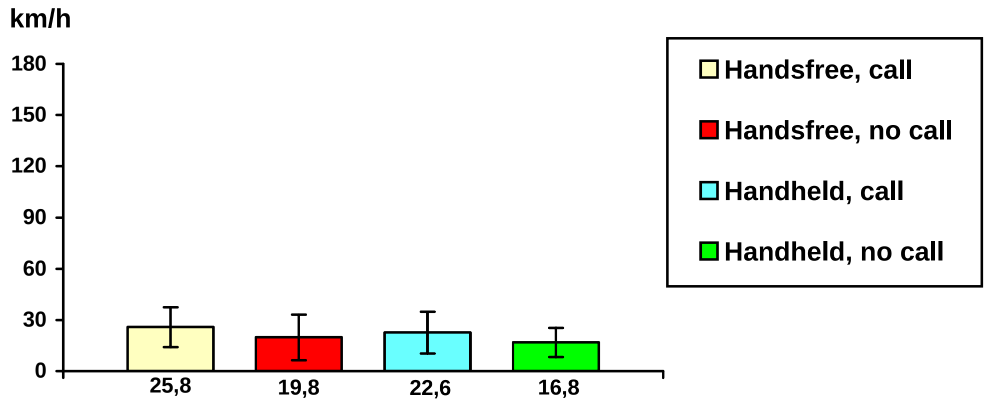


Figure 19 *Speed variance at 50 km/h urban medium: no event (± SD).*

2.4.2.2.6 50 km/h urban simple: No event

The average intra-individual speed variance at the *50 km/h urban simple: no event* situation is presented in Figure 20. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, speed variance was not affected by phone use (Table 30).

No differences between phone modes emerged (Table 31).

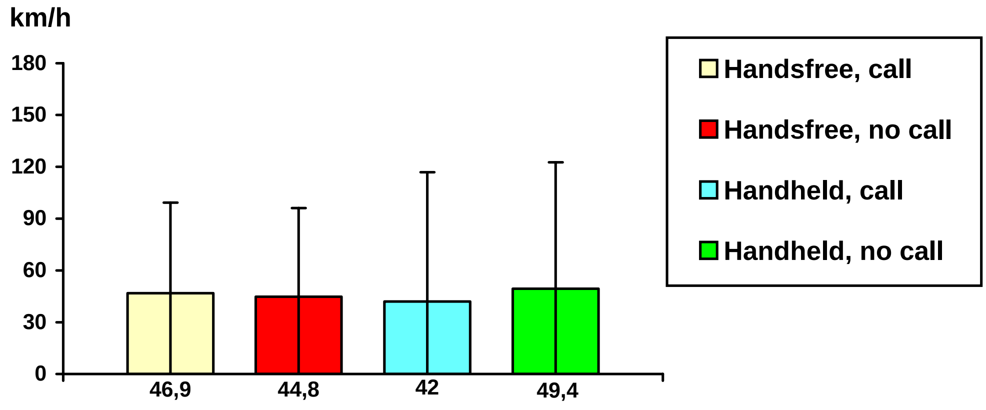


Figure 20 *Speed variance at 50 km/h urban simple: no event (± SD).*

2.4.2.3 Maximum speed

The average maximum speed at the analysed six situations combined is shown in Figure 21. Maximum speed was reduced by phone use for handheld mode ($t(20)=4.29$; $p<.001$), but not for handsfree mode ($t(23)=.93$; $p>.05$). The effect of phone use was greater for handheld than for handsfree mode ($t(43)=2.11$; $p<.05$). The size of the difference was (71.29–69.20) – (70.87–70.35) = 1.57 km/h.

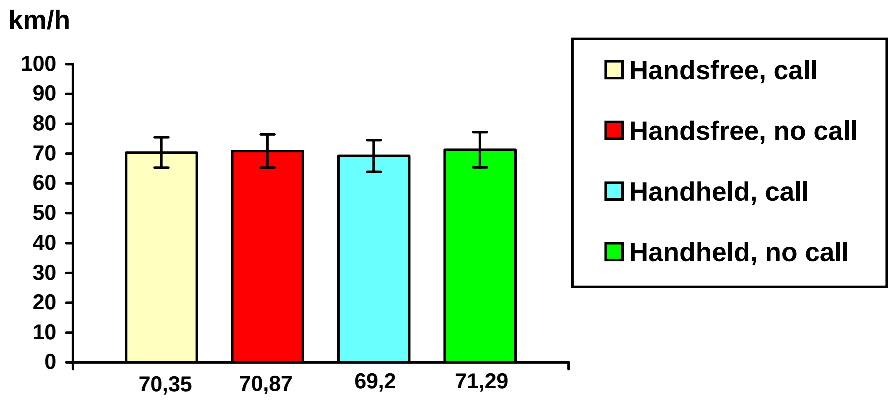


Figure 21 *Maximum speed at the six situations combined (± SD).*

The result for the six situations analysed separately (see below) can be summarised as follows:

Maximum speed was not affected by handsfree phone use. It was reduced, however, by handheld phone use in two situations – rural environment with speed limit 90 km/h without event and complex urban environment without event.

2.4.2.3.1 90 km/h rural: car following

The average maximum speed at the *90 km/h rural: car following* situation is presented in Figure 22. Speed data in both conditions were obtained for all 24 participants for handsfree, but limited to 21 participants for handheld phone. According to performed t-tests, maximum speed was not affected by phone use (Table 32).

No differences between the two phone modes emerged (Table 33).

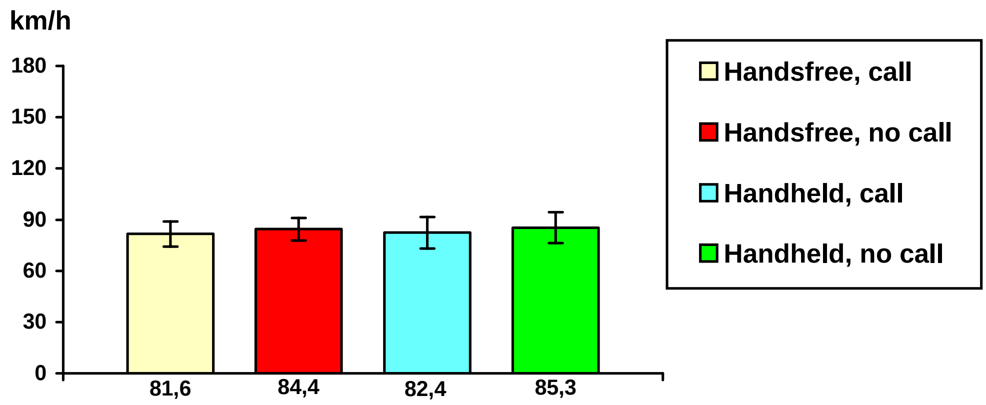


Figure 22 *Maximum speed at 90 km/h rural: car following (± SD).*

2.4.2.3.2 *90 km/h rural: No event*

The average maximum speed at the *90 km/h rural: no event* situation is presented in Figure 23. Speed data in both conditions were obtained for all 48 participants. According to performed t-tests, maximum speed was reduced by phone use, but only for handheld phone ($t(23)=2.558$; $p<.05$). The speed reduction was 4.8 km/h (Table 34).

No differences between the two phone modes emerged, however (Table 35).

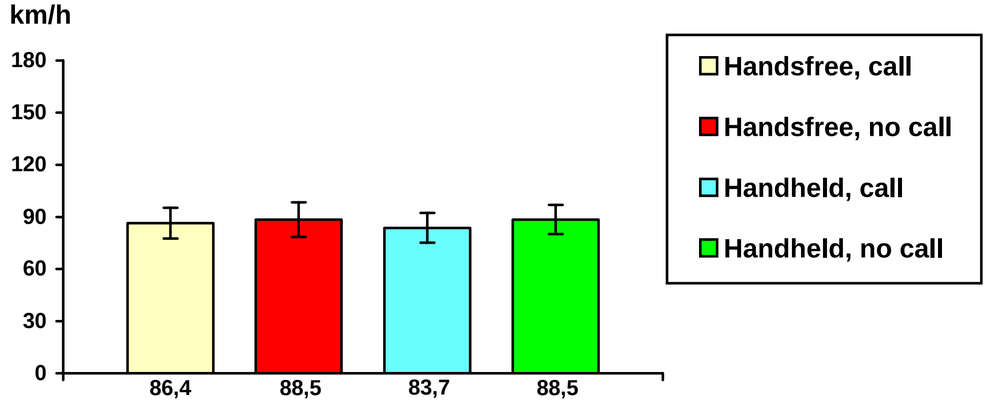


Figure 23 *Maximum speed at 90 km/h rural: no event (± SD).*

2.4.2.3.3 *70 km/h rural: No event*

The average maximum speed at the *70 km/h rural: no event* situation is presented in Figure 24. Speed data in both conditions were obtained for all 48 participants. According to performed t-tests, maximum speed was not affected by phone use (Table 36).

No differences between phone modes emerged (Table 37).

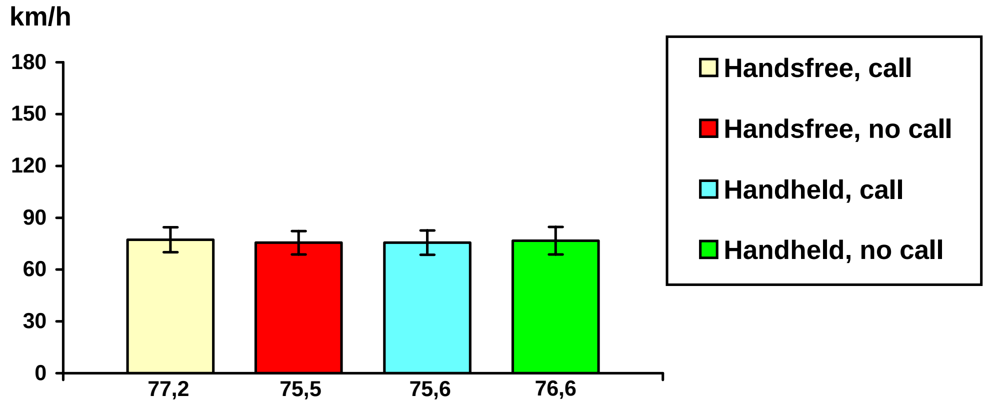


Figure 24 *Maximum speed at 70 km/h rural: no event (± SD).*

2.4.2.3.4 50 km/h urban complex: no event

The average maximum speed at the *50 km/h urban complex: no event* situation is presented in Figure 25. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, maximum speed was reduced by phone use, but only for handheld phone (t(22)=2.520; p<.05). The speed reduction was 2.8 km/h (Table 38).

There also appeared a difference between phone modes – the speed was lower for handheld phone than for handsfree phone when the phone was used (t(46)=2.094; p<.05). The difference was 3 km/h (Table 39).

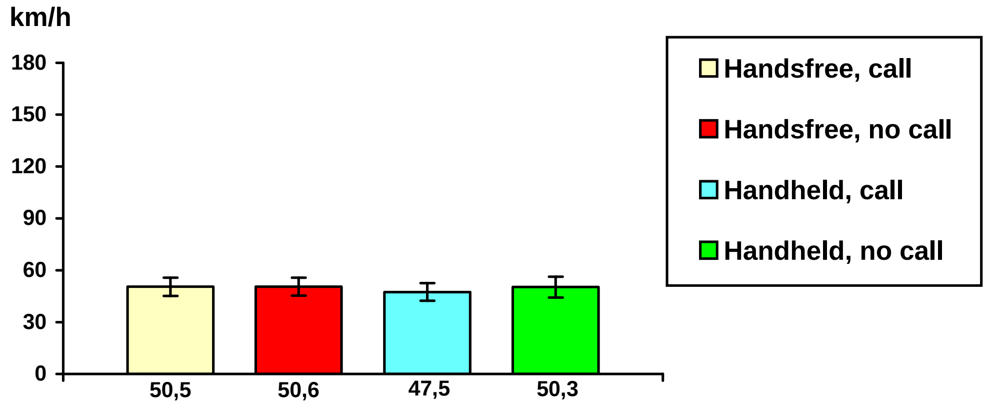


Figure 25 *Maximum speed at 50 km/h urban complex: no event (± SD).*

2.4.2.3.5 50 km/h urban medium: No event

The average maximum speed at the *50 km/h urban medium: no event* situation is presented in Figure 26. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, maximum speed was not influenced by phone use (Table 40).

No differences between phone modes emerged (Table 41).

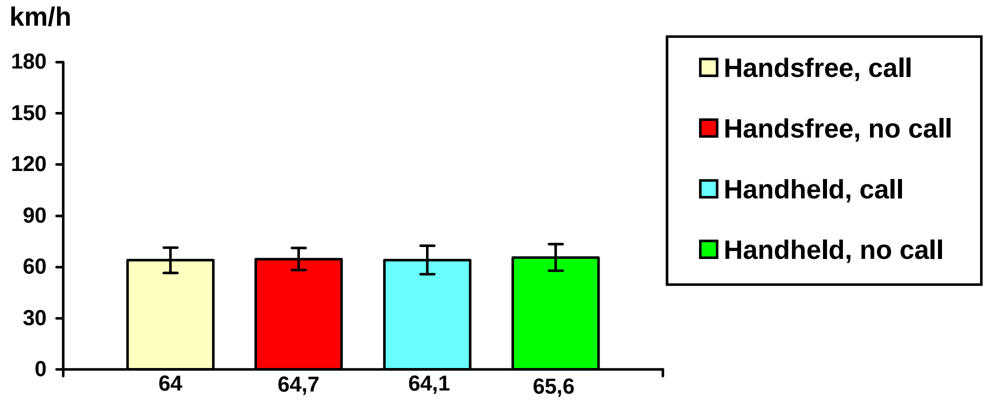


Figure 26 *Maximum speed at 50 km/h urban medium: no event(± SD).*

2.4.2.3.6 50 km/h urban simple: No event

The average maximum speed at the *50 km/h urban simple: no event* situation is presented in Figure 27. Speed data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 of those who used a handheld phone. According to performed t-tests, maximum speed was not affected by phone use (Table 42).

No differences between phone modes emerged (Table 43).

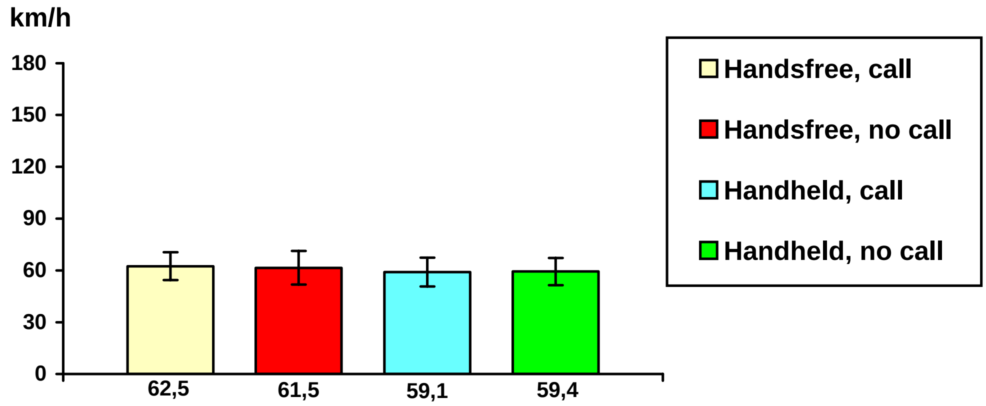


Figure 27 *Maximum speed at 50 km/h urban simple: no event (± SD).*

2.4.3 Brake reaction time performance at events

Brake reaction time performance was studied at four traffic environments with events (motorbike, bicycle, traffic light, bus).

Regarding brake reaction time, the following comparisons were made for each of four traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:
   a. difference between phone modes regarding effect of phone call
   b. difference between phone modes when phone was used

The average brake reaction time at the analysed four situations combined is shown in Figure 28. Reaction time was not markedly affected by phone use for handsfree mode (t(9)=1.19; p>.05), nor for handheld mode (t(10)=.20; p>.05). The effect of phone use was not different for the two phone modes (t(19)=.84; p>.05).

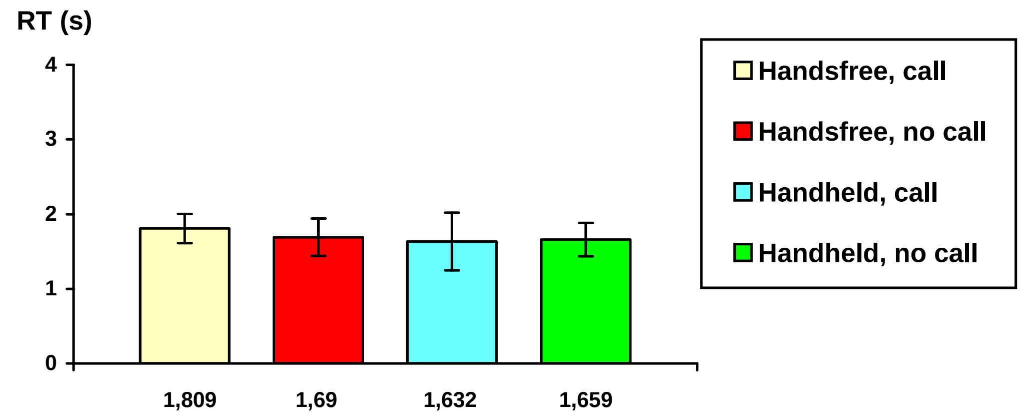


Figure 28 *Brake reaction time at the four situations combined (± SD).*

The result for the four situations analysed separately (see below) can be summarised as follows:

Brake reaction time performance was impaired by handheld phone use in one situation – urban 50 km/h simple with event (bus).

2.4.3.1 70 km/h rural: motorbike

The average reaction times at the *motorbike* situation are presented in Figure 29. Reaction time data in both conditions (phone call – no phone call) were obtained for 23 participants using a handsfree phone, and for the same number of participants who used a handheld phone. No effects of phone use were demonstrated, and no differences between phone modes emerged (Table 44, Table 45).

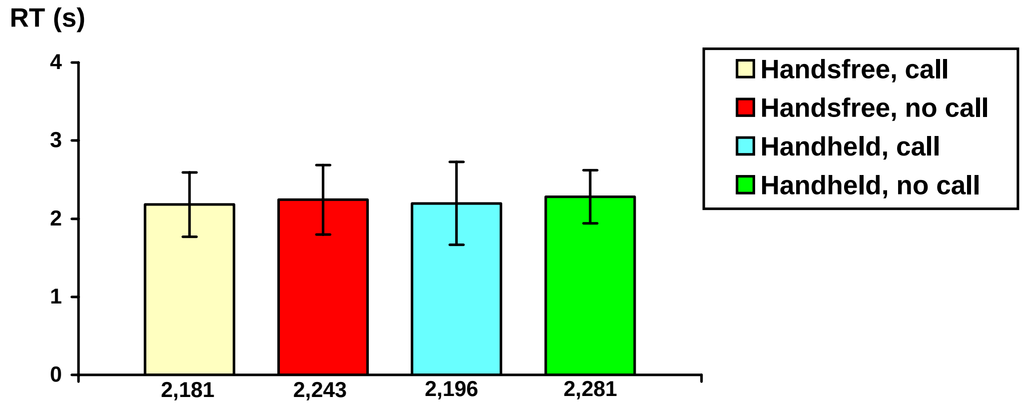


Figure 29 *Brake reaction time at motorbike situation (± SD).*

2.4.3.2 50 km/h urban complex: bicycle

The average reaction times at the *bicycle* situation are presented in Figure 30. Reaction time data in both conditions (phone call – no phone call) were obtained for 19 participants using a handsfree phone, whereas the number of participants giving complete reaction time data was 21 for those who used a handheld phone. No effects of phone use were demonstrated, and no differences between phone modes emerged (Table 46, Table 47).

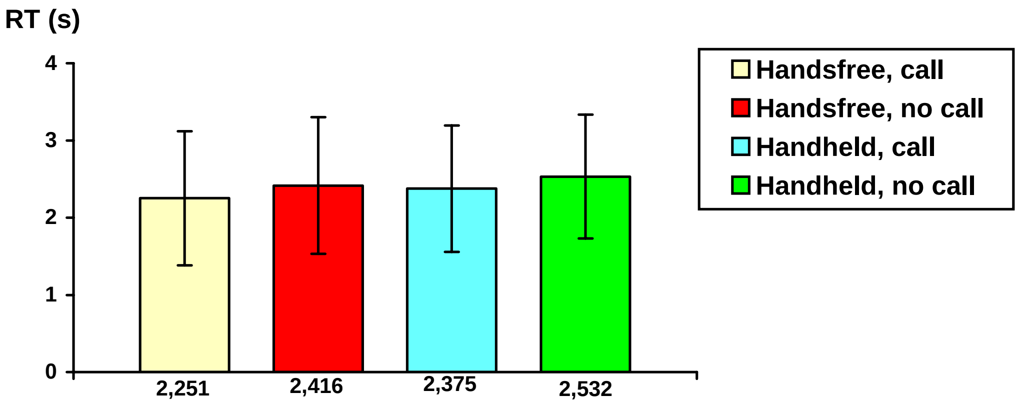


Figure 30 *Brake reaction time at bicycle situation (± SD).*

2.4.3.3 50 km/h urban medium: traffic light

The average reaction times at the *traffic light* situation are presented in Figure 31. Reaction time data in both conditions (phone call – no phone call) were obtained for 18 participants using a handsfree phone, and for the same number of participants who used a handheld phone. No effects of phone use were demonstrated for handsfree nor for handheld phone (Table 48).

No differences between phone modes emerged (Table 49).

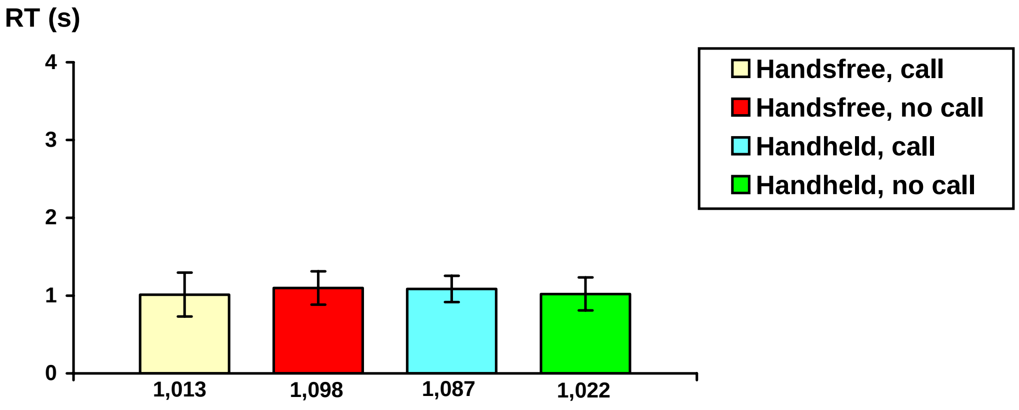


Figure 31 *Brake reaction time at traffic light situation (± SD).*

2.4.3.4 50 km/h urban simple: bus

The average reaction times at the *bus* situation are presented in Figure 32. Reaction time data in both conditions (phone call – no phone call) were obtained for all 16 participants using a handsfree phone, whereas the number of participants giving complete reaction time data was limited to 13 for those who used a handheld phone. The reaction time was prolonged by phone use, but only for handheld phone ($t(12)=2.617$; $p<.05$) (Table 50). The time difference was 320 ms.

No differences between phone modes emerged (Table 51).

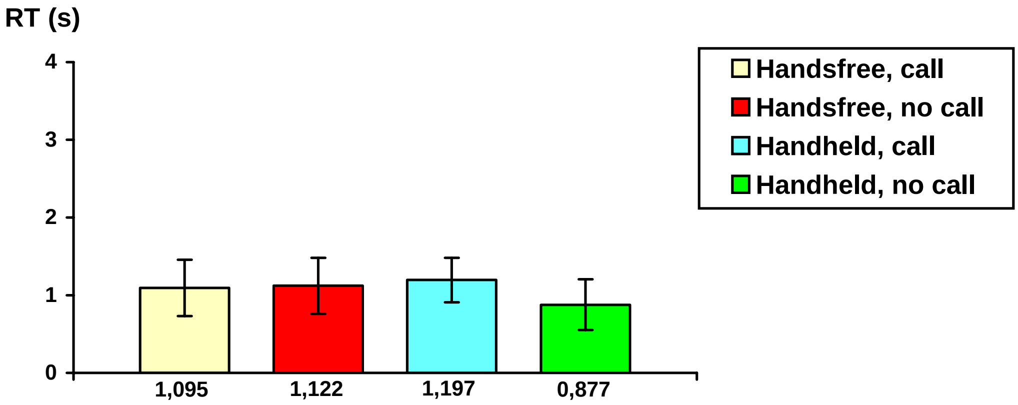


Figure 32 *Brake reaction time at bus situation (± SD).*

2.4.4 Lateral position variance

As to lateral position variance, comparisons were made for each of three traffic environments with events (car following, motorbike, bus) and the corresponding three traffic environments without events.

The following comparisons were made for each of six traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:

   a. difference between phone modes regarding effect of phone call

   b. difference between phone modes when phone was used

An analysis was, however, also performed for the combined result for the six traffic situations. The average lateral position variance at the analysed situations combined is shown in Figure 33. The lateral position variance was reduced by phone use for handsfree mode ($t(23)=2.10$; $p<.05$), but not for handheld mode ($t(20)=1.38$; $p>.05$). The effect of phone use was not different for the two phone modes ($t(43)=.58$; $p>.05$).

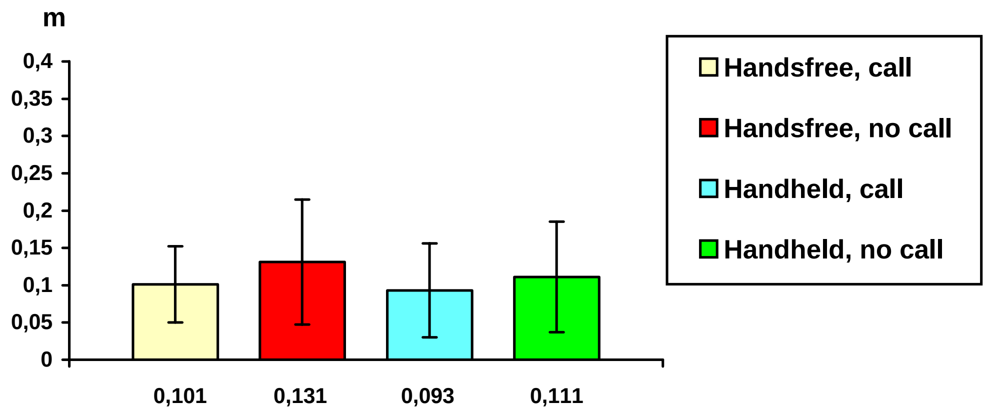


Figure 33 *Lateral position variance at the six situations combined (± SD).*

The result for the six situations analysed separately (see below) can be summarised as follows:

Lateral position variance decreased as an effect of phone use at the no event situation at the rural environment with speed limit 90 km/h – the result applies to both phone modes.

2.4.4.1 90 km/h rural: car following and no event

The average lateral position variance at the *90 km/h rural: car following* and *no event* situations is presented in Figure 34 and Figure 35. For the *car following* situation, lateral position data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 21 of those who used a handheld phone. For the other situation, lateral position data in both conditions were obtained for all 48 participants. According to performed t-tests, lateral position variance decreased for both phone modes at the *no event* situation. The results of t-tests were: $t(23)=2.082$; $p<.05$ for handsfree and $t(23)=2.112$; $p<.05$ for handheld (Table 52).

No differences between the two phone modes emerged, however (Table 53).

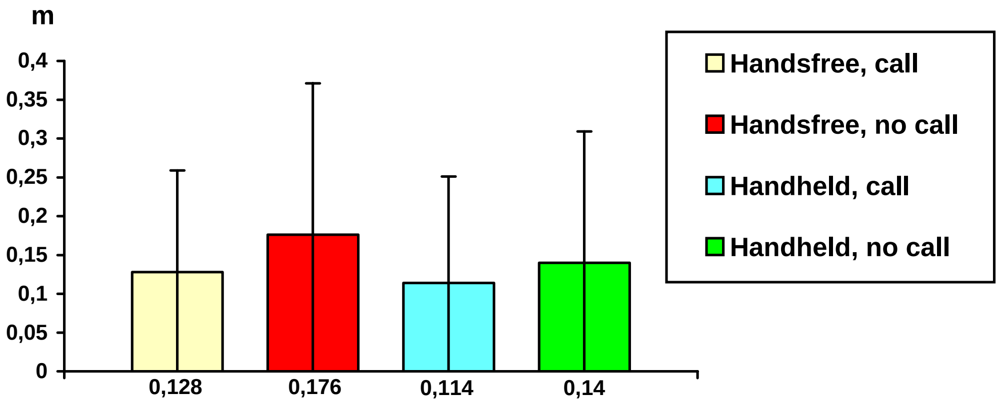


Figure 34 *Lateral position variance at 90 km/h rural: car following (± SD).*

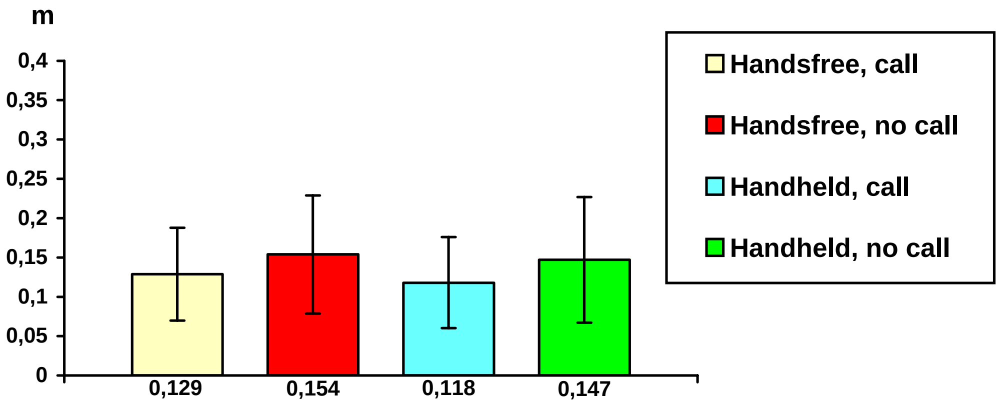


Figure 35 *Lateral position variance at 90 km/h rural: no event (± SD).*

2.4.4.2 70 km/h rural: motorbike and no event

The average lateral position variance at the *70 km/h rural: motorbike* and *no event* situations is presented in Figure 36 and Figure 37. For the *motorbike* situation, lateral position data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a handheld phone. For the other situation, lateral position data in both conditions were obtained for all 48 participants. According to performed t-tests, no effects were found (Table 54, Table 55).

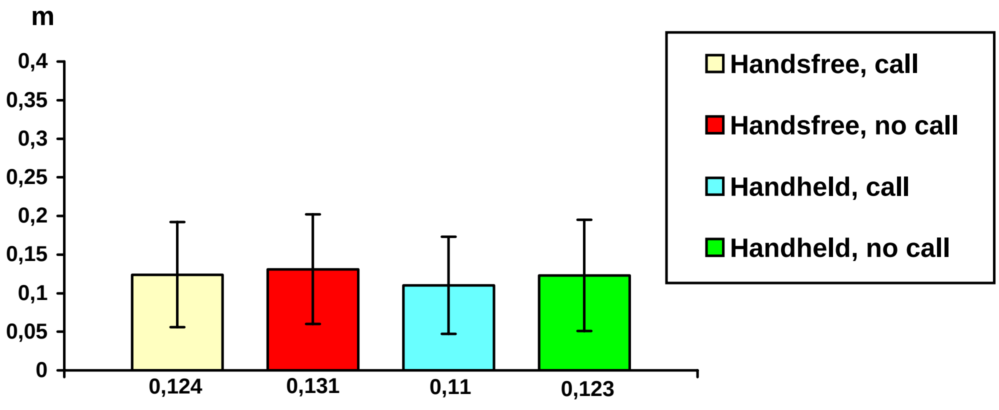


Figure 36 *Lateral position variance at 70 km/h rural: motorbike (± SD).*

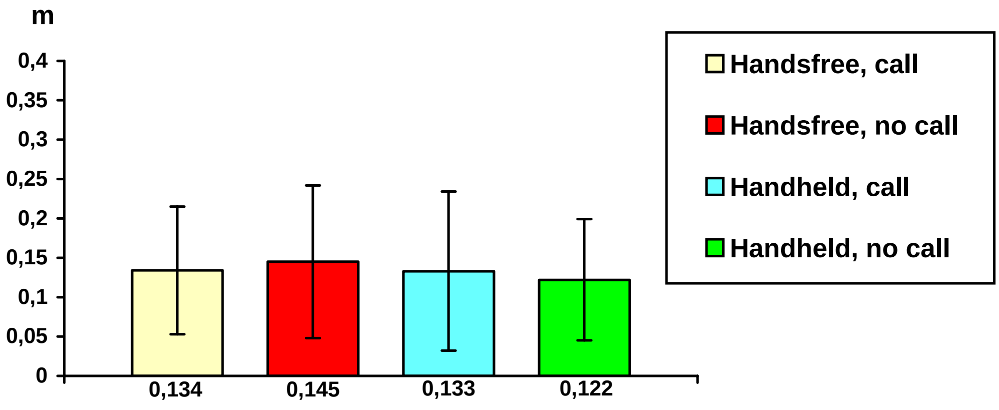


Figure 37 *Lateral position variance at 70 km/h rural: no event (± SD).*

2.4.4.3 50 km/h urban simple: bus and no event

The average lateral position variance at the *50 km/h urban simple: bus* and *no event* situations is presented in Figure 38 and Figure 39. For the *bus* situation, lateral position data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 for those who used a handheld phone. The same number of participants provided useful lateral position data in the other situation. According to performed t-tests, no effects were found (Table 56, Table 57).

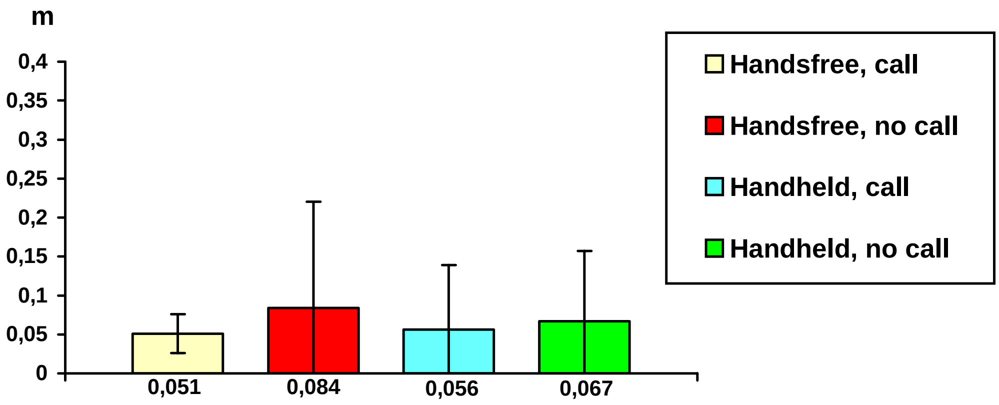


Figure 38 *Lateral position variance at 50 km/h urban simple: bus (± SD).*

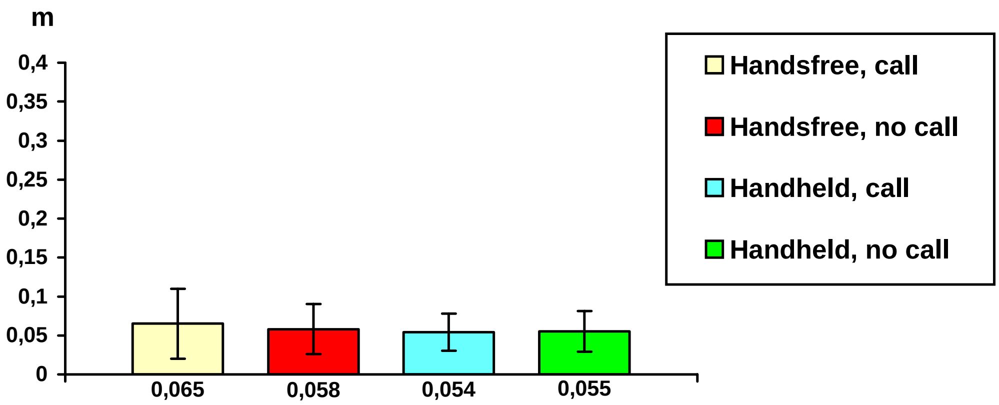


Figure 39 *Lateral position variance at 50 km/h urban simple: no event (± SD).*

2.4.5 Lateral acceleration

As to lateral acceleration, comparisons were made for each of three traffic environments with events (car following, motorbike, bus) and the corresponding three traffic environments without events.

The following comparisons were made for each of six traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:

  a. difference between phone modes regarding effect of phone call

  b. difference between phone modes when phone was used

The result description, however, starts with an analysis of the combined result for the six traffic situations.

2.4.5.1 Lateral acceleration variance

The average lateral acceleration variance at the analysed six situations combined is shown in Figure 40. Lateral acceleration variance was reduced by phone use for handheld mode ($t(20)=4.38$; $p<.001$), but not for handsfree mode ($t(23)=1.76$; $p>.05$). The effect of phone use was not, however, different for the two phone modes ($t(43)=1.53$; $p>.05$).

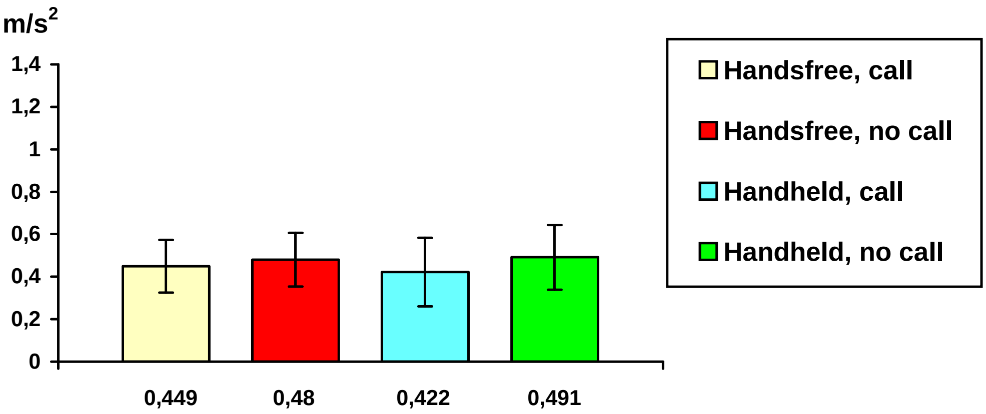


Figure 40 *Lateral acceleration variance at the six situations combined (± SD).*

The result for the six situations analysed separately (see below) can be summarised as follows:

Lateral acceleration variance was reduced by handsfree phone use in three situations – rural 90 km/h with event (car following), rural 70 km/h with event (motorbike), and rural 70 km/h without event. Lateral acceleration variance was reduced by handheld phone use in two situations – rural 90 km/h without event, and rural 70 km/h with event (motor-bike). The effect of phone use differed between phone modes in one situation – rural 70 km/h without event.

2.4.5.2 90 km/h rural: car following and no event

The average lateral acceleration variance at the *90 km/h rural: car following* and *no event* situations is presented in Figure 41 and Figure 42. For the *car following* situation, lateral acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 21 of those who used a hand-held phone. For the other situation, lateral acceleration data in both conditions were obtained for all 48 participants. According to performed t-tests, lateral acceleration variance decreased by phone use at the *car following* situation, but only for handsfree phone (t(23)=2.984; p<.01). The difference was .078 m/s^2. It also decreased by .167 m/s^2 at the *no event* situation, but only for handheld phone (t(23)=2.865 p<.01) (Table 58).

No differences between the two phone modes emerged (Table 59).

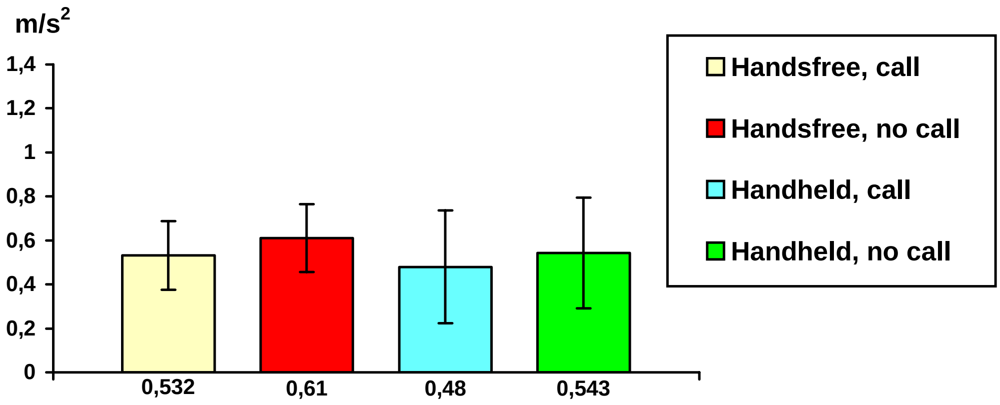


Figure 41 *Lateral acceleration variance at 90 km/h rural: car following (± SD).*

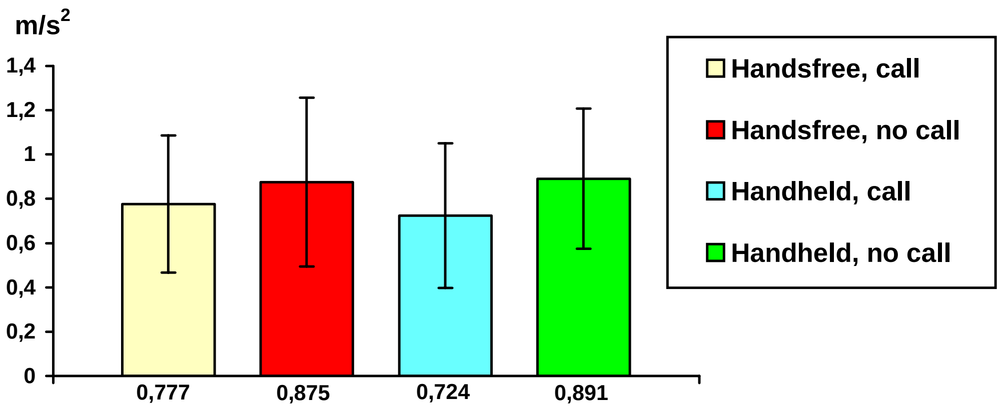


Figure 42 *Lateral acceleration variance at 90 km/h rural: no event (± SD).*

2.4.5.3 70 km/h rural: motorbike and no event

The average lateral acceleration variance at the *70 km/h rural: motorbike* and *no event* situations is presented in Figure 43 and Figure 44. For the *motorbike* situation, lateral acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a hand-held phone. For the other situation, lateral acceleration data in both conditions were obtained for all 48 participants. According to performed t-tests, lateral acceleration variance decreased during phone use at the motorbike situation for both phone modes. The difference was .139 m/s^2 for handsfree phone ($t(23)=3.383$; $p<.01$) and .147 m/s^2 for handheld phone ($t(22)=3.736$; $p<.001$). The lateral acceleration variance decreased for handsfree phone use at the *no event* situation as well ($t(23)=2.121$; $p<.05$). The difference was .122 m/s^2 (Table 60).

The effect of phone use at the *no event* situation was different for the two phone modes ($t(46)=2.448$; $p<.05$). The difference was (.846–.724) – (.735–.800) = .187 m/s^2 (Table 61).

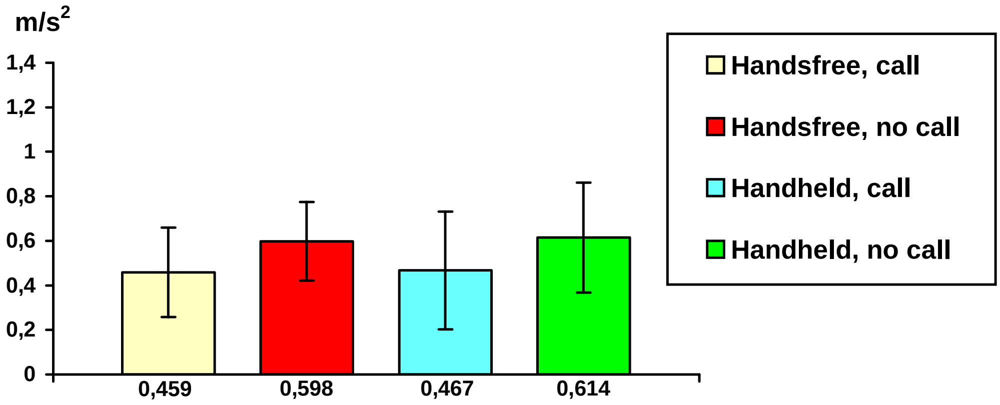


Figure 43 *Lateral acceleration variance at 70 km/h rural: motorbike (± SD).*

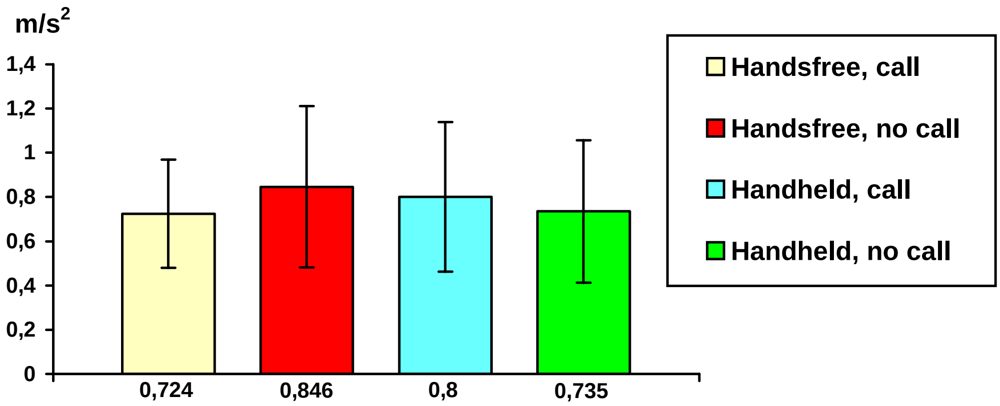


Figure 44 *Lateral acceleration variance at 70 km/h rural: no event (± SD).*

2.4.5.4 50 km/h urban simple: bus and no event

The average lateral acceleration variance at the *50 km/h urban simple: bus* and *no event* situations is presented in Figure 45 and Figure 46. For the *bus* situation, lateral acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a handheld phone. Also for the other situation, lateral acceleration data in both conditions were obtained for 24 participants with handsfree phone and 23 participants with handheld phone. According to performed t-tests, no effects emerged (Table 62, Table 63).

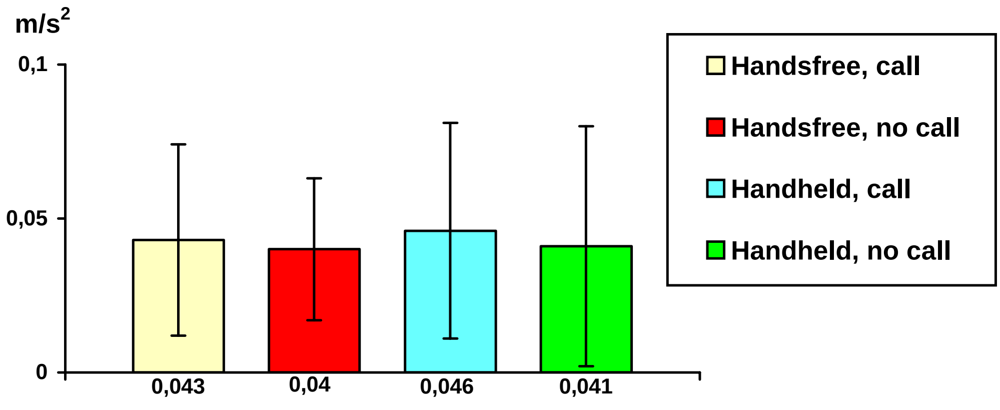


Figure 45 *Lateral acceleration variance at 50 km/h urban simple: bus (± SD).*

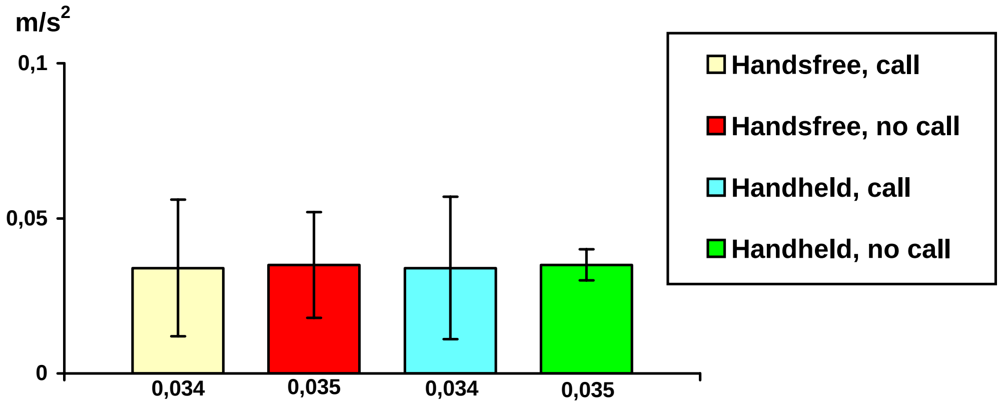


Figure 46 *Lateral acceleration variance at 50 km/h urban simple: no event (± SD).*

2.4.5.5 Maximum lateral acceleration

The maximum lateral acceleration at the analysed six situations combined is shown in Figure 47. Reaction time was not affected by phone use for handsfree mode (t(23)=1.80; p>.05), nor for handheld mode (t(20)=.97; p>.05). The effect of phone use was not different for the two phone modes (t(43)=.30; p>.05).

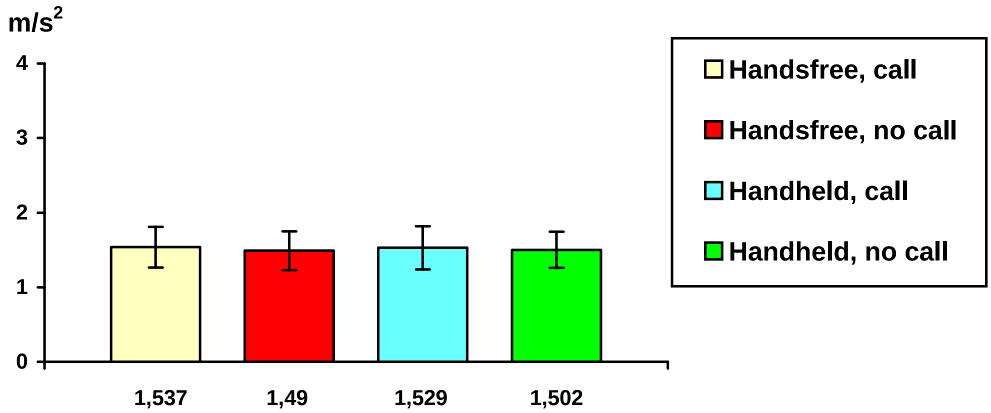


Figure 47 *Lateral acceleration variance at the six situations combined (± SD).*

The result for the six situations analysed separately (see below) can be summarised as follows:

Maximum lateral acceleration was reduced by handsfree phone use in two situations – car following, and motorbike. It, however, was increased by handheld phone use in one situation – urban 50 km/h simple with event (bus).

2.4.5.4.1 90 km/h rural: car following and no event

The average maximum lateral acceleration at the *90 km/h rural: car following* and *no event* situations is presented in Figure 48 and Figure 49. For the *car following* situation, lateral acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 21 of those who used a handheld phone. For the other situation, lateral acceleration data in both conditions were obtained for all 48 participants. According to performed t-tests, maximum lateral acceleration decreased by phone use at the *car following* situation, but only for handsfree phone ($t(23)=2.536$; $p<.05$). The difference was .148 m/s^2. No other effects emerged (Table 64, Table 65).

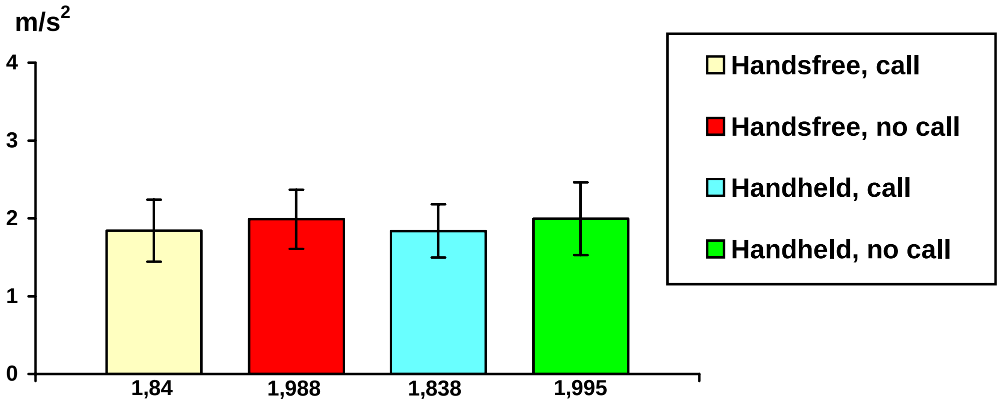


Figure 48 *Maximum lateral acceleration at 90 km/h rural: car following (± SD).*

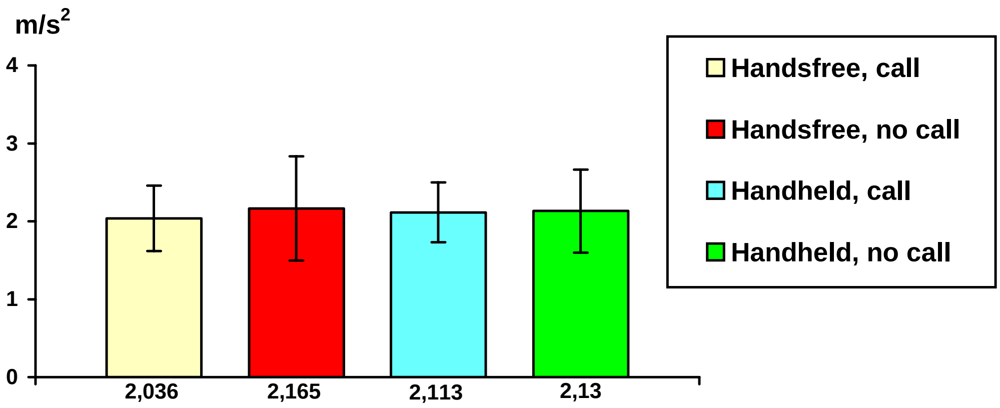


Figure 49 *Maximum lateral acceleration at 90 km/h rural: no event (± SD).*

2.4.5.4.2 70 km/h rural: motorbike and no event

The average maximum lateral acceleration at the *70 km/h rural: motorbike* and *no event* situations is presented in Figure 50 and Figure 51. For the *motorbike* situation, lateral acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a hand-held phone. For the other situation, lateral acceleration data in both conditions were obtained for all 48 participants. According to performed t-tests, maximum lateral acceleration decreased during phone use at the *motorbike* situation, but only for handsfree phone ($t(23)=2.841$, $p<.01$). The difference was .212 m/s^2 (Table 66).

No other effects were found (Table 67).

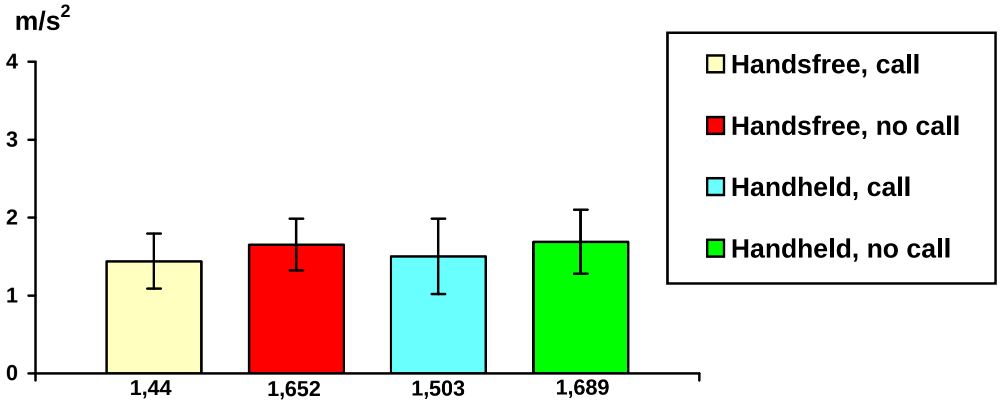


Figure 50 *Maximum lateral acceleration at 70 km/h rural: motorbike (± SD).*

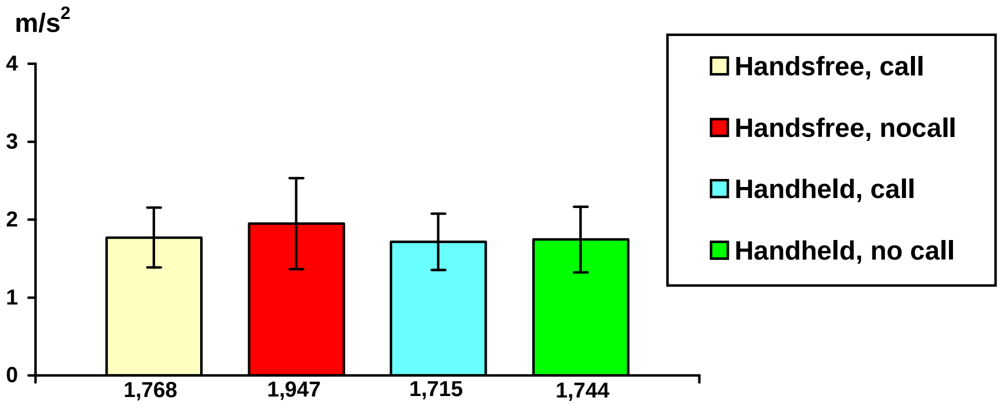


Figure 51 *Maximum lateral acceleration at 70 km/h rural: no event (± SD).*

2.4.5.4.3 50 km/h urban simple: bus and no event

The average maximum lateral acceleration at the *50 km/h urban simple: bus* and *no event* situations is presented in Figure 52 and Figure 53. For the *bus* situation, lateral acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a handheld phone. Also for the *no event* situation, lateral acceleration data in both conditions were obtained for 24 participants with handsfree phone and 23 participants with handheld phone. According to performed t-tests, maximum lateral acceleration increased as an effect of phone use at the *bus* situation for handheld phone ($t(22)=2.449$; $p<.05$). The difference was .101 m/s^2. No other effects emerged (Table 68, Table 69).

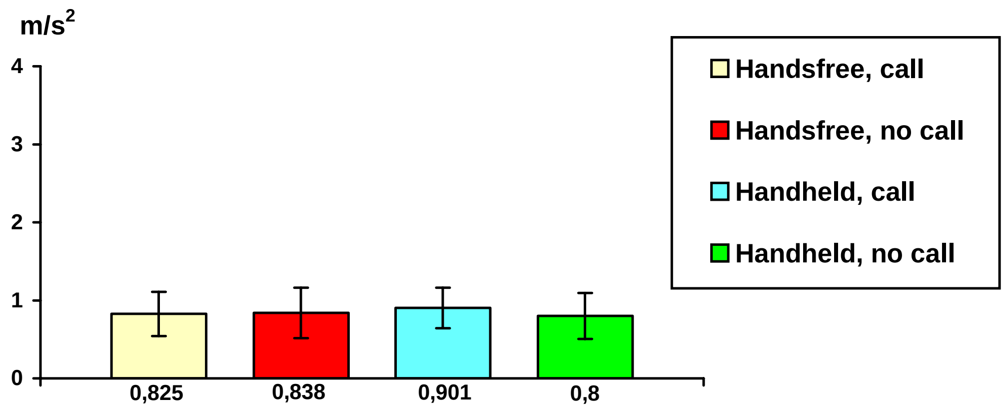


Figure 52 *Maximum lateral acceleration at 50 km/h urban simple: bus (± SD).*

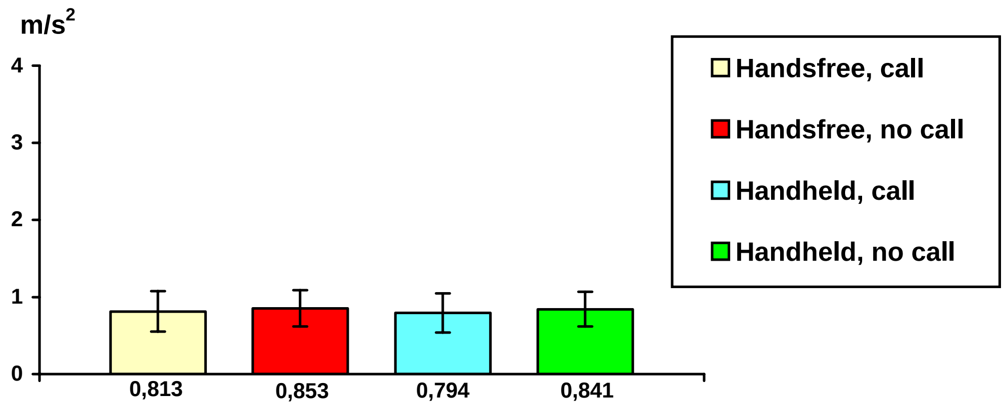


Figure 53 *Maximum lateral acceleration at 50 km/h urban simple: no event (± SD).*

2.4.6 Longitudinal acceleration

Comparisons were made for each of four traffic environments with events (bicycle, motorbike, traffic light, bus).

The following comparisons were made for each of the four traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:

a. difference between phone modes regarding effect of phone call

b. difference between phone modes when phone was used

The result description, however, starts with an analysis of the combined result for the four traffic situations.

2.4.6.1 Longitudinal acceleration variance

The average longitudinal acceleration variance at the analysed four situations combined is shown in Figure 54. It was reduced by phone use for handsfree mode ($t(23)=2.68$; $p<.05$), but not for handheld mode ($t(22)=1.81$; $p>.05$) The effect of phone use was, however, not different for the two phone modes ($t(45)=.51$; $p>.05$).

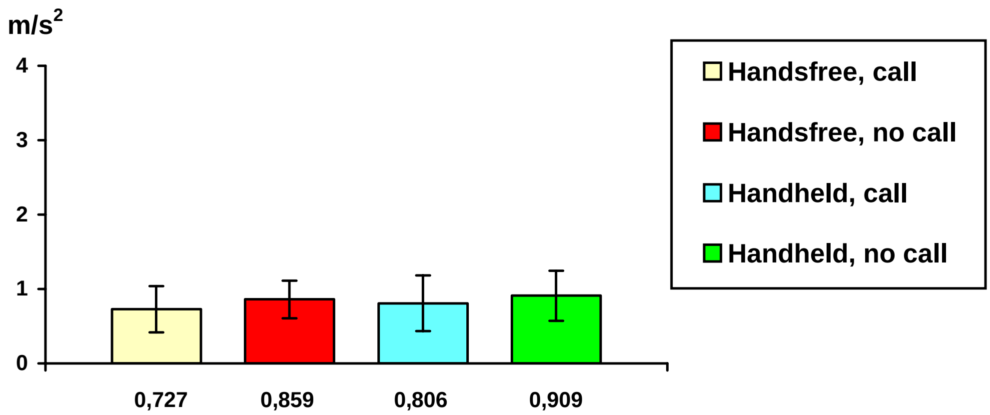


Figure 54 *Longitudinal acceleration variance at the four situations combined (± SD).*

The result for the four situations analysed separately (see below) can be summarised as follows:

Longitudinal acceleration variance was reduced by handsfree phone use at the motorbike and bicycle situations, and by handheld phone use at the bicycle situation.

2.4.6.1.1 *70 km/h rural: motorbike*

The average longitudinal acceleration variance at the *70 km/h rural: motorbike* situation is presented in Figure 55. Longitudinal acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a handheld phone. According to performed t-tests, longitudinal acceleration variance decreased by phone use, but only for handsfree phone ($t(23)=2.466$; $p<.05$). The difference was .261 m/s^2 (Table 70).

No differences between the two phone modes emerged, however (Table 71).

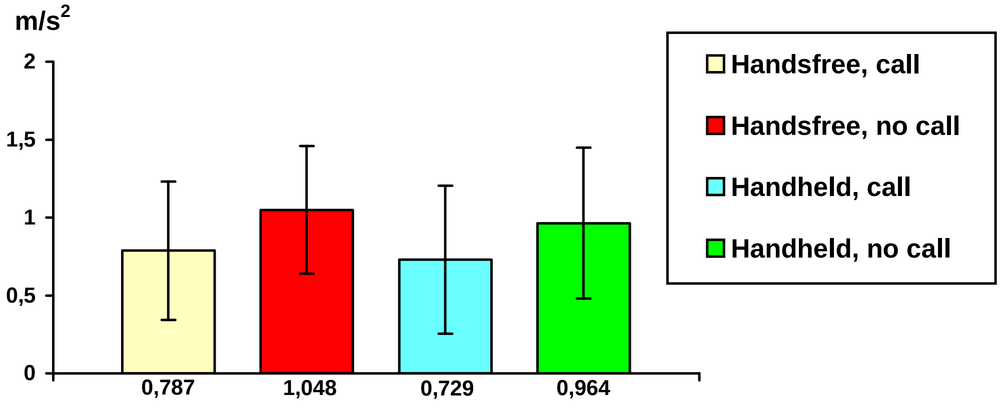


Figure 55 *Longitudinal acceleration variance at motorbike situation (± SD).*

2.4.6.1.2 *50 km/h urban complex: bicycle*

The average longitudinal acceleration variance at the *50 km/h urban complex: bicycle* situation is presented in Figure 56. Longitudinal acceleration data in both conditions were obtained for all 48 participants. According to performed t-tests, longitudinal acceleration variance decreased by phone use for both phone modes. The difference was .212 m/s^2 for handsfree phone ($t(23)=2.783$; $p<.05$) and .215 m/s^2 for handheld phone ($t(23)=2.256$; $p<.05$) (Table 72).

No difference between the two phone modes emerged (Table 73).

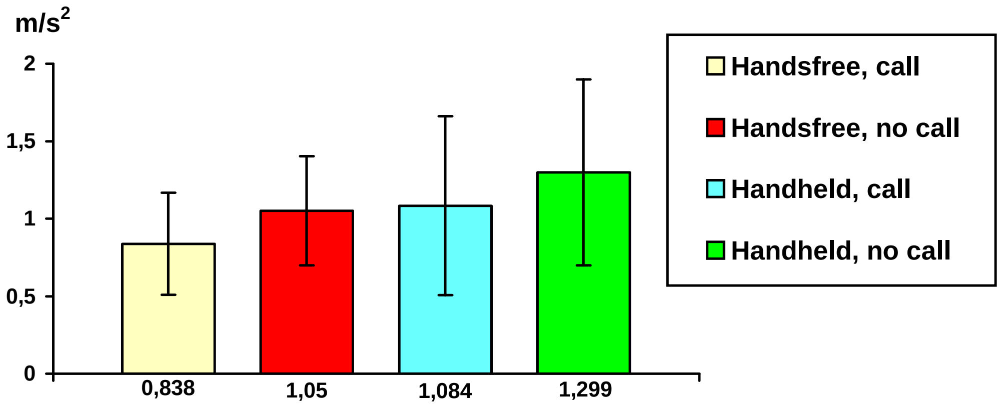


Figure 56 *Longitudinal acceleration variance at bicycle situation (± SD).*

2.4.6.1.3 50 km/h urban medium: traffic light

The average longitudinal acceleration variance at the *50 km/h urban medium: traffic light* situation is presented in Figure 57. Longitudinal acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a handheld phone. According to performed t-tests, no effects emerged (Table 74, Table 75).

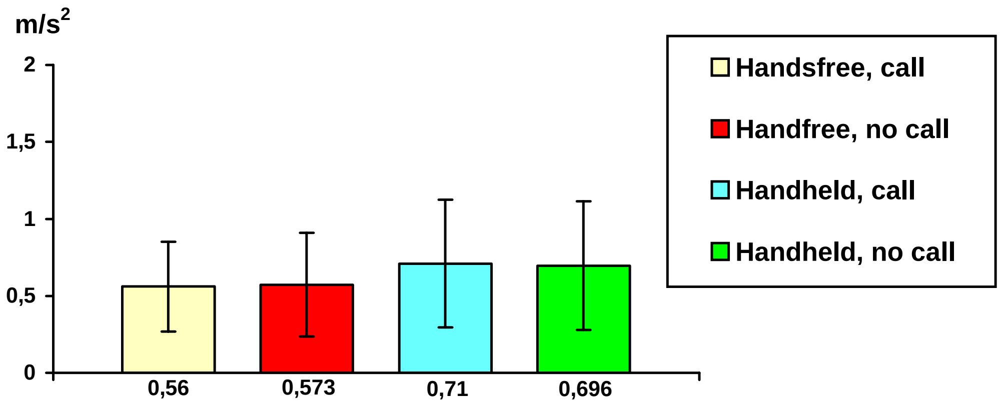


Figure 57 *Longitudinal acceleration variance at traffic light situation (± SD).*

2.4.6.1.4 50 km/h urban simple: bus

The average longitudinal acceleration variance at the *50 km/h urban simple: bus* situation is presented in Figure 58. Longitudinal acceleration data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 23 of those who used a handheld phone. According to performed t-tests, no effects emerged (Table 76, Table 77).

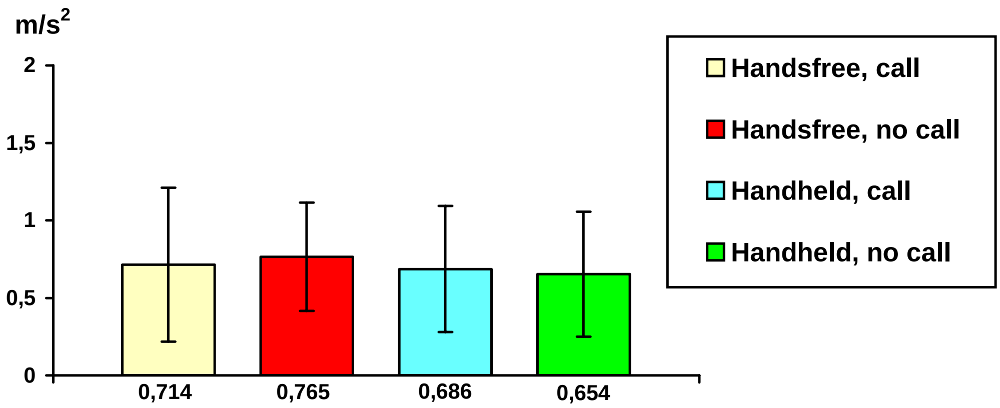


Figure 58 *Longitudinal acceleration variance at bus situation (± SD).*

2.4.6.2 Maximum longitudinal deceleration

The average maximum longitudinal acceleration at the analysed four situations combined is shown in Figure 59. It was not affected by phone use (for handsfree mode $t(23)=1.60$; $p>.05$; handheld mode ($t(22)=.30$; $p>.05$). The effect of phone use was not different for the two phone modes ($t(45)=1.43$; $p>.05$).

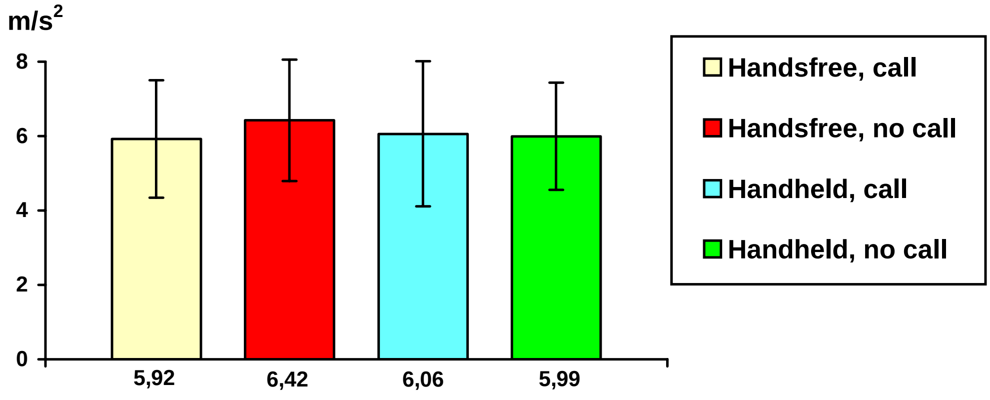


Figure 59 *Maximum longitudinal acceleration at the four situations combined (± SD).*

The result for the four situations analysed separately (motorbike, bicycle, traffic light and bus) can be summarised as follows: There were no effects of phone use on maximum longitudinal deceleration (Table 78–Table 85).

2.4.7 Distance headway

2.4.7.1 Mean distance headway

The following comparisons were made for one of the five traffic environments with events (car following):

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:
   - a. difference between phone modes regarding effect of phone call
   - b. difference between phone modes when phone was used

Mean distance headway increased by handsfree phone use as well as by handheld phone use.

2.4.7.1.1 *90 km/h rural: car following*

The average mean distance headway at the *90 km/h rural: car following situation* is presented in Figure 60. Distance headway data in both conditions were obtained for 22 participants using a handsfree phone, but for only 19 of those who used a handheld phone. According to performed t-tests, mean distance headway increased as an effect of phone use. The size of the difference was 24.6 m for handsfree ($t(21)=2.390$; $p<.05$) and 27.3 m for handheld phone ($t(18)=3.593$; $p<.01$) (Table 86). No difference between phone modes emerged, however (Table 87).

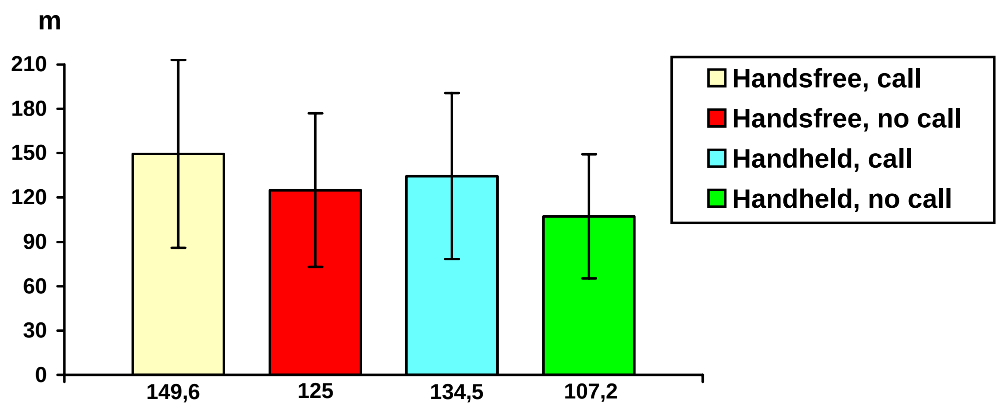


Figure 60 *Mean distance headway at car following situation (± SD).*

2.4.7.2 Distance headway variance

Average distance headway variance was analysed for one situation; the *90 km/h rural: car following* situation. The same analysis was performed as for mean distance headway. No effects of phone use on distance headway variance emerged (Table 88, Table 89).

2.4.7.3 Minimum distance headway

Results for two traffic environments with events were analysed (car following and bus).

The following comparisons were made for each of two traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:

   a. difference between phone modes regarding effect of phone call

   b. difference between phone modes when phone was used

The combined result for the two traffic situations was also analysed. The average minimum distance headway at the analysed two situations combined is shown in Figure 61. It was increased by phone use, for handsfree mode (t(18)=2.11; p<.05), and for handheld mode as well (t(15)=2.39; p<.05). The effect of phone use was, however, not different for the two phone modes (t(33)=.28; p>.05).

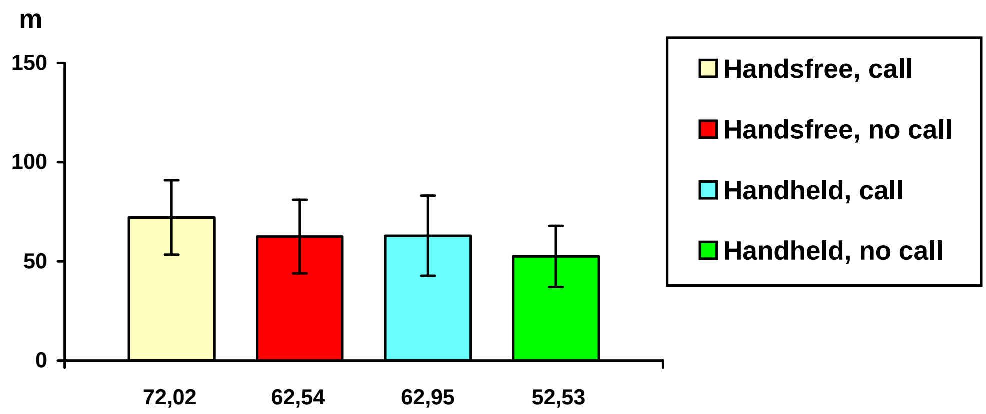


Figure 61 *Minimum distance headway at the two situations combined (± SD).*

The result for the two situations analysed separately (car following, bus) can be summarised as follows:

Minimum distance headway increased by handsfree phone use as well as by handheld phone use at the car following situation.

2.4.7.3.1 90 km/h rural: car following

The average minimum distance headway at the *90 km/h rural: car following situation* is presented in Figure 62. Distance headway data in both conditions were obtained for 22 participants using a handsfree phone, but for only 19 of those who used a handheld phone. According to performed t-tests, minimum distance headway increased as an effect of phone use. The distance increase was 22.3 m for handsfree (t(21)=3.192; p<.01) and 13.9 m for handheld phone (t(18)=2.609; p<.05) (Table 90). No difference between phone modes emerged, however (Table 91).

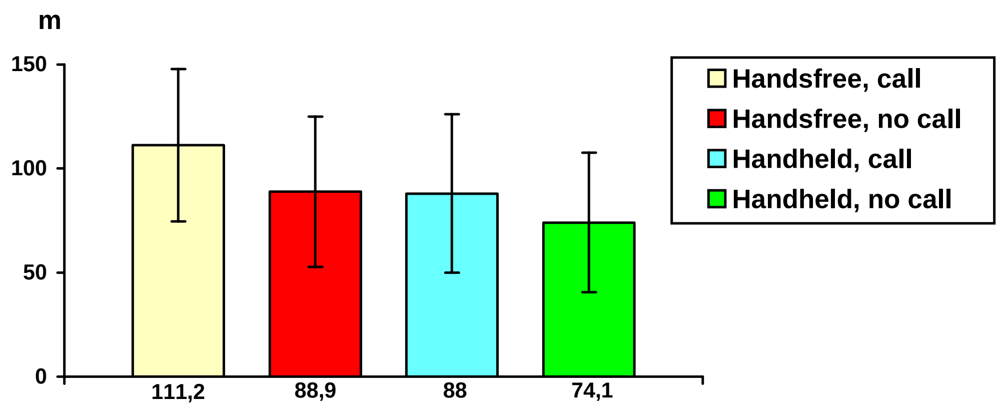


Figure 62 *Minimum distance headway at car following situation (± SD).*

2.4.7.3.2 50 km/h urban simple: bus

The average minimum distance headway at the *50 km/h urban simple: bus* situation is presented in Figure 63. Distance headway data in both conditions were obtained for 21 participants using a handsfree phone, and for 19 of those who used a handheld phone. According to performed t-tests, no effects emerged (Table 92, Table 93).

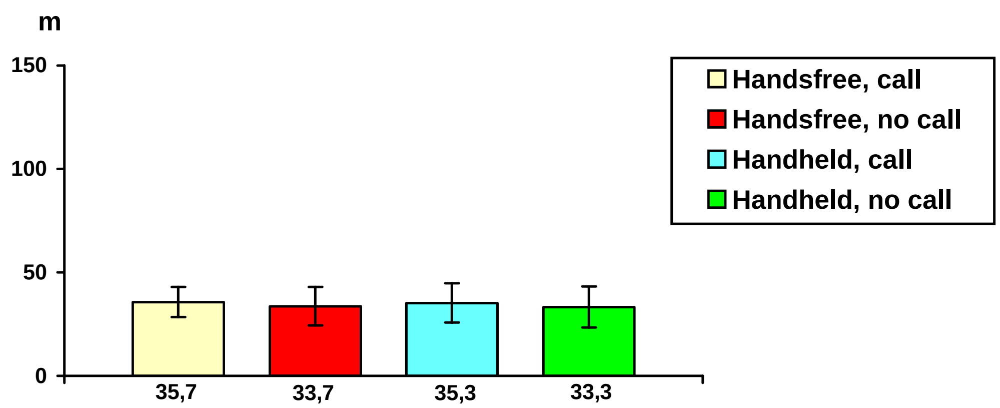


Figure 63 *Minimum distance headway at bus situation (± SD).*

2.4.8 Minimum time headway

Results for two situations were analysed (car following and bus).

The following comparisons were made for each of two traffic environments with events (car following, bus):

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:
   a. difference between phone modes regarding effect of phone call
   b. difference between phone modes when phone was used

The combined result for the two traffic situations was also analysed. The average minimum time headway at the analysed two situations combined is shown in Figure 64. It was not influenced by phone use, for handsfree mode ($t(18)=1.33$; $p>.05$), nor for handheld mode ($t(16)=1.72$; $p>.05$). The effect of phone use was not different for the two phone modes ($t(34)=.33$; $p>.05$).

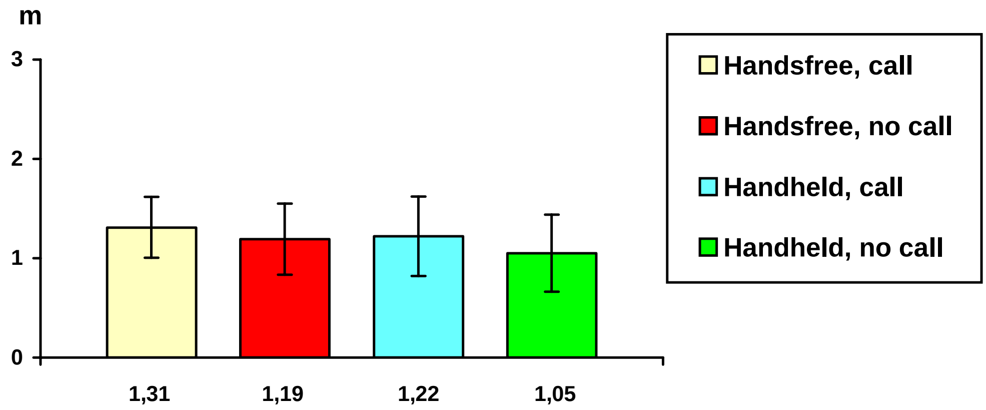


***Figure 64** Minimum time headway at the two situations combined (± SD).*

The result for the two situations analysed separately (car following, bus) can be summarised as follows:

Minimum time headway increased by handsfree phone use as well as by handheld phone use at the car following situation.

2.4.8.1 90 km/h rural: car following

The average minimum time headway at the *90 km/h rural: car following* situation is presented in Figure 65. Time headway data in both conditions were obtained for all 22 participants using a handsfree phone, but for only 19 of those who used a handheld phone. According to performed t-tests, minimum time headway increased as an effect of phone use. The time increase was .25 s for handsfree ($t(21)=2.268$; $p<.05$) and .35 s for handheld phone ($t(18)=2.432$; $p<.05$) (Table 94). No differences between phone modes emerged, however (Table 95).

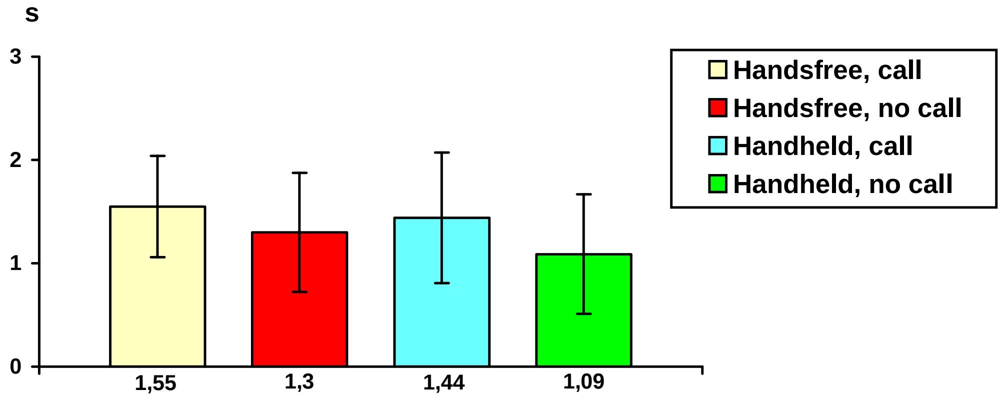


Figure 65 *Minimum time headway at car following situation (± SD).*

2.4.8.2 50 km/h urban simple: bus

The average minimum time headway at the *50 km/h urban simple: bus situation* is presented in Figure 66. Time headway data in both conditions were obtained for 21 participants using a handsfree phone, but for only 19 of those who used a handheld phone. According to performed t-tests, no effects emerged (Table 96, Table 97).

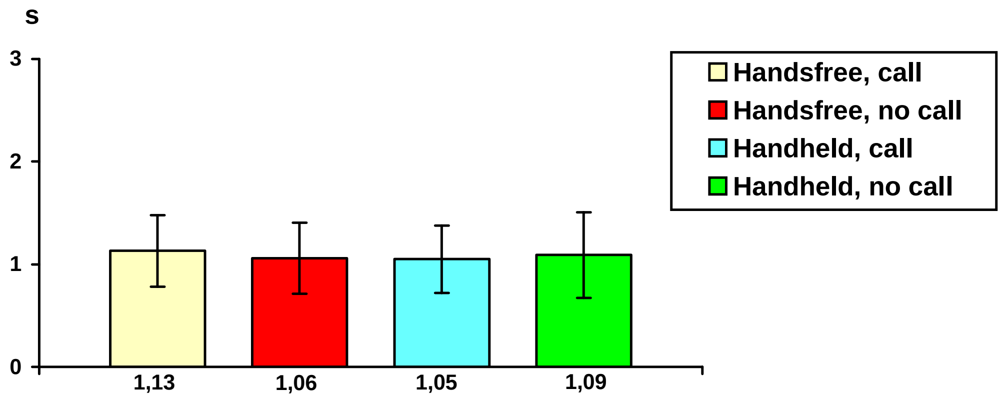


Figure 66 *Minimum time headway at bus situation (± SD).*

2.4.9 Minimum time to collision

Average minimum time to collision was analysed for two situations; car following and bus.

The average minimum time to collision at the analysed two situations combined is shown in Figure 67. It was not affected by phone use – not for hands-free mode (t(18)=.67; p>.05), nor for handheld mode as well (t(15)=1.00; p>.05). The effect of phone use was not different for the two phone modes (t(33)=.47; p>.05).

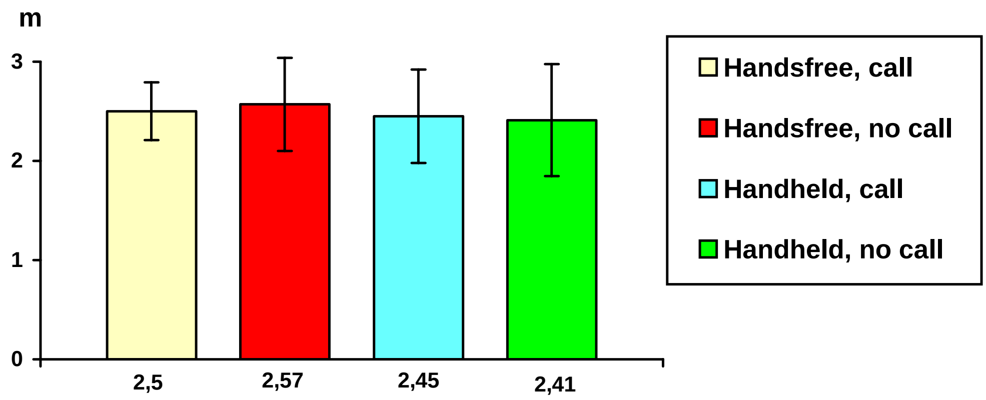


Figure 67 *Minimum time to collision at the two situations combined (± SD).*

The result for the two situations analysed separately (car following and bus) can be summarised as follows: No effects of phone use on minimum time to collision emerged (Table 98–Table 101).

2.4.10 Number of participants stopping at events

The number of participants who stopped at three situations – bicycle, traffic light and bus – was analysed. No effects of phone use were established for any of the situations. This result was valid for both phone modes (Table 123, Table 124).

2.4.11 PDT performance

PDT performance was analysed with respect to average reaction times to detected signals and percentage of missed PDT signals. Whenever there were missed signals, average reaction times were consequently underestimations of true effects – the greater number of missed signals, the greater the underestimation.

PDT performance was analysed for each of all ten traffic situations: five traffic environments with events (car following, motorbike, bicycle, traffic light, bus) and the corresponding five traffic environments without events.

The following comparisons were made for each of the ten traffic situations:

A. effect of phone call for each of the two phone modes

B. comparisons between phone modes:
   a. difference between phone modes regarding effect of phone call
   b. difference between phone modes when phone was used

The result description, however, starts with an analysis of the combined result for all ten traffic situations.

2.4.11.1 Reaction time

The average PDT reaction time at the analysed ten situations combined is shown in Figure 68. Reaction time was increased by phone use for handsfree mode ($t(23)=7.72$; $p<.001$), as well as for handheld mode ($t(18)=7.18$; $p<.001$). The effect of phone use was not, however, different for the two phone modes ($t(41)=1.41$; $p>.05$).

On average the participants had a PDT reaction time which was 0.16 seconds higher when using the phone (= 27.7% higher).

Note: 0.16 seconds longer reaction time at 90 km/h corresponds to 4 metres longer braking distance.

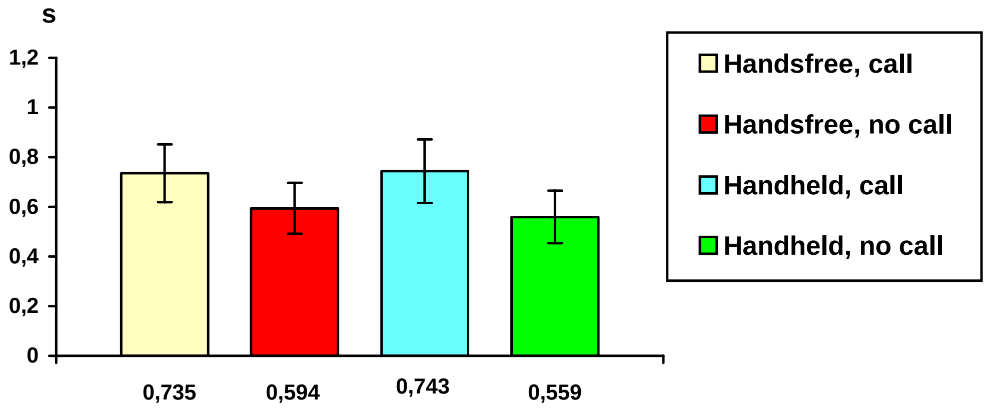


Figure 68 *PDT reaction time at the ten situations combined (± SD).*

The result for the ten situations analysed separately (see below) can be summarised as follows:

PDT Reaction time performance was impaired in all situations in all environments by handsfree and handheld phone use alike.

2.4.11.1.1 90 km/h rural: car following and no event

The average reaction times at the *90 km/h rural: car following* and *no event* situations are presented in Figure 69 and Figure 70. For the *car following* situation, reaction time data in both conditions were obtained for all 24 participants using a handsfree phone, but for only 20 of those who used a handheld phone. For the other situation, reaction time data in both conditions were obtained for all 24 participants using a handsfree phone, but for 23 of those who used a handheld phone. According to performed t-tests, reaction time performance was impaired by phone use. This result emerged for both phone modes in both situations. For the car following situation the results of t-tests were: $t(23)=2.617$; $p<.05$ for handsfree, and $t(19)=4.229$; $p<.001$ for handheld. For the other situation the results of t-tests were: $t(23)=7.451$; $p<.001$ for handsfree, and $t(22)=4.156$; $p<.001$ for handheld. The size of the effect was 128 ms for handsfree and 177 ms for handheld phone at the car following situation, and 233 ms and 164 ms respect-tively at the other situation (Table 104).

No differences between the two phone modes emerged, however (Table 105).

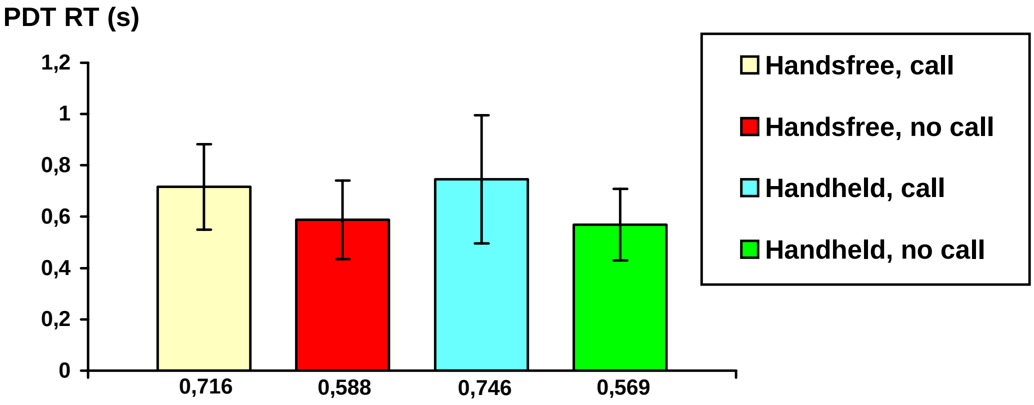


Figure 69 *PDT reaction time at 90 km/h rural: car following (± SD).*

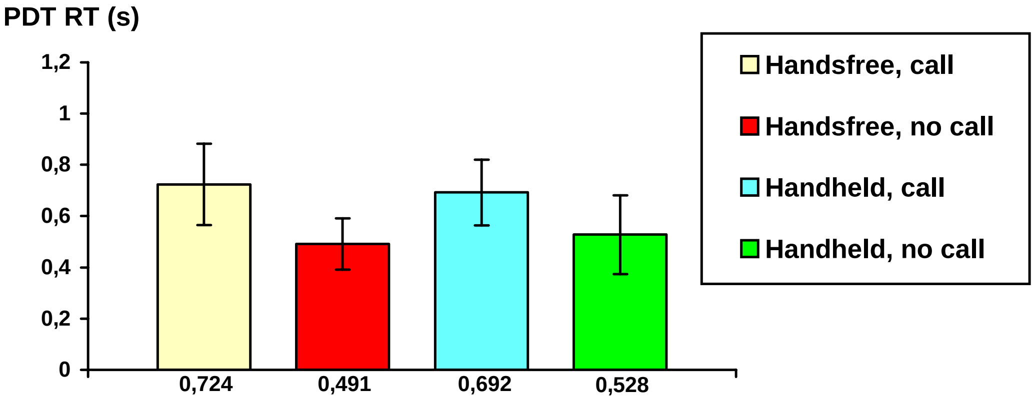


Figure 70 *PDT reaction time at 90 km/h rural: no event (± SD).*

2.4.11.1.2 70 km/h rural: motorbike and no event

The average reaction times at the *70 km/h rural: motorbike* and *no event* situations are presented in Figure 71 and Figure 72. For the *motorbike* situation, reaction time data in both conditions were obtained for all 24 participants using a hands-free phone, but limited to 23 for those who used a handheld phone. For the other situation there were useful data for all 24 participants. According to performed t-tests, reaction time performance was impaired by phone use. This result emerged for both phone modes in both situations. For the motorbike situation the results of t-tests were: $t(23)=5.540$; $p<.001$ for handsfree, and $t(22)=5.648$; $p<.001$ for handheld. For the other situation the results of t-tests were: $t(23)=5.360$; $p<.001$ for handsfree, and $t(23)=3.649$; $p<.001$ for handheld. The size of the effect was 138 ms for handsfree and 207 ms for handheld phone at the motorbike situation, and 185 ms and 169 ms respectively at the other situation (Table 106).

No differences between phone modes emerged (Table 107).

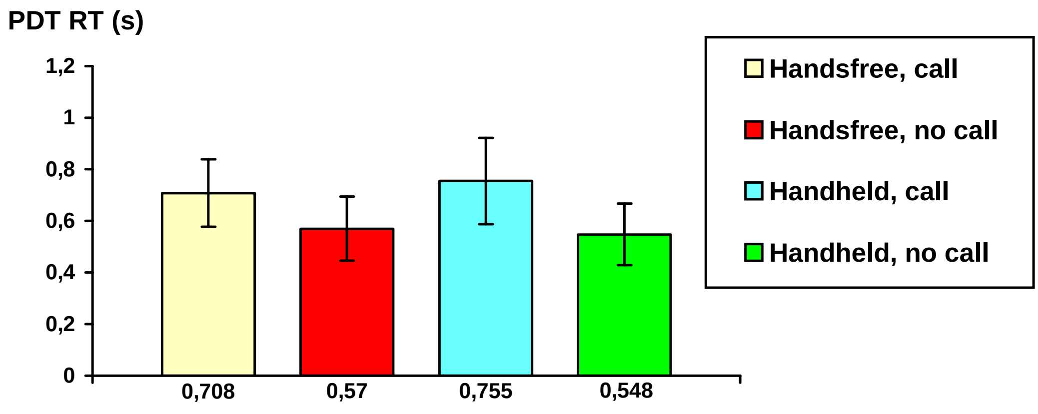


Figure 71 *PDT reaction time at 70 km/h rural: motorbike (± SD).*

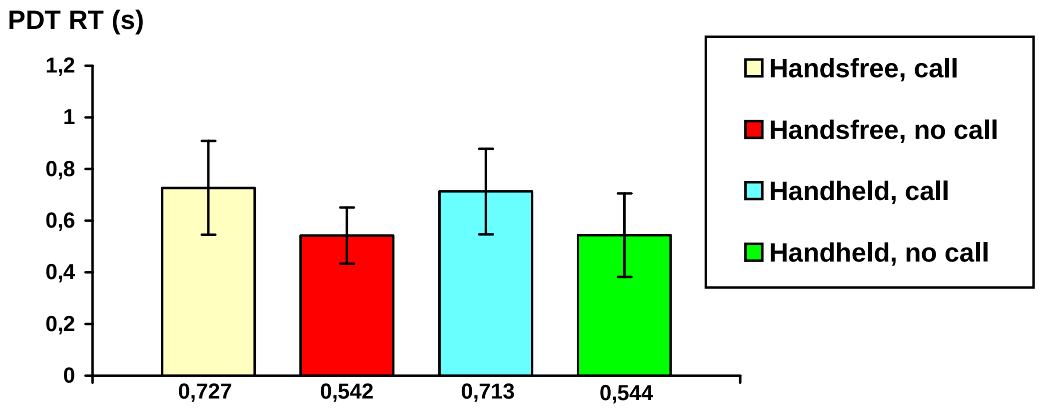


Figure 72 *PDT reaction time at 70 km/h rural: no event (± SD).*

2.4.11.1.3 *50 km/h urban complex: bicycle and no event*

The average reaction times at the *50 km/h urban complex: bicycle* and *no event* situations are presented in Figure 73 and Figure 74. For the *bicycle* situation, reaction time data in both conditions were obtained for all 48 participants. For the other situation useful reaction time data were obtained for all 24 participants with handsfree phone, but restricted to 23 participants for handheld phone. According to performed t-tests, reaction time performance was impaired by phone use. This result emerged for both phone modes in both situations. For the bicycle situation the results of t-tests were: $t(23)=2.943$; $p<.05$ for handsfree, and $t(23)=4.748$; $p<.001$ for handheld. For the other situation the results of t-tests were: $t(23)=2.896$; $p<.01$ for handsfree, and $t(22)=5.271$; $p<.001$ for handheld. The size of the effect was 118 ms for handsfree and 196 ms for handheld phone at the bicycle situation, and 106 ms and 184 ms respectively at the other situation (Table 108).

However, no differences between the two phone modes emerged (Table 109).

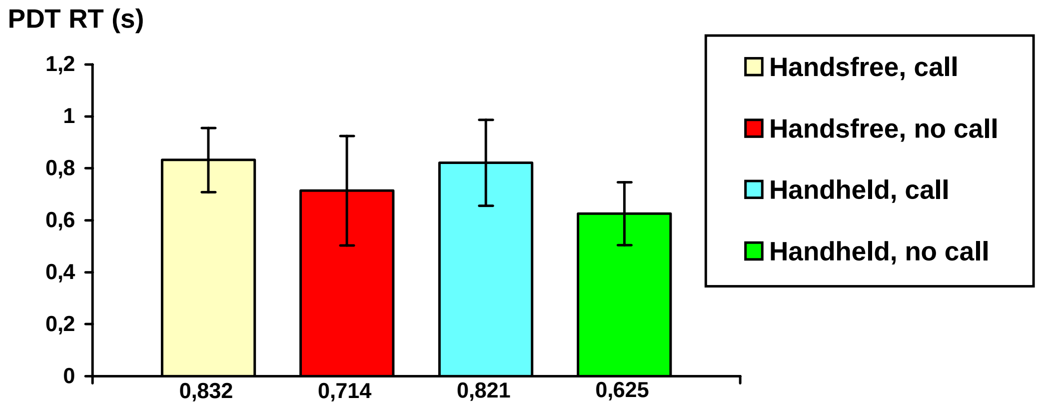


Figure 73 *PDT reaction time at 50 km/h urban complex: bicycle (± SD).*

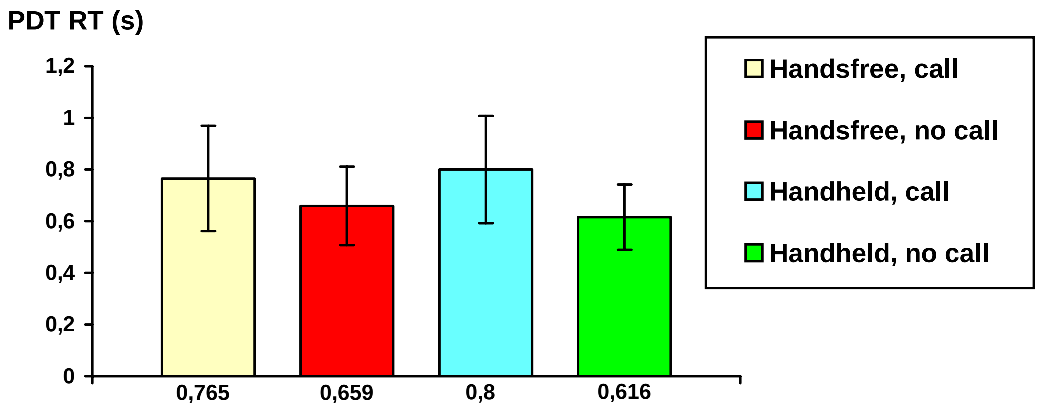


Figure 74 *PDT reaction time at 50 km/h urban complex: no event (± SD).*

2.4.11.1.4 50 km/h urban medium: traffic light and no event

The average reaction times at the *50 km/h urban medium: traffic light* and *no event* situations are presented in Figure 75 and Figure 76. For the *traffic light* situation, reaction time data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 for those who used a handheld phone. For the other situation, the corresponding number of participants was 24 and 22 respectively. According to performed t-tests, reaction time performance was impaired by phone use. This result emerged for both phone modes in both situations. For the traffic light situation the results of t-tests were: $t(23)=2.393$; $p<.05$ for handsfree, and $t(22)=3.397$; $p<.01$ for handheld. For the other situation the results of t-tests were: $t(23)=5.232$; $p<.001$ for handsfree, and $t(21)=4.065$; $p<.001$ for handheld. The size of the effect was 76 ms for handsfree and 187 ms for handheld phone at the traffic light situation, and 182 ms and 174 ms respectively at the other situation (Table 110).

No differences between phone modes emerged, however (Table 111).

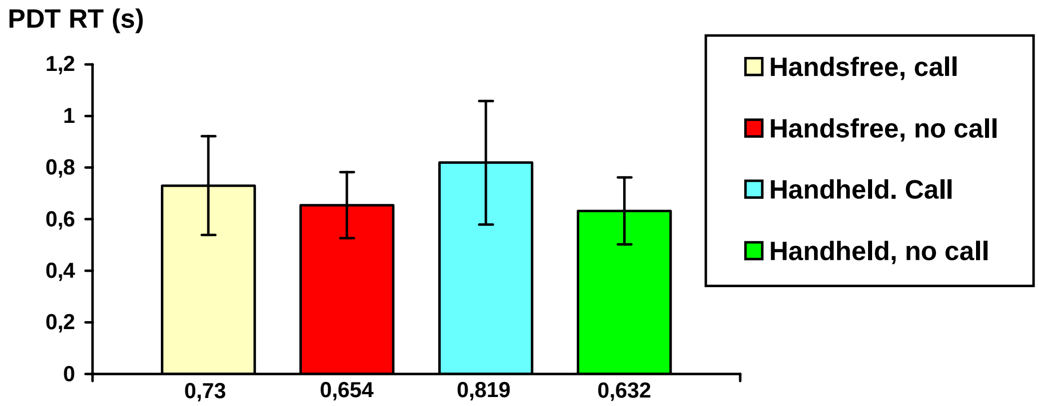


Figure 75 *PDT reaction time at 50 km/h urban medium: traffic light (± SD).*

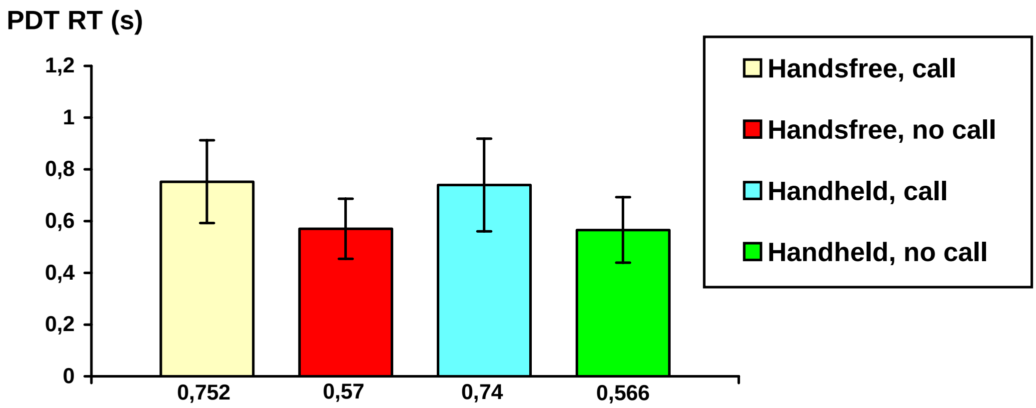


Figure 76 *PDT reaction time at 50 km/h urban medium: no event(± SD).*

2.4.11.1.5 50 km/h urban simple: bus and no event

The average reaction times at the *50 km/h urban simple: bus* and *no event* situations are presented in Figure 77 and Figure 78. For the *bus* situation, reaction time data in both conditions were obtained for all 24 participants using a handsfree phone, but limited to 23 for those who used a handheld phone. The same number of participants provided useful reaction time data at the other situation. According to performed t-tests, reaction time performance was impaired by phone use. This result emerged for both phone modes in both situations. For the bus situation the results of t-tests were: $t(23)=4.732$; $p<.001$ for handsfree, and $t(22)=5.288$; $p<.001$ for handheld. For the other situation the results of t-tests were: $t(23)=4.079$; $p<.001$ for handsfree, and $t(22)=3.469$; $p<.01$ for handheld. The size of the effect was 129 ms for handsfree and 203 ms for handheld phone at the bus situation, and 119 ms and 108 ms respectively at the other situation (Table 112).

No differences between phone modes emerged (Table 113).

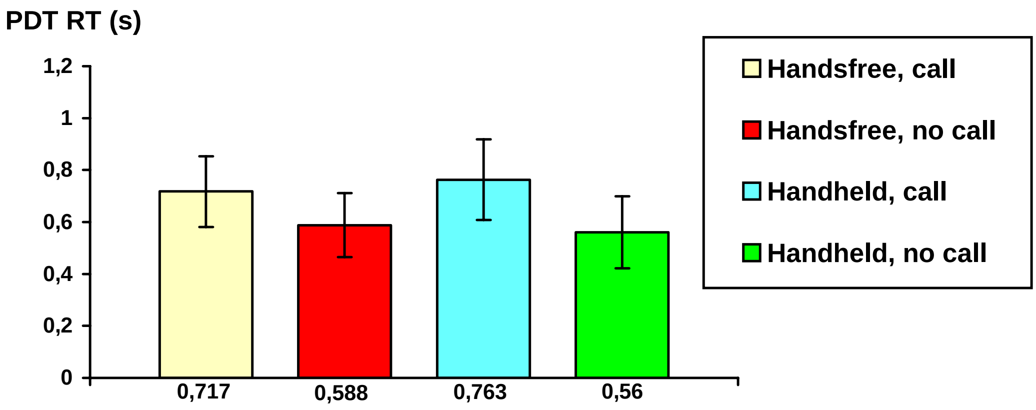


Figure 77 *PDT reaction time at 50 km/h urban simple: bus (± SD).*

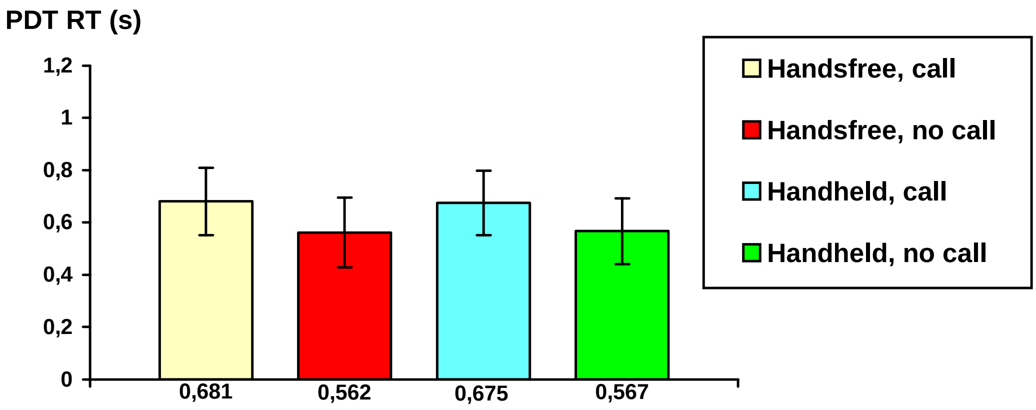


Figure 78 *PDT reaction time at 50 km/h urban simple: no event (± SD).*

2.4.11.2 Missed signals

The average percentage of missed signals at the analysed ten situations combined is shown in Figure 79. The percentage of missed signals increased by phone use for handsfree mode ($t(23)=5.11$; $p<.001$), as well as for handheld mode ($t(19)=4.74$; $p<.001$). The effect of phone use was not, however, different for the two phone modes ($t(42)=1.18$; $p>.05$).

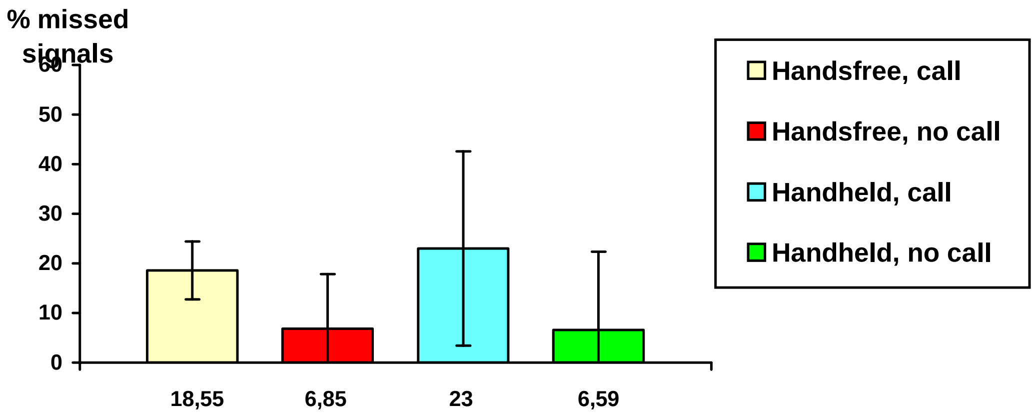


Figure 79 *Percentage missed signals at the ten situations combined (± SD).*

The result for the ten situations analysed separately (see below) can be summarised as follows:

PDT performance in terms of missed signals was impaired by phone use in all situations in all environments. This result was valid for both phone modes.

2.4.11.2.1 90 km/h rural: car following and no event

The median percentage of missed PDT signals at the *90 km/h rural: car following* and *no event* situations is presented in Figure 80 and Figure 81.

There were more missed signals with phone call than without phone call in both situations. This applied to both phone modes. For the car following situation the results of Wilcoxon Signed Ranks tests were: z=2.295; p<.05 for handsfree and z=2.727; p<.01 for handheld. For the other situation the results of Wilcoxon Signed Ranks tests were: z=3.078; p<.01 for handsfree and z=3.408; p<.001 for handheld (Table 114).

The median value with no phone call was 0 missed signals both with handsfree and handheld phone. The size of the effect was 9.6 percentage units for handsfree and 6.5 percentage units for handheld phone at the car following situation, and 10.0 and 7.7 percentage units respectively at the other situation.

No differences between the phone modes emerged (Table 115).

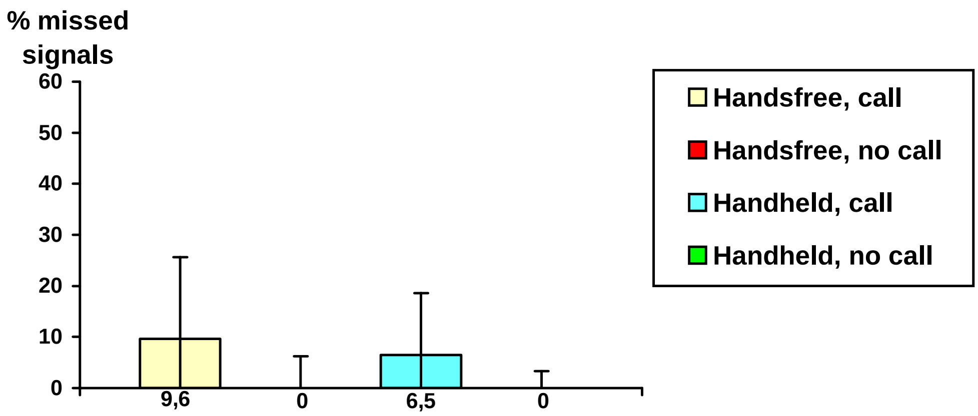


Figure 80 *PDT Missed signals at 90 km/h rural: car following (± quartile deviation).*

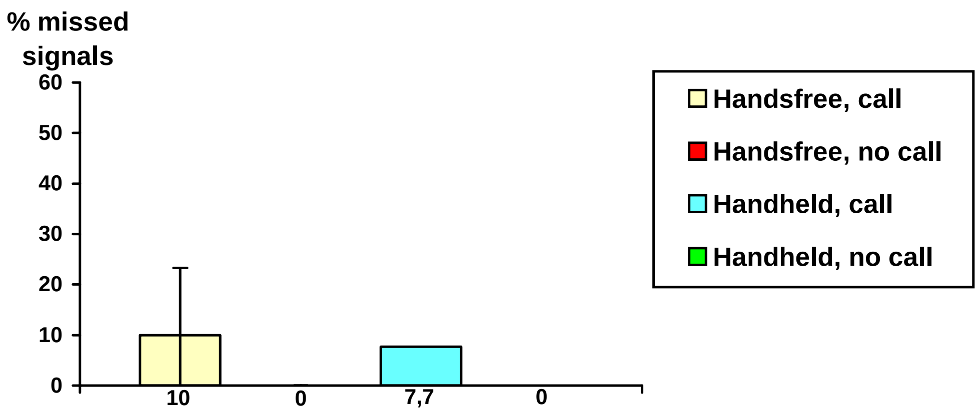


Figure 81 *PDT Missed signals at 90 km/h rural: no event (± quartile deviation).*

2.4.11.2.2 70 km/h rural: motorbike and no event

The median percentage of missed PDT signals at the *70 km/h rural: motorbike* and *no event* situations is presented in Figure 82 and Figure 83.

There were more missed signals with phone call than without phone call in both situations (*motorbike, no event*). This applied to both phone modes. For the motorbike situation the results of Wilcoxon Signed Ranks tests were: z=3.407; p<.001 for handsfree and z=3.599; p<.001 for handheld. For the other situation the results of Wilcoxon Signed Ranks tests were: z=3.446; p<.001 for handsfree and z=2.953; p<.01 for handheld (Table 116).

The difference was 10.5 percentage units for handsfree and 16.7 percentage units for handheld phone at the motorbike situation, and 15.4 and 9.5 percentage units respectively at the other situation.

No differences between the phone modes emerged (Table 117).

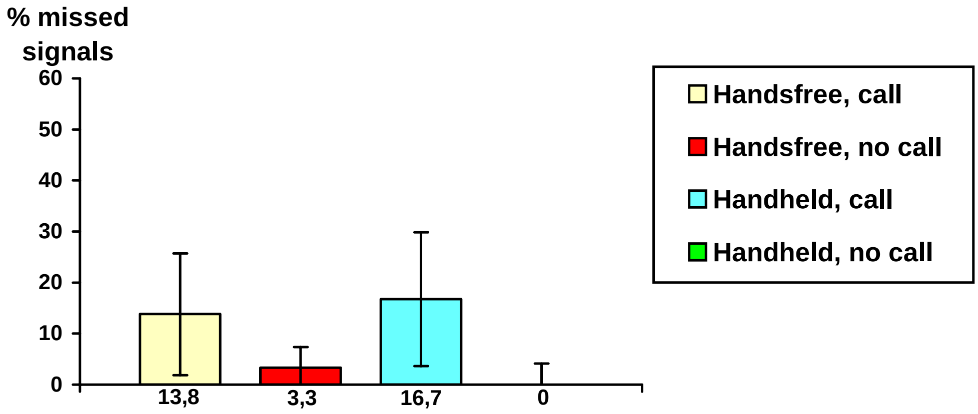


Figure 82 *PDT Missed signals at 70 km/h rural: motorbike (± quartile deviation).*

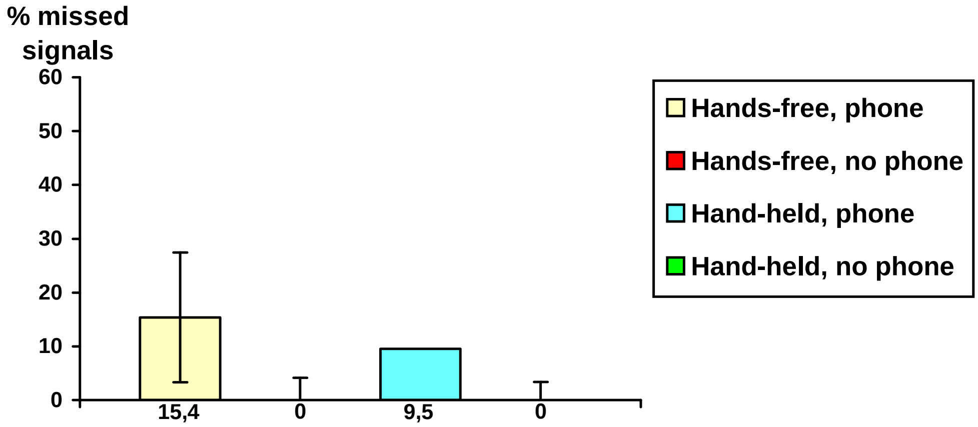


Figure 83 *PDT Missed signals at 70 km/h rural: no event (± quartile deviation).*

2.4.11.2.3 50 km/h urban complex: bicycle and no event

The median percentage of missed PDT signals at the *50 km/h urban complex: bicycle* and *no event* situations is presented in Figure 84 and Figure 85.

There were more missed signals with phone call than without phone call in both situations (*bicycle, no event*). This applied to both phone modes. For the bicycle situation the results of Wilcoxon Signed Ranks tests were: $z=2.450$; $p<.05$ for handsfree and $z=2.890$; $p<.01$ for handheld. For the other situation the results of Wilcoxon Signed Ranks tests were: $z=2.254$; $p<.05$ for handsfree and $z=3.660$; $p<.001$ for handheld (Table 118).

The difference was 16.1 percentage units for handsfree and 13.9 percentage units for handheld phone at the bicycle situation, and 8.4 and 11.7 percentage units respectively at the other situation.

No differences between the phone modes emerged (Table 119).

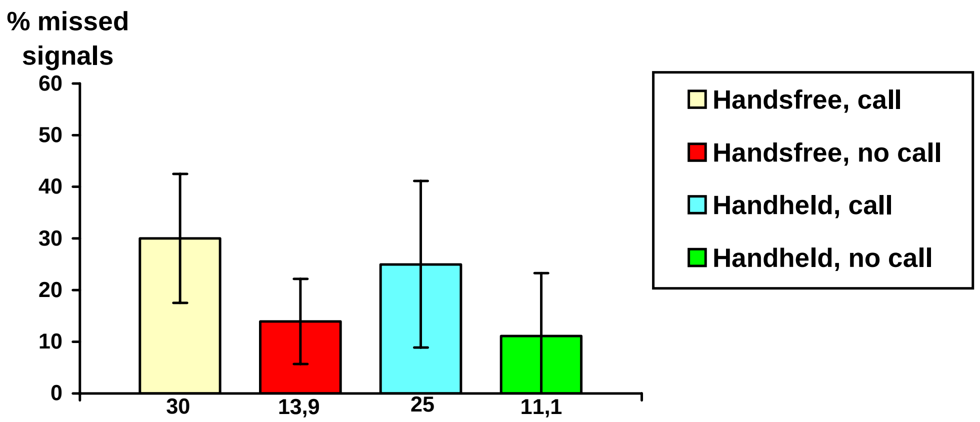


Figure 84 *PDT Missed signals at 50 km/h urban complex: bicycle (± quartile deviation).*

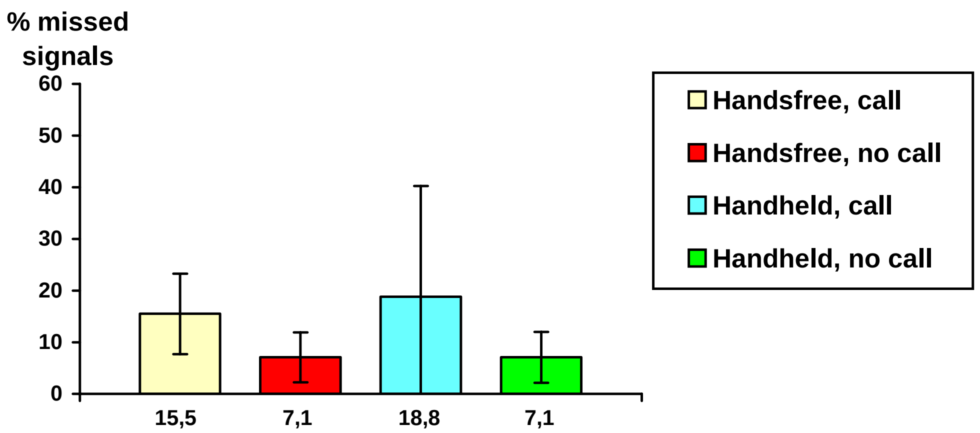


Figure 85 *PDT Missed signals at 50 km/h urban complex: no event (± quartile deviation).*

2.4.11.2.4 50 km/h urban medium: traffic light and no event

The median percentage of missed PDT signals at the *50 km/h urban medium: traffic light* and *no event* situation is presented in Figure 86 and Figure 87.

There were more missed signals with phone call than without phone call in both situations. This applied to both phone modes. For the traffic light situation the results of Wilcoxon Signed Ranks tests were: z=2.768; p<.01 for handsfree and z=2.792; p<.01 for handheld. For the other situation the results of Wilcoxon Signed Ranks tests were: z=3.435; p<.001 for handsfree and z=3.332; p<.001 for handheld (Table 120).

The difference was 8.5 percentage units for handsfree and 9.1 percentage units for handheld phone at the *traffic light* situation, and 12.4 and 12.5 percentage units respectively at the other situation.

No differences between the phone modes emerged (Table 121).

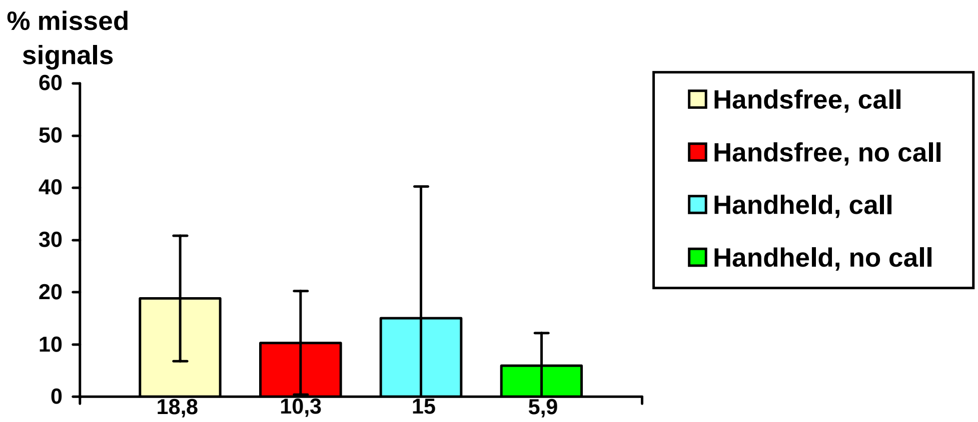


Figure 86 *PDT Missed signals at 50 km/h urban medium: traffic light (± quartile deviation).*

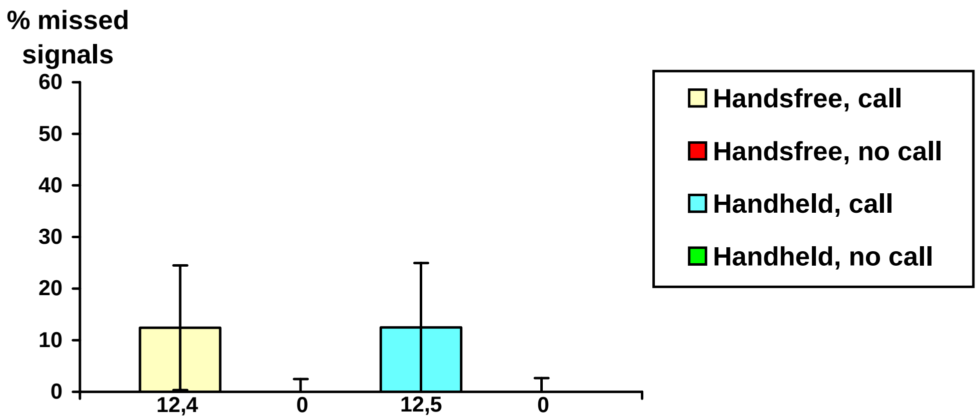


Figure 87 *PDT Missed signals at 50 km/h urban medium: no event (± quartile deviation).*

2.4.11.2.5 *50 km/h urban simple: bus and no event*

The median percentage of missed PDT signals at the *50 km/h urban simple: bus* and *no event* situation is presented in Figure 88 and Figure 89.

There were more missed signals with phone call than without phone call in both situations. This applied to both phone modes.

For the bus situation the results of Wilcoxon Signed Ranks tests were: z=3.332; p<.001 for handsfree and z=3.633; p<.001 for handheld. For the other situation the results of Wilcoxon Signed Ranks tests were: z=2.158; p<.05 for handsfree and z=3.093; p<.01 for handheld (Table 122).

The difference was 7.1 percentage units for handsfree and 16.9 percentage units for handheld phone at the *bus* situation, and 6.6 and 7.1 percentage units respectively at the other situation.

No differences between the phone modes emerged (Table 123).

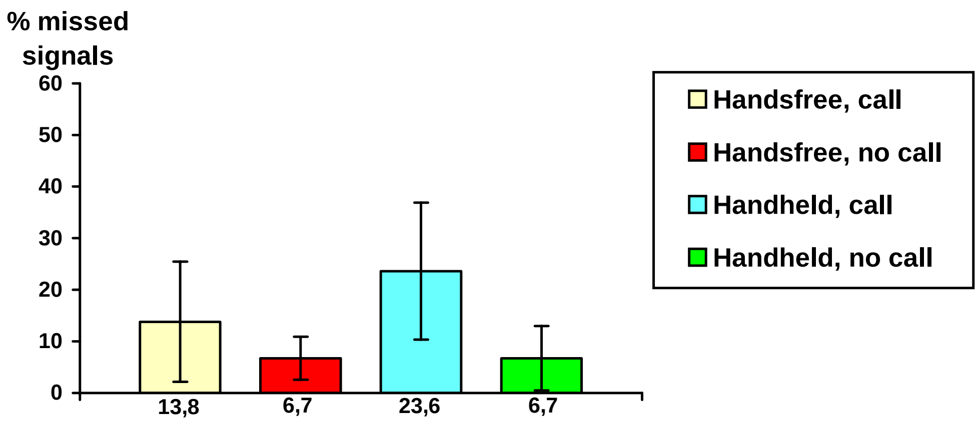


Figure 88 *PDT Missed signals at 50 km/h urban simple: bus (± quartile deviation).*

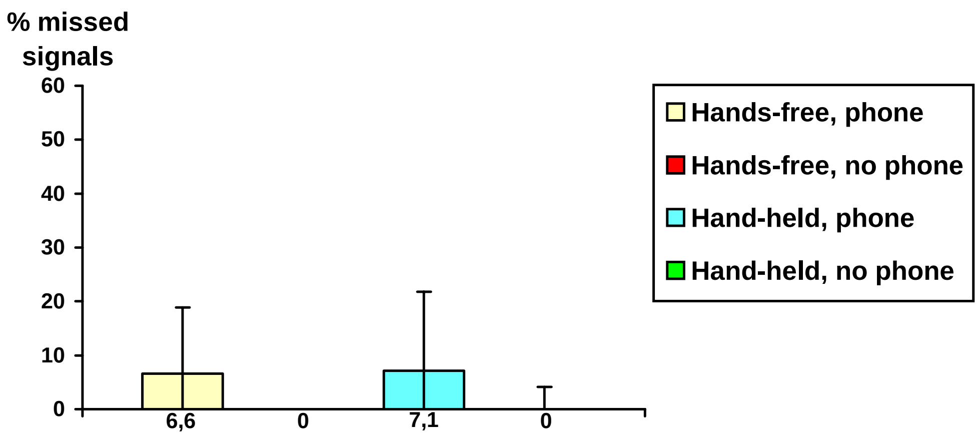


Figure 89 *PDT Missed signals at 50 km/h urban simple: no event (± quartile deviation).*

2.4.12 Secondary task performance

Number of additions, number of errors and percentage correct answers given by the participants were analysed. No differences between phone modes were apparent.

Similarly, no difference between phone modes regarding percentage of correct answers were apparent when all ten situations were analysed separately. When comparing the average percentage of correct answers for all traffic situations added together, the result was 82.8% correct answers for handsfree mode, and 85.2% correct answers for handheld mode, a non-significant difference ($t(44)=.94$; $p>.05$) (Table 124, Table 125).

2.4.13 Other results

2.4.13.1 PDT reaction time

Comparisons were made between traffic environments (Figure 90). The figure shows the average reaction times for the traffic environments with and without events combined. The reaction time was prolonged by phone use ($F(1,41)=106.76$; $p<.001$), with no difference between the two phone modes. The difference between the situations was, however, significant ($F(3,123)=29.97$; $p<.001$). Post hoc tests (Tukey) reveal that all pair-wise comparisons, except one (Rural road – Urban simple), were significant (Rural road – Urban medium: $q=6.08$; $p<.01$. Rural road – Urban complex: $q=12.06$; $p<.01$. Urban simple – Urban medium: $q=5.03$; $p<.01$. Urban simple – Urban complex: $q=11.01$; $p<.01$. Urban medium – Urban complex: $q=5.62$; $p<.01$).

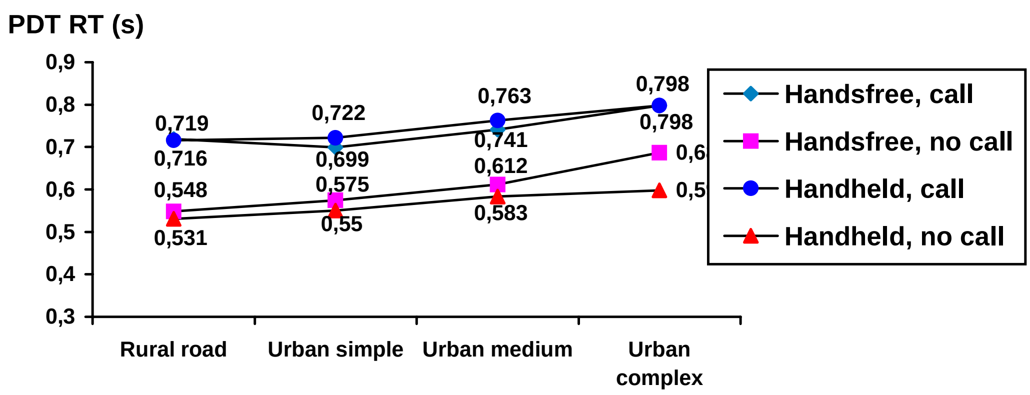


Figure 90 *PDT reaction time at different traffic environments.*

2.4.14 Learning effects on PDT

There are no learning effects for the mean PDT reaction time for round one and round two. ($t(42)=.086$; n.s.).

2.5 Plots

In this chapter some data plots of the mobile phone experiment are shown. This is believed to allow a more qualitative look at the data than the results of the statistical analyses permit.

Figure 91 shows the average speed in the handsfree part for the traffic light event (traffic light turns from green to amber while the drivers approach the crossing). Note: the two curves do not reach zero since the drivers stopped at different distances from the traffic light. Figure 92 shows the average speed for the bicycle event (where a bicycle suddenly crossed the road and forced the drivers to stop). It seems that the drivers stopped later when using the mobile phone. Figure 93 shows the speed development for each driver in the traffic light event. Here the large variability in speed between the drivers is visible, furthermore it can be seen that four drivers did not stop at the traffic light. Figure 94 shows that the average speed was lower when the drivers used the mobile phone. Figure 95 compares the speed development in the bus event for the handheld part, here the speed variability seems to be lower for the drivers with mobile phone. It can also be seen that some drivers did not stop for the bus.

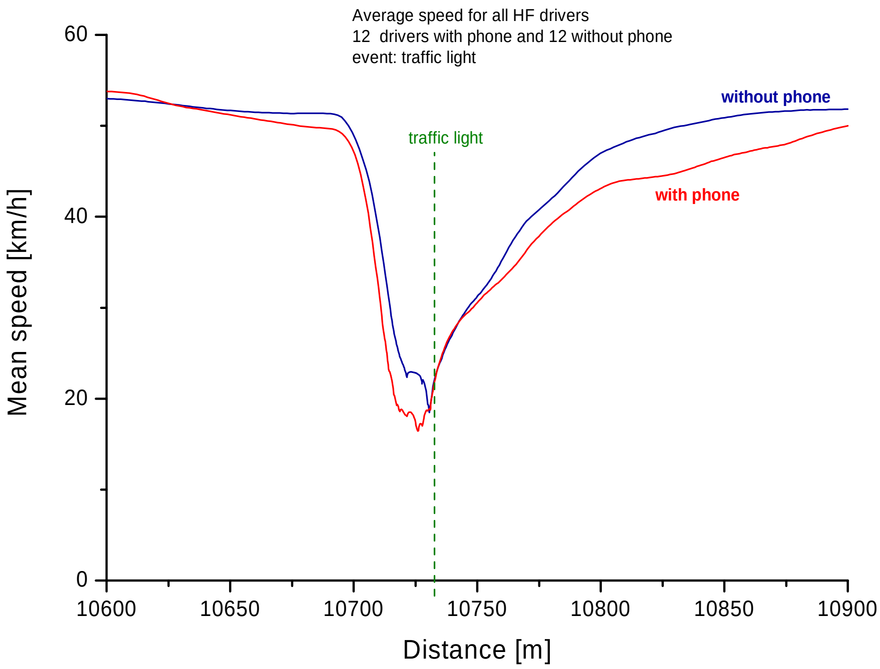


Figure 91 *Average speed plot for the handsfree part. The event plotted is the traffic light turning to amber when the car approached.*

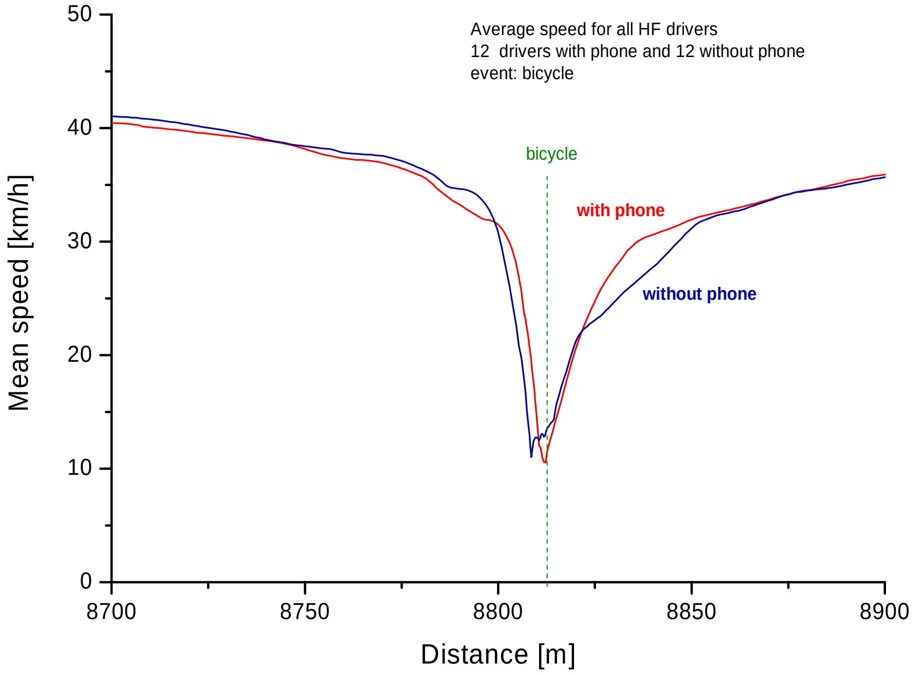


Figure 92 *Average speed plot for the handsfree part. The event plotted is the bicycle crossing the road.*

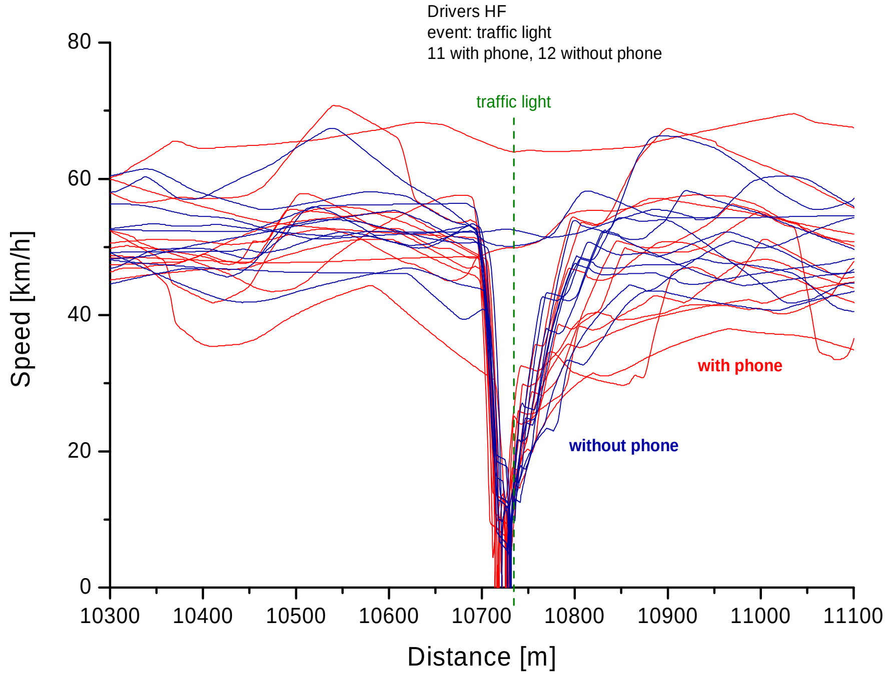


Figure 93 *Speed development for the handsfree drivers at the traffic light event.*

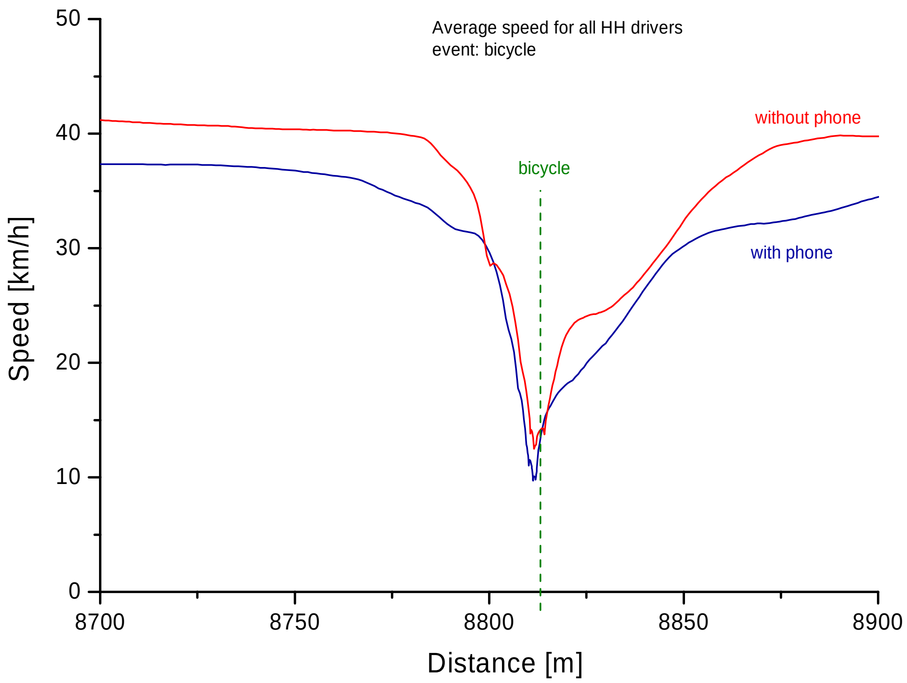


Figure 94 *Average speed plot for the handheld part. The event plotted is the bicycle crossing the road.*

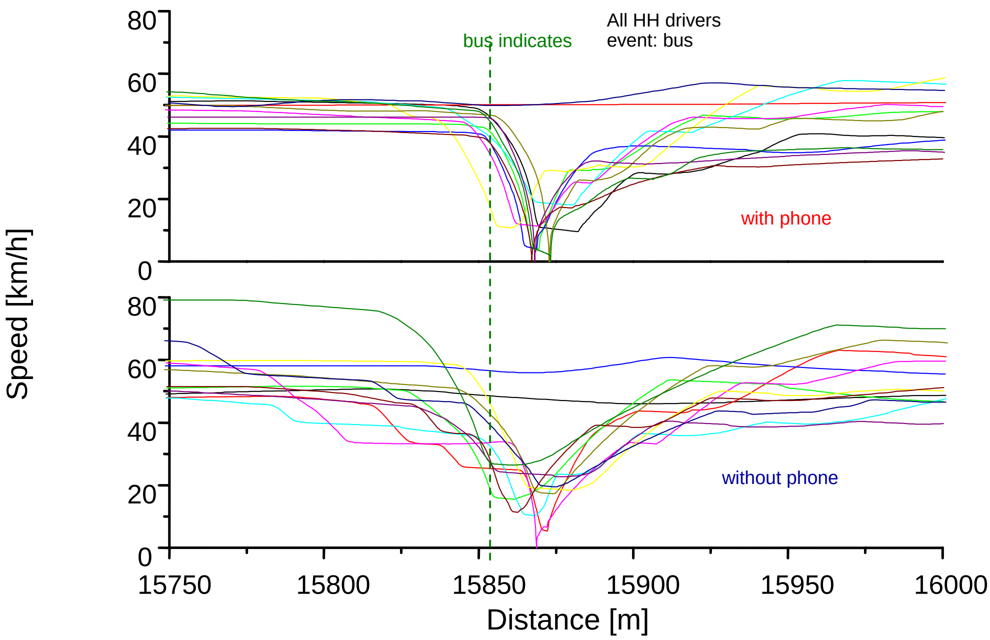


Figure 95 *Speed development for the handheld part in the bus event.*

2.6 Results mobile phone experiment – subjective effects

2.6.1 Perceived mental effort

Perceived mental effort is measured on the RSME scale, 0–150, where 0 represents "absolutely no effort" and 110 "very great effort".

Figure 96 shows the average mental effort for all 24 participants using a handsfree phone and all 24 participants using a handheld phone. There was no difference between the two groups (t(46)=.508; n.s.).

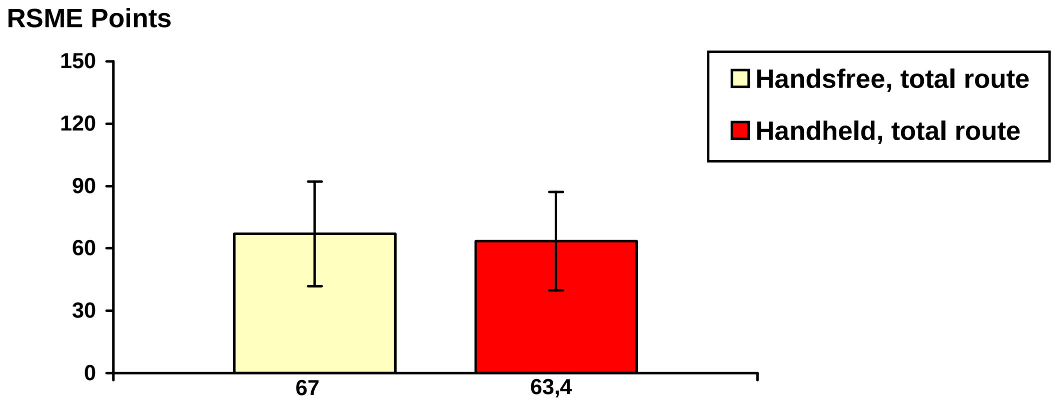


__Figure 96__ Perceived mental effort during total route (± SD).

2.6.2 Perceived mental effort (phone call during MC situation)

Half of the participants using the handsfree phone and half of the participants using the handheld phone received phone calls during the last motorbike situation. The average perceived mental effort is shown in Figure 97. According to performed t-tests, the perceived mental effort was not affected by the phone calls (Table 7).

The four conditions depicted in Figure 97 were compared with each other with respect to statistical significance. No difference between the four conditions was found (variance analysis: F(3,44)=.256; n.s.). Consequently, no difference between the phone modes was found.

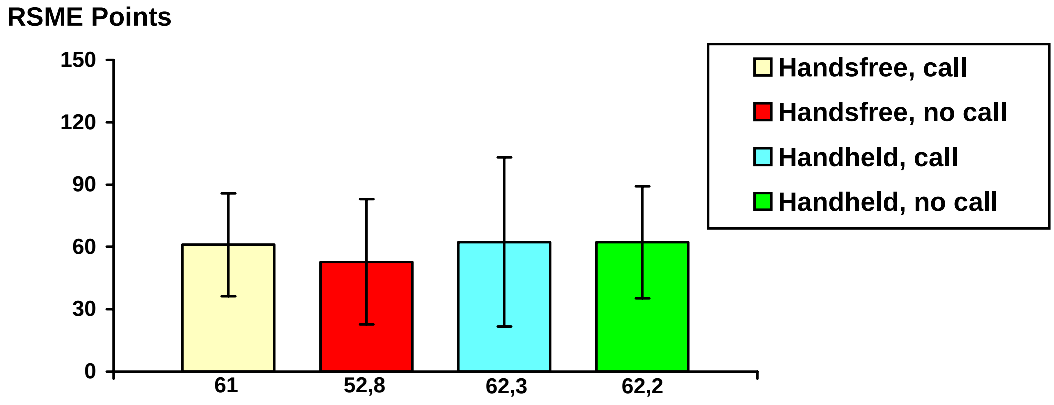


__Figure 97__ Perceived mental effort at last motorbike situation (± SD).

2.6.3 Opinion of handsfree and handheld phone

Question: *What is your opinion of using a handsfree/handheld phone while driving?*

Scale 0–100, where 0 represents “very negative” and 100 “very positive”.

Figure 98 shows the average ratings for the two phone modes. There was a large difference between the participants’ opinions of using either handsfree or handheld phone while driving. They were more positively inclined to the handsfree phone (t= 8.961; p<.001).

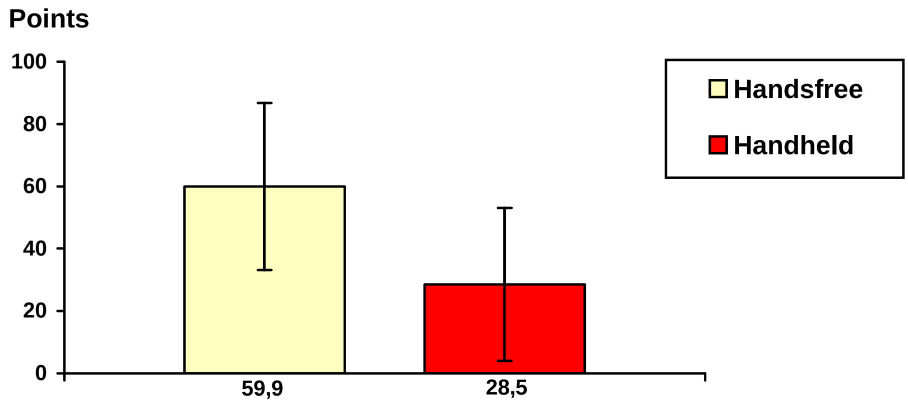


Figure 98 *Opinion about handsfree phone and handheld phone (± SD).*

2.6.3.1 Differences in opinion for participants using handsfree or handheld phone

Data on opinion of handsfree was obtained from 22 participants using a handsfree phone and 24 participants using a handheld phone. Data on opinion of handheld phone was obtained from 24 participants using handsfree and 23 participants using handheld phone. The average ratings are shown in Figure 99.

According to performed t-tests, participants’ opinions were not affected by phone mode (Table 8).

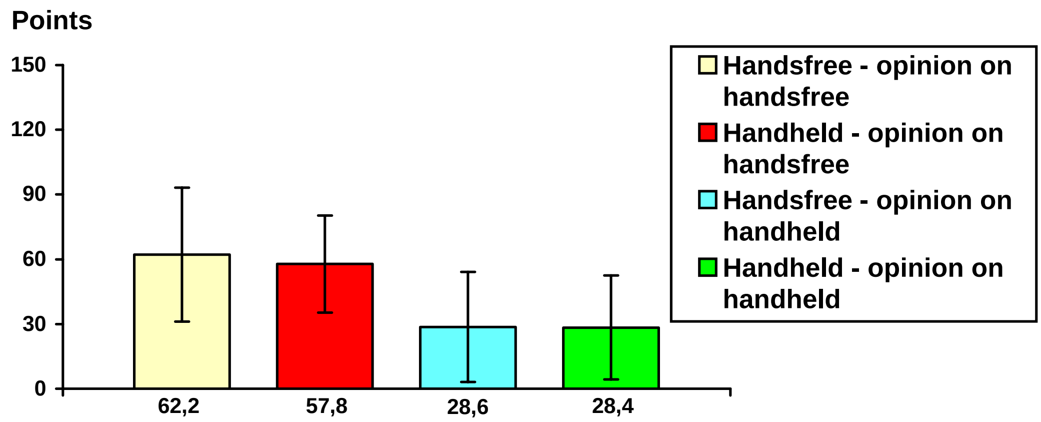


Figure 99 *Opinion on handsfree and handheld phone (± SD).*

2.6.4 Mobile phone use

2.6.4.1 Phone use while driving

Almost 60% of the 48 participants asked used a handheld phone in the car. Second most common was using a phone with a headset (see Figure 100). 12.5% of the participants did not use any mobile phone while driving.

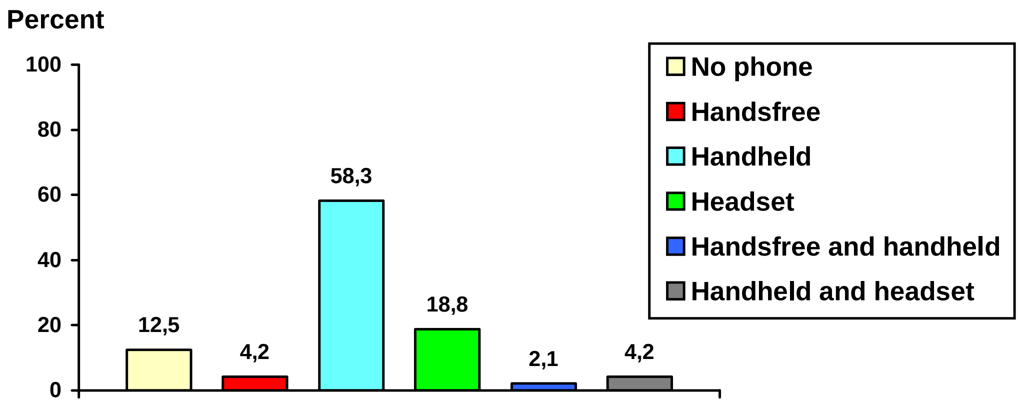


Figure 100 *Phone use while driving.*

2.6.4.2 Frequency of phone use

Question 2b: *If you use a mobile phone while driving, how often do you use it?*
Scale 0–100, where 0 represents “very rarely” and 100 represents “very often”. Figure 101 shows the average percentage of mobile phone use.

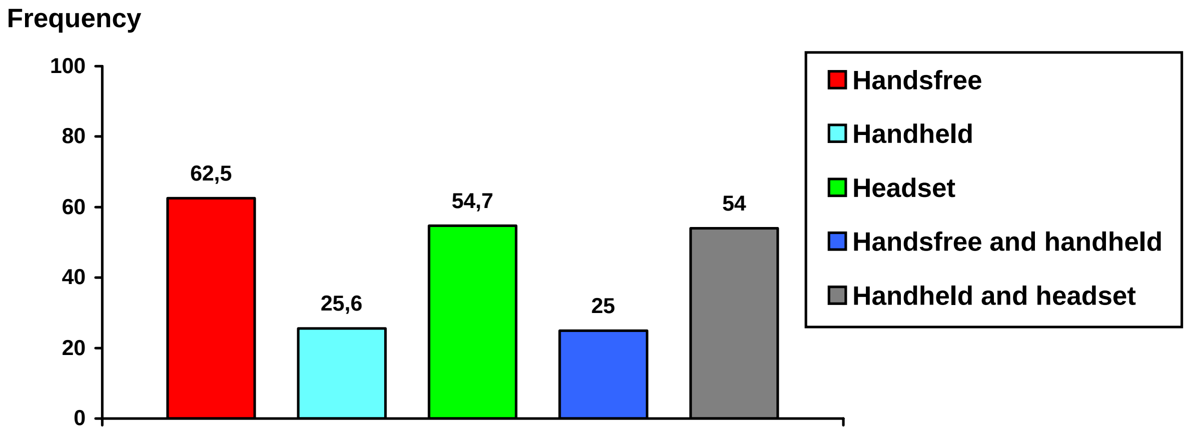


Figure 101 *Frequency of phone use.*

2.6.4.3 Perceived required effort when talking on the mobile phone

Question 3: *How much effort did it require to talk on the mobile phone while driving?*

Scale 0–100, where 0 represents “no effort” and 100 represents “very great effort”.

Figure 102 shows the average perceived effort when talking on the phone while driving. The scale was 0 to 100, where 0 represents “no effort” and 100 represents “very great effort”. Perceived effort was not affected by phone mode (t(46)=.604; n.s.).

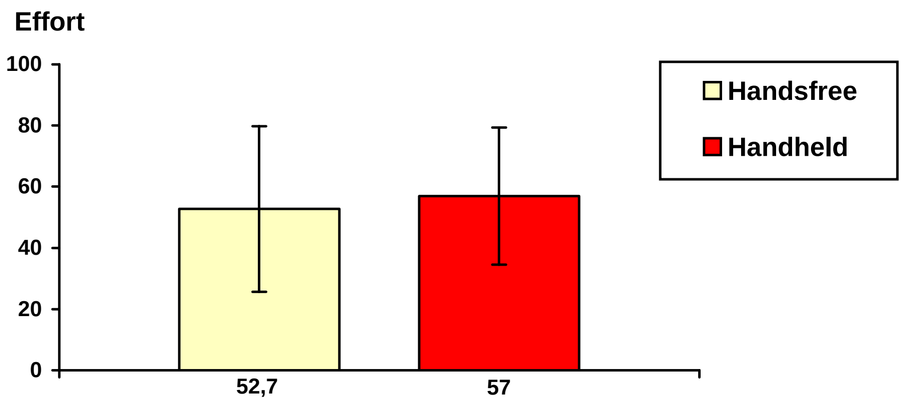


Figure 102 *Perceived effort (0-100) when talking on the phone (± SD).*

2.6.4.4 Preference of phone mode

Question 4 (participants using a handsfree phone): *If you could have chosen, would you have taken the phone in your hand instead of leaving it in its position?*

Almost 80% of the 24 participants using a handsfree phone would not have taken the phone in their hand if they had had the choice (see Figure 103).

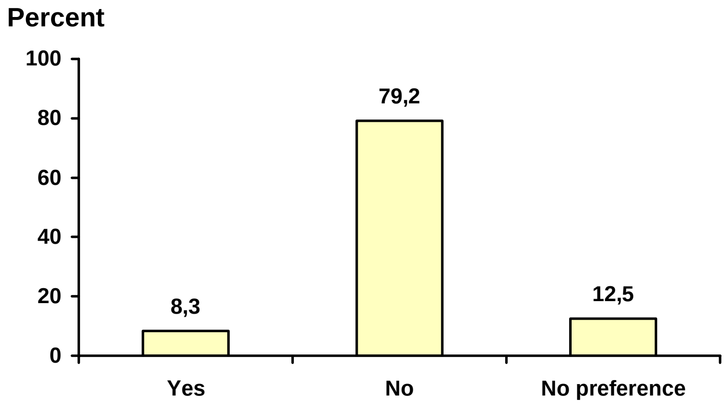


Figure 103 *Preference of phone mode for participants using a handsfree phone.*

Question 4 (participants using a handheld phone): *If you could have chosen, would you have let the phone remain in its holder instead of taking it in your hand?*

Almost 80% of the 24 participants using a handheld phone would have let the phone remain in its holder (see Figure 104).

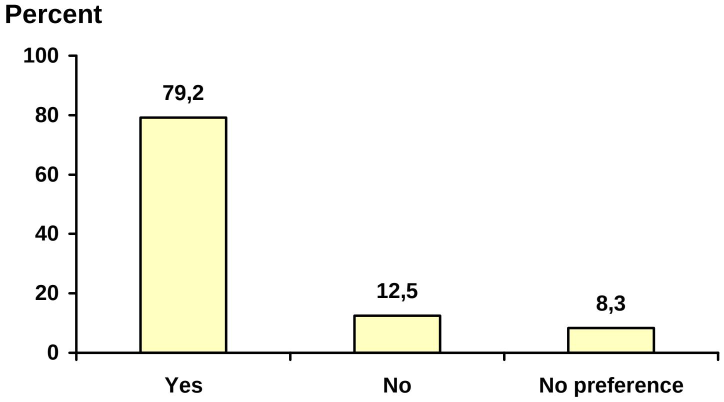


Figure 104 *Preference of phone mode for participants using a handheld phone.*

2.6.4.5 Concentration during the phone calls

Question 5: *What did you concentrate on during the phone calls?*

More than half of all participants reported they were mostly concentrated on the driving task during the phone call (see Figure 105). However, one-third of the participants stated that they were mostly concentrated on the device. Data were obtained for all 48 participants.

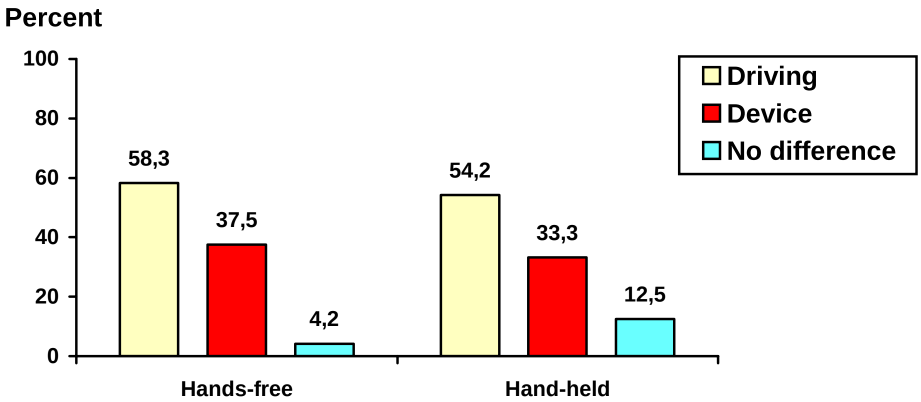


Figure 105 *Concentration during the phone calls.*

2.6.5 Effects of using mobile phone while driving

2.6.5.1 Speed change

Question 6: *Did the fact that you were using the mobile phone while driving affect your speed?*

Data were obtained for 24 participants using a handsfree phone and 23 participants using a handheld phone. The most common answer reported by the participants using a handsfree phone was an unconscious reduction of speed when talking on the phone, while the most common answer from the participants using a handheld phone was a conscious reduction of speed (see Figure 106).

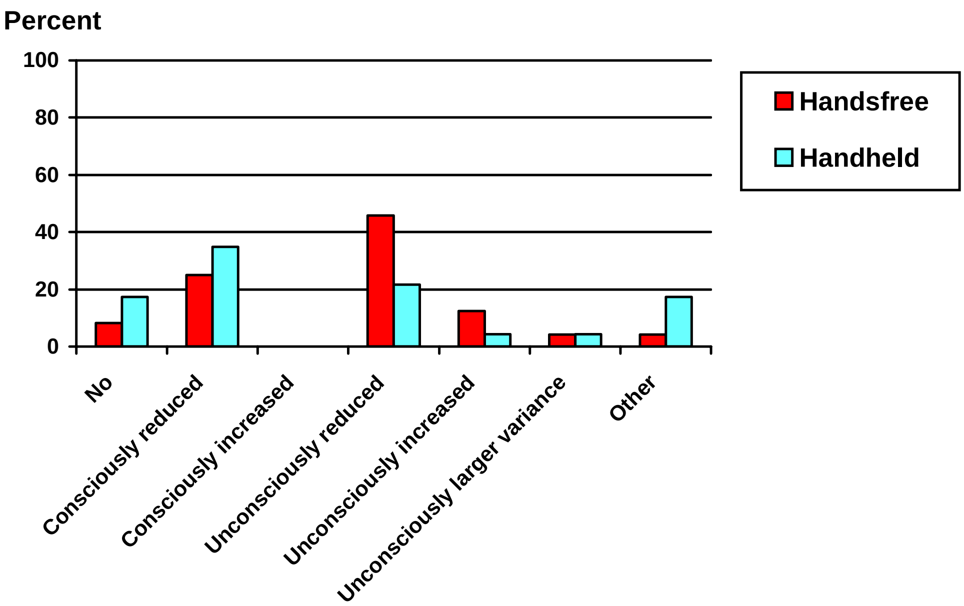


Figure 106 *Reported speed change as a result of talking on the phone.*

2.6.5.2 Headway change

Question 7: *Did the fact that you were using the mobile phone while driving affect your distance to the car in front of you?*

Data were obtained for all 48 participants. There were participants who answered that their distance to the car in front of them unconsciously both increased and decreased: these answers were put in the category “unconsciously larger variance”. The most common answer from the participants using the handheld phone was that speaking on the phone did not affect their distance to the car in front of them (see Figure 107). This answer was also very common for the handheld group. Twenty-nine per cent of the participants in both groups reported a conscious increase of distance.

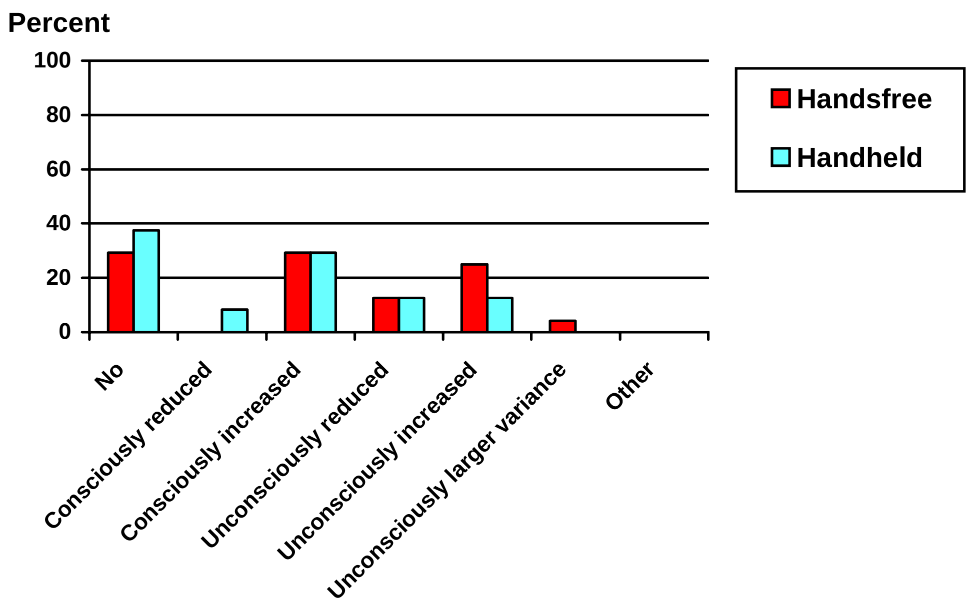


Figure 107 *Headway change as a result of talking on the phone.*

2.6.5.3 Change of lateral position

Question 8: *Did the fact that you were using the mobile phone while driving affect your lateral position?*

The majority of the participants reported no effect on lateral position (see Figure 108).

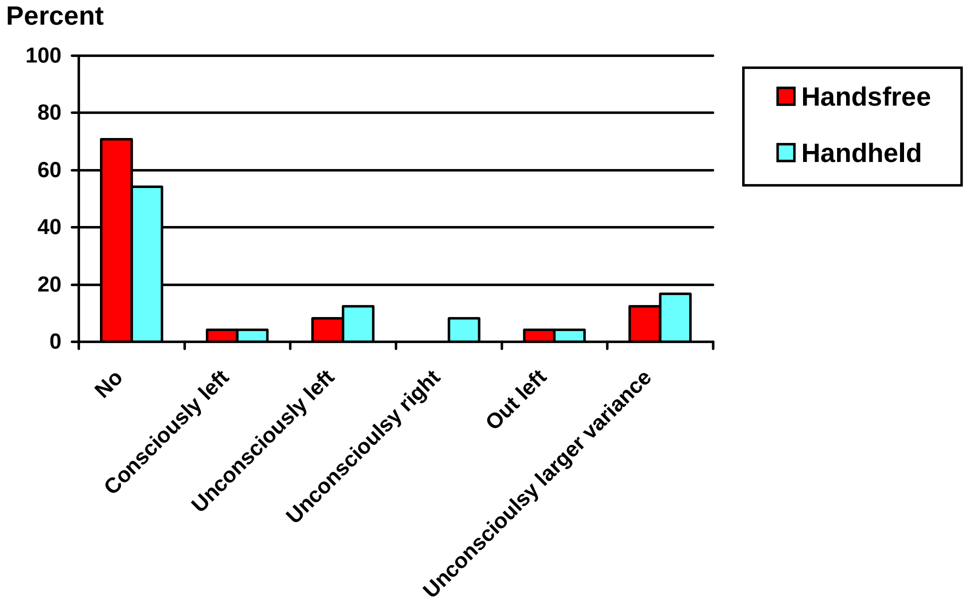


Figure 108 *Change of lateral position as a result of talking on the phone.*

2.6.6 Performance

Question 10: *Do you think your driving performance was better or worse than normal when talking on the phone?*

All 48 participants answered on a scale of 0 to 100, where 0 represents “much worse”, 50 represents “equal performance” and 100 represents “much better”. The average perceived driving performance is shown in Figure 109. There was a significant difference in perceived performance between participants using a handsfree phone and participants using a handheld phone, ($t(46)=2.387$; $p<.05$). Participants using the handheld phone reported a lower perceived driving performance, but for both phone modes the perceived driving performance was clearly reduced compared to driving without telephone.

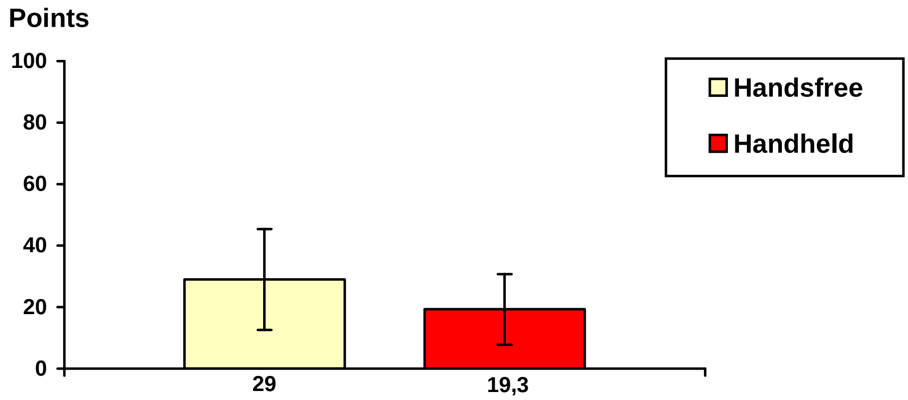


Figure 109 *Perceived driving performance (± SD).*

2.6.7 Traffic environment

Question 12: *In which traffic environment do you think it was easiest to use the mobile phone?*

The majority of the participants thought it was easiest to use the phone when driving in a rural traffic environment (see Figure 110). No participants reported that it was easiest to use the phone when driving in urban areas.

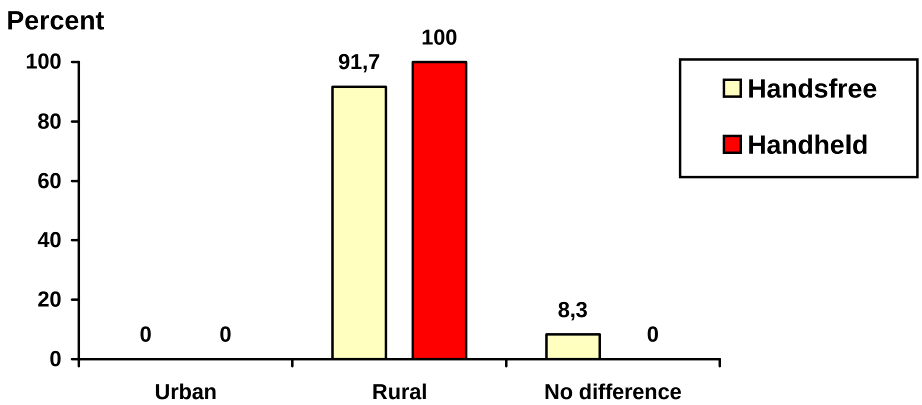


Figure 110 *Traffic environment and mobile phone use.*

2.6.8 Summary of results – Subjective effects

No difference in perceived mental effort (RSME) was apparent between handsfree and handheld phone. No effect of phone use regarding perceived mental effort was apparent at the last motorbike situation.

Similarly, there was no clear difference between the two phone modes regarding perceived effort (effort scale) when talking on the mobile phone.

The opinion of using a mobile phone while driving was more positive to handsfree than to handheld phone. The opinion was not differently affected by previous experience of phone use (handsfree or handheld) during the experiment.

More than 70% of the users of handsfree phone reported a speed reduction as an effect of phone use.

More than 55% of the users of handheld phone reported a speed reduction as an effect of phone use.

29% of the users of handsfree phones, and 46% of the users of handheld phones, reported an effect of phone use on lateral position.

More than 50% of the users of handsfree phone reported a headway increase as an effect of phone use.

More than 40% of the users of handheld phone reported a headway increase as an effect of phone use.

Driving performance was rated lower for handheld than for handsfree phone.

It was rated easiest to use the mobile phone in rural areas for both phone modes.

3 SMS experiment

3.1 Participants

Ten participants took part in the experiment, seven males and three females. The mean age was 28.7±4.5 years. The drivers had held a driving licence for 10±4 years. The drivers had no problems when using the mobile phone.

3.2 Design

The SMS experiment had the same design as the telephone experiment (see Figure 2 on page 39). All ten participants received ten SMS messages containing short questions during the experiment, which had to be read aloud and answered orally. This procedure was adopted since it was the goal of the experiment to investigate how driving behaviour was affected when dealing with an incoming SMS message, so it was essential to make sure that the participant actually read and understood the message. The messages arrived in approximately the same locations along the route as the telephone calls in the phone conditions. The telephone was placed on the passenger seat in stand-by and had to be taken into the hand while reading the SMS. When receiving an SMS the mobile phone's display lit up and the phone beeped.

3.3 SMS task

The SMS messages were selected according to the following criteria: The messages should not place high cognitive demands on the participant, but it should be ensured that the participants read and understood the message (as mentioned above). The level of difficulty should be comparable for all messages the participant would receive during the trial. The message should be long enough to ensure that participants will have to deal with it for enough time that a critical situation can occur while the participant is busy with the SMS. The message should contain a simple question, which the participant has to answer. No scrolling should be necessary, thus SMS has to fit in "one screen" on the mobile phone. Also, it should be possible to verify whether the participant has given the correct answer. The same phone was used in the SMS condition as in the phone conditions.

It was decided to base each message on one of the four following patterns:

- *Which day follows X? (e. g. Monday, Tuesday, etc.)*
- *Which day comes before X?*
- *Which month follows X? (e. g. January, February, etc.)*
- *Which month comes before X?*

The advantages with this type of message are:

- All are approximately equally simple.
- All messages are approximately equally long.
- The correct answer is known.
- Everybody is capable of knowing the answer.

In Swedish, the messages varied between 29 and 35 characters in length, including spaces. Figure 111 shows what such a question looked like on the telephone.

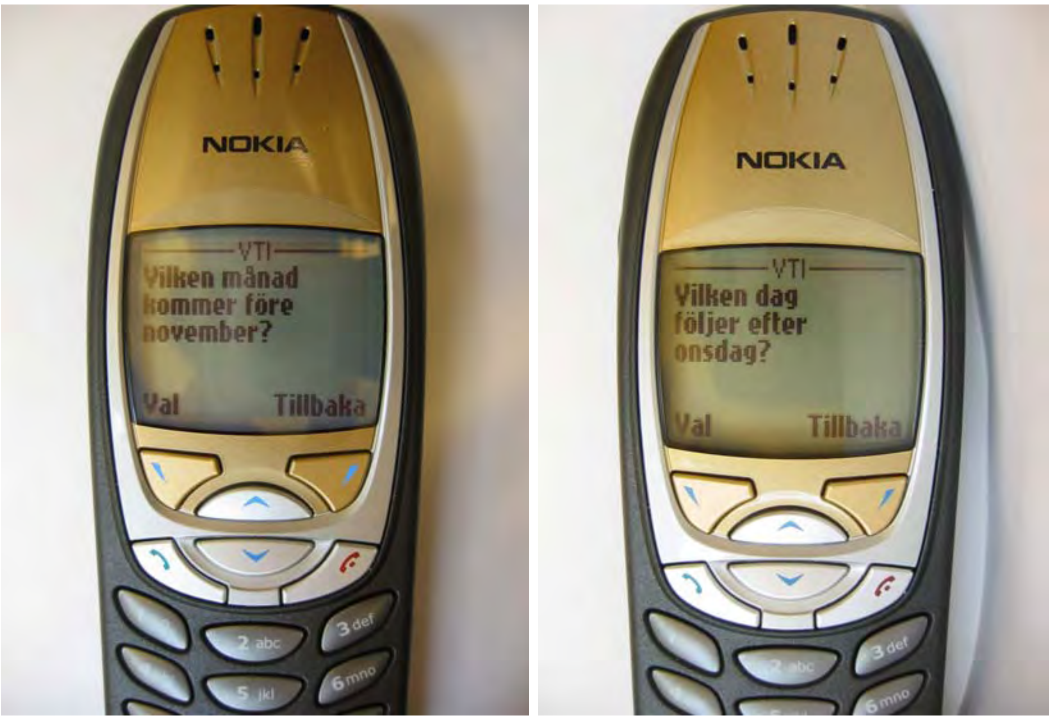


Figure 111 *Pictures of the telephone with two example messages in Swedish ("Which month comes before November?" and "Which day follows Wednesday?").*

The SMS messages were sent automatically via a computer. The standard cellular network was used in transmitting the SMS message; this caused some problems – at times the message was delayed and on a few occasions the message was not transmitted at all.

When the SMS arrived the driver had to pick up the phone, press the "Show" button ("Visa" in Swedish) on the mobile phone and read the message aloud. Then the message had to be answered verbally. The experimenter heard the answer over the microphone and noted whether the answer was correct or incorrect. After having answered the question the participant pressed "Back" ("Tillbaka" in Swedish) on the mobile phone (to get back to standard mode) and put the telephone back on the passenger seat.

3.4 Results SMS experiment – behavioural effects

The sample size was small: n = 10, and for one of the participants the data was incomplete for one of the situations and therefore excluded from that particular analysis (the motorbike situation) – the apparent reason behind quitting before the end of the session was motion sickness. In spite of that, statistical tests were performed in order to point out tendencies. This means that only very large and/or consistent effects become statistically significant. The results presented here cannot be considered to be very reliable, due to the small sample size.

Brake reaction times and longitudinal acceleration were analysed for four events – motorbike, bicycle, traffic light and bus. The number of participants stopping was analysed for three of the four events. After the drive the participants answered two questionnaires including RSME – Rating Scale of Mental Effort (see 1.6 Questionnaires above).

3.4.1 Brake reaction time performance at events

Effect of SMS on brake reaction time was analysed for each of four traffic environments with events (motorbike, bicycle, traffic light, bus).

Reaction time was prolonged by SMS in one situation – motorbike.

3.4.1.1 70 km/h rural: motorbike

The average reaction times at the motorbike situation are presented in Figure 112. The brake reaction time was prolonged by SMS ($t(8)=3.185$; $p<.05$). The time difference was 679 ms (Table 177).

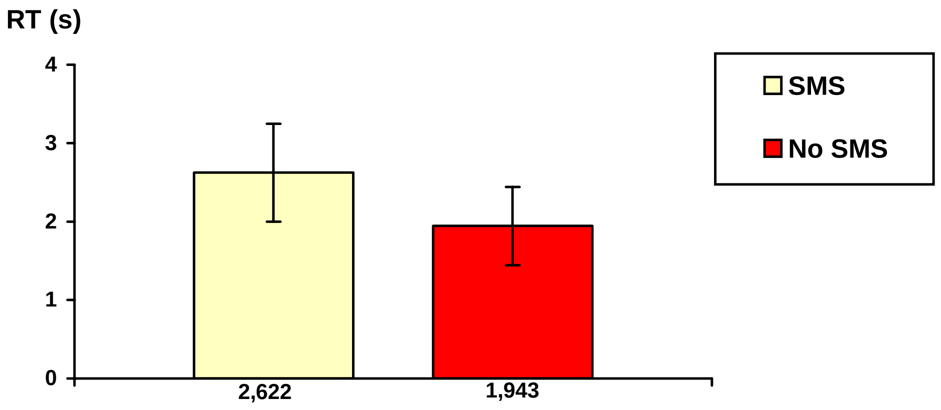


Figure 112 *Brake reaction time at motorbike situation (± SD), n=9.*

3.4.1.2 50 km/h urban complex: bicycle

The average reaction times at the bicycle situation are presented in Figure 113. No effect of SMS was demonstrated (Table 178).

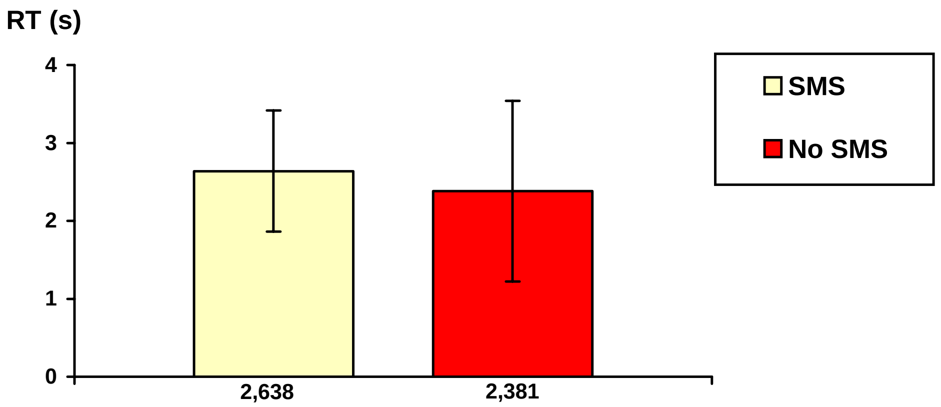


Figure 113 *Brake reaction time at bicycle situation (± SD), n=9.*

3.4.1.3 50 km/h urban medium: traffic light

The average reaction times at the traffic light situation are presented in Figure 114. No effect of SMS was demonstrated (Table 179).

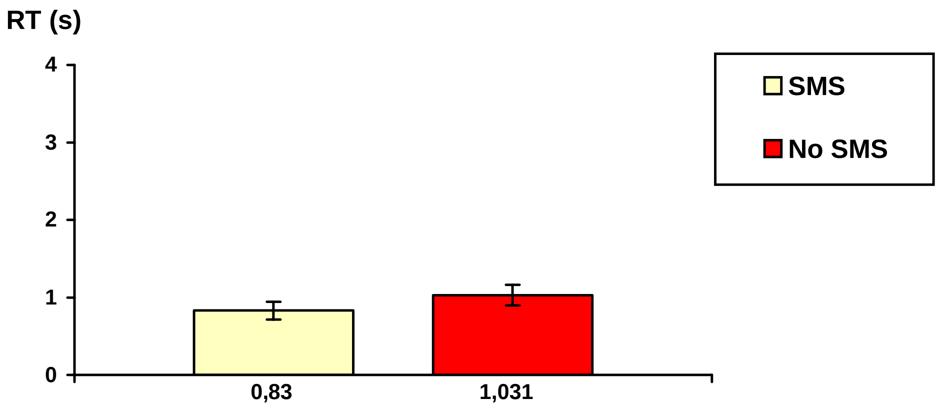


***Figure 114** Brake reaction time at traffic light situation (± SD), n=5.*

3.4.1.4 50 km/h urban simple: bus

The average reaction times at the bus situation are presented in Figure 115. No effect of SMS emerged (Table 180).

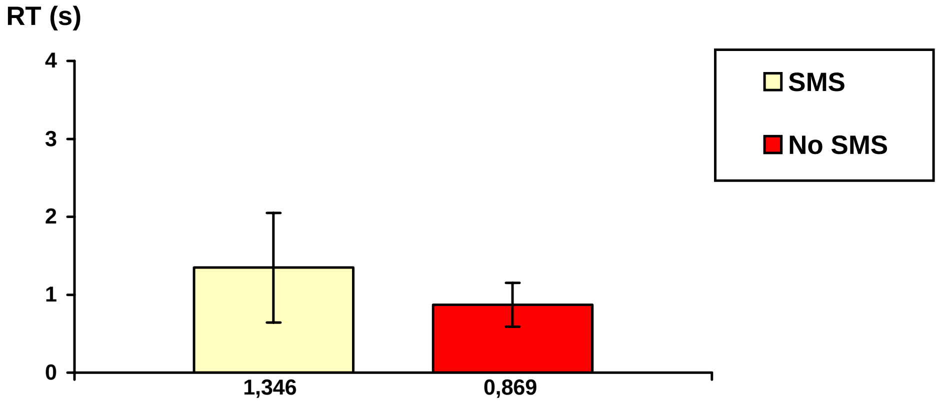


***Figure 115** Brake reaction time at bus situation (± SD), n=5.*

3.4.2 Maximum longitudinal deceleration

Effect of SMS on maximum longitudinal deceleration was analysed for each of four traffic environments with events (motorbike, bicycle, traffic light, bus). No effect of SMS was found (Table 181–Table 184).

3.4.3 Number of participants stopping at events

Effects of SMS on number of participants stopping at three events (bicycle, traffic light, bus) were analysed. No effects of SMS were found (Table 185).

3.5 Plots

In this chapter some data plots of the SMS experiment are shown. This is believed to allow a more qualitative look at the data than the results of the statistical analyses permit.

Figure 116 shows the speed development for a typical driver in the SMS experiment in the bus event. It can be seen that the driver brakes later and more hastily when reading the SMS. Figure 117 shows the speed and the side acceleration for the same driver in the 90 km/h rural environment without event. The side acceleration seems to have larger variability when reading the SMS. Note: in Figure 116 and Figure 117 the lower plot represents round one, and the upper plot represents round 2. Figure 118 shows the speed and lateral position development of five drivers in the SMS group in the 90 km/h rural environment. The time when each of the drivers reads the SMS is marked by boxes (colour refers to curves). The left turn – right turn sequence is the same two times in the graph, which means that the behaviour of the drivers can be compared for the left-right curve before the SMS and during the SMS. In Figure 118 the speed limit was 90 km/h over most of the curve, and the beginning of the 70 km/h speed limit is marked in the graph.

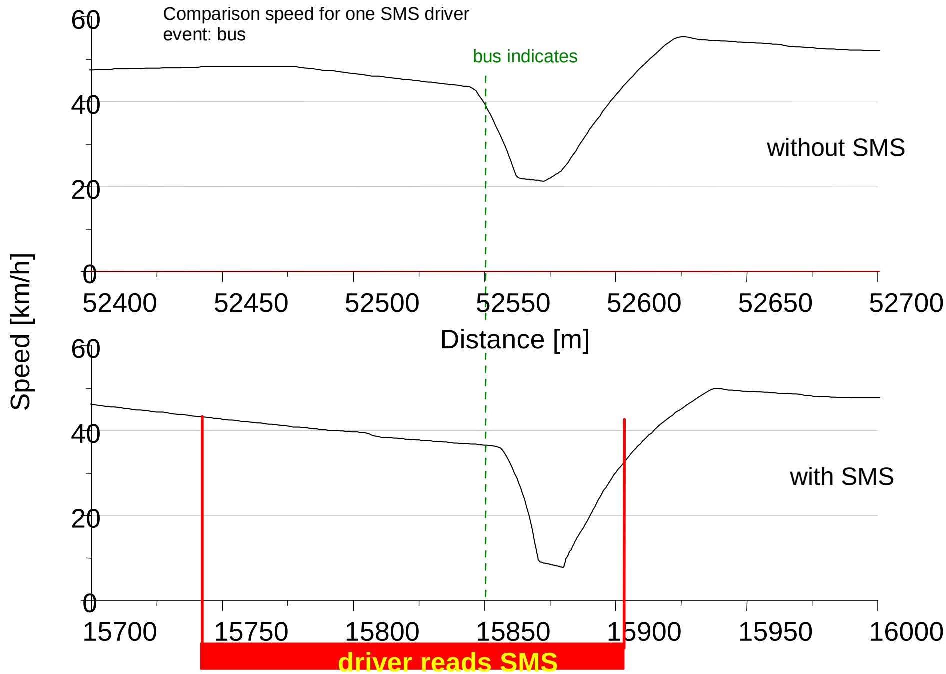


***Figure 116** Speed of a typical driver in the SMS group at the bus event.*

Figure 117 *Speed (black) and side acceleration (red) for a typical driver in the 90 km/h environment.*

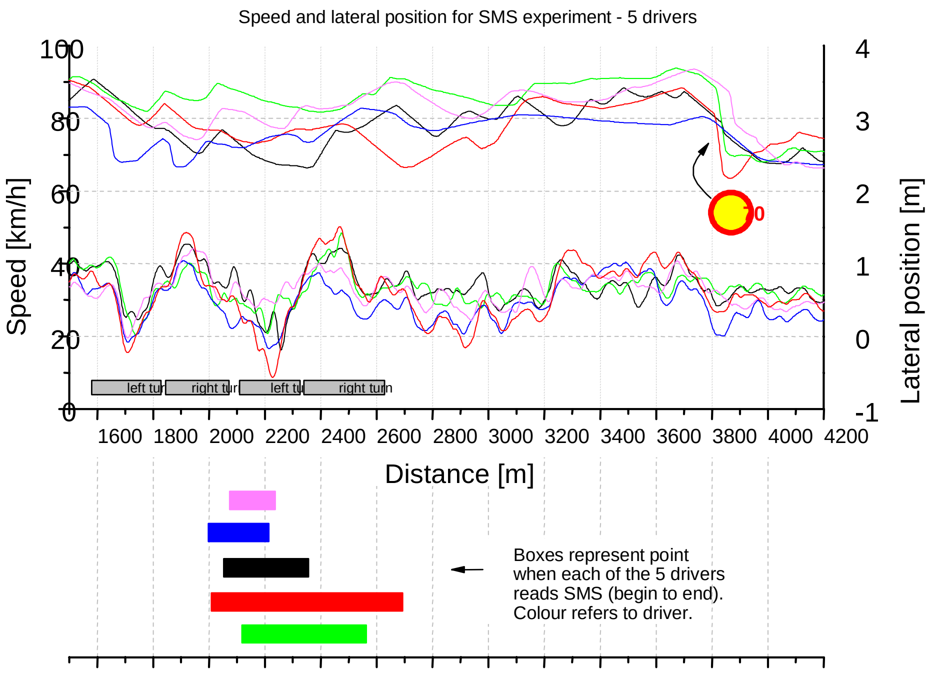


Figure 118 *Speed (upper curves) and lateral position (lower curves) of five drivers in the SMS part. Time when they read the SMS is marked.*

3.6 Results SMS experiment – subjective effects

3.6.1 Perceived mental effort

Perceived mental effort is measured on the RSME scale, 0–150, where 0 represents “absolutely no effort” and 110 “very great effort”. The average perceived mental effort for all eight participants was 62.5±50.2.

3.6.2 Perceived mental effort (SMS during last motorbike situation)

Half of the participants received an SMS message during the last motorbike situation, and the remaining participants did not. The average perceived mental effort is shown in Figure 119. According to a performed t-test, the perceived mental effort was not affected by SMS (t(8)=1.244; n.s.).

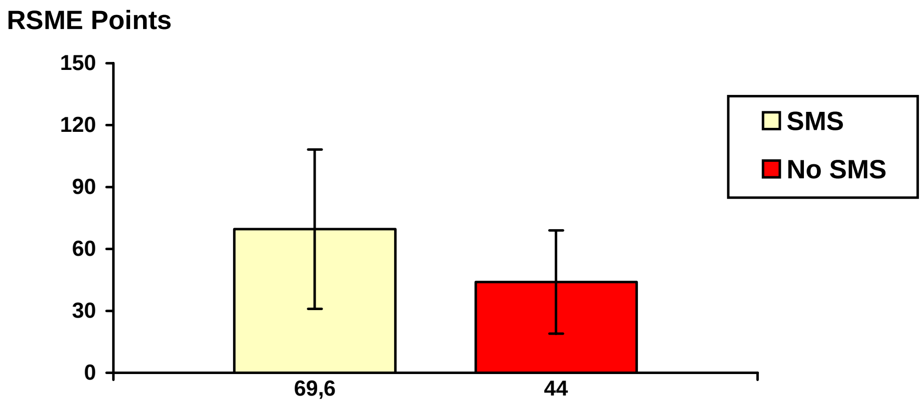


Figure 119 *Perceived mental effort at last motorbike situation (± SD).*

3.6.3 Opinion of SMS

Question: *What is your opinion of sending and receiving SMS messages while driving?*

Scale 0–100, where 0 represents “very negative” and 100 “very positive”.

Nine (out of ten) participants answered the question. Figure 120 shows the average rating for sending and receiving SMS messages. The opinion of sending SMS while driving is very negative, but more indifferent for receiving SMS.

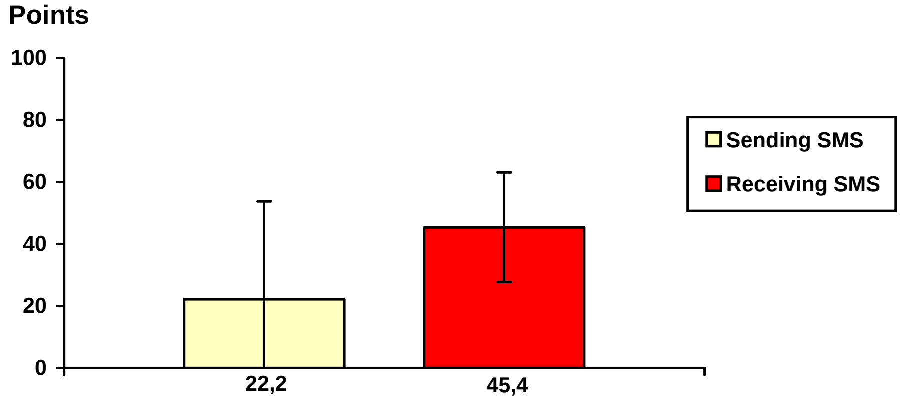


Figure 120 *Opinion about SMS (± SD).*

3.6.4 SMS use

3.6.4.1 SMS use while driving

Question: *Do you use SMS in the car while you drive (no, read, send)?*

Answers were given by nine participants. Four of the participants reported that they never use SMS while driving. Two participants reported that they read incoming SMS messages, whereas the remaining participants reported that the both send and read SMS messages while driving.

3.6.4.2 Frequency of using SMS in car

Question: *How often do you use SMS in the car while you drive (0=never, 100=always)?*

Answers were given by five participants. The answers ranged from 0 to 40 with 21 as the average.

3.6.4.3 Perceived required effort reading SMS

Question 3: *How much effort did it require to read SMS messages while driving?*

Scale 0–100, where 0 represents “no effort” and 100 represents “very great effort”.

Nine participants answered the question. The scale was 0 to 100, where 0 represents “no effort” and 100 represents “very great effort”. The average perceived effort when receiving SMS while driving was 27.7±24.

3.6.4.4 Concentration while reading SMS

Question: *What did you concentrate on when the SMS message arrived (the message, driving, no difference)?*

Two participants reported that they were most concentrated on reading the SMS message, whereas the remaining eight participants reported that they were most concentrated on driving.

3.6.5 Effects of receiving SMS message while driving

3.6.5.1 Speed change

Question 6: *Did the fact that you were reading the SMS message while driving affect your speed?*

Data were obtained for all 10 participants. Seven participants reported that they had reduced their speed while reading the SMS message (see Figure 121).

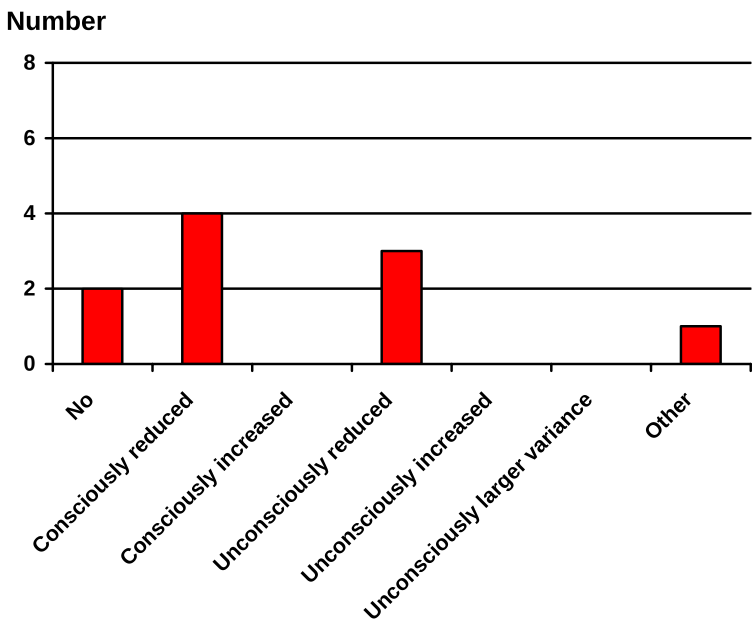


Figure 121 *Reported speed change as a result of reading the SMS message.*

3.6.5.2 Headway change

Question 7: *Did the fact that you were receiving the SMS while driving affect your distance to the car in front of you?*

Nine participants answered the question. Three of them reported that headway was not affected by the SMS (see Figure 122).

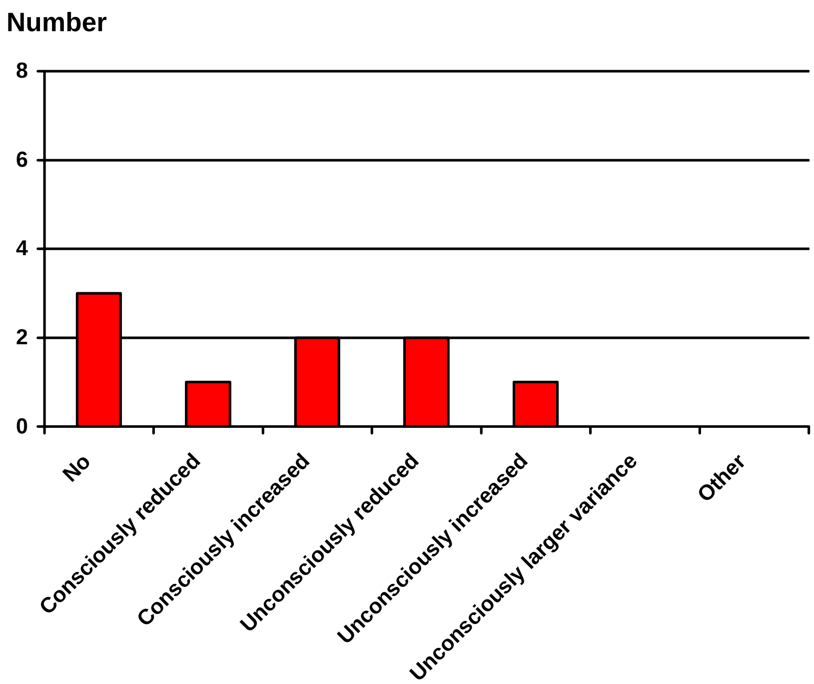


Figure 122 *Headway change as a result of reading SMS message.*

3.6.5.3 Change of lateral position

Question 8: *Did the fact that you received an SMS while driving affect your lateral position?*

Four participants reported that they kept to the left unconsciously, whereas four of reported that their lateral position had not changed as an effect of reading an SMS message (see Figure 123).

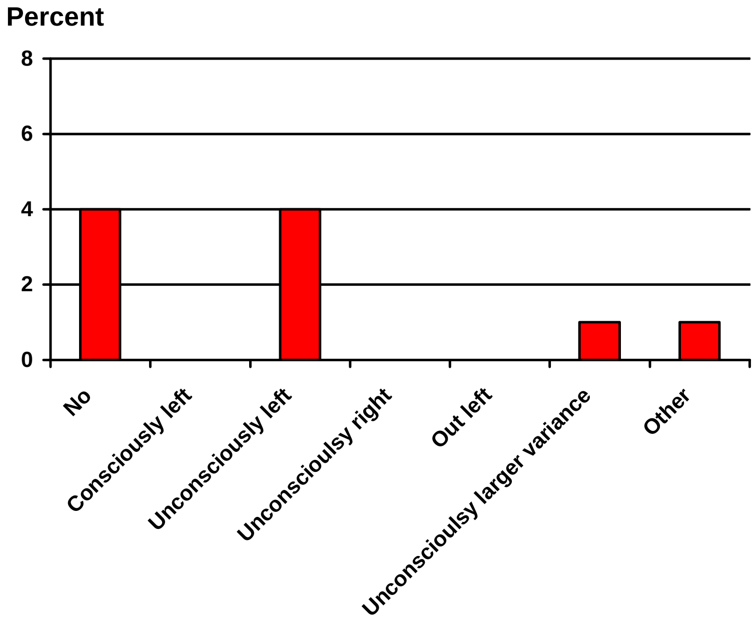


Figure 123 *Change of lateral position as a result of reading SMS message.*

3.6.6 Performance

Question 10: *Do you think your driving performance was better or worse than normal when reading the SMS message?*

The ten participants answered on a scale of 0 to 100, where 0 represents “much worse”, 50 represents “equal performance” and 100 represents “much better”. The average perceived driving performance was 33.7±12.8.

3.6.7 Traffic environment

Question 12: *In which traffic environment do you think it was easiest to read the SMS message?*

All participants but one thought it was easiest to read the message when driving in a rural traffic environment (see Figure 124).

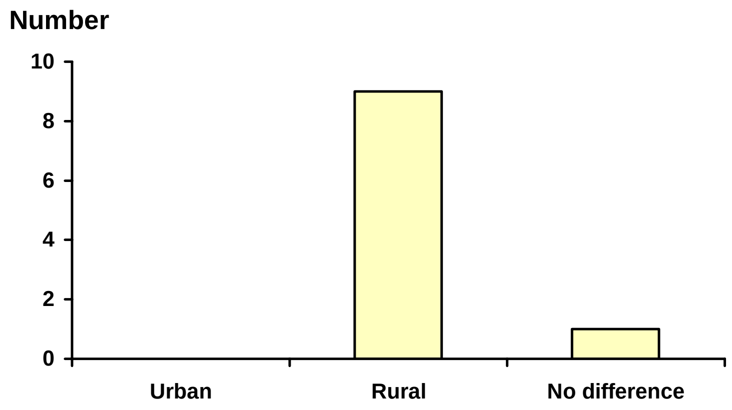


Figure 124 *Traffic environment and reading SMS message.*

3.6.8 Summary of results – Subjective effects

Perceived mental effort (RSME) was analysed for the last motorbike situation. No effect of SMS was apparent.

The opinion of sending SMS while driving was rated rather negative. It was not that negative for receiving SMS while driving.

7 out of 10 reported a speed reduction as an effect of SMS.

6 out of 9 reported a change in headway as an effect of SMS.

6 out of 10 reported a change in lateral position as an effect of SMS.

Driving performance was rated not too low.

4 DVD experiment

4.1 Participants

Eight participants took part in the experiment, six males and two females. The mean age was 28.8±4.4 years. The drivers had held a driving licence for 10.7±4.7 years.

4.2 Design

The participants were required to watch a DVD film during one round of the drive. In order to make sure that the participants did not completely ignore the film, they were asked to name orally occurrences of certain events in the film. The participants did not have to operate the DVD player; they only watched the film while driving.

4.3 DVD task

The following requirements were placed on the DVD screen:

- Screen and player separated.
- Colour screen with good contrast.
- Possibility to control the player remotely.
- Screen size: 7" (diagonal)

A Panasonic CY-VM1500 screen was selected (display size: 160 mm x 87.5 mm, Resolution: 336x960 pixels).

The driving simulator with DVD screen is shown in Figure 125. The positioning of the screen was the same as with the mobile phone.

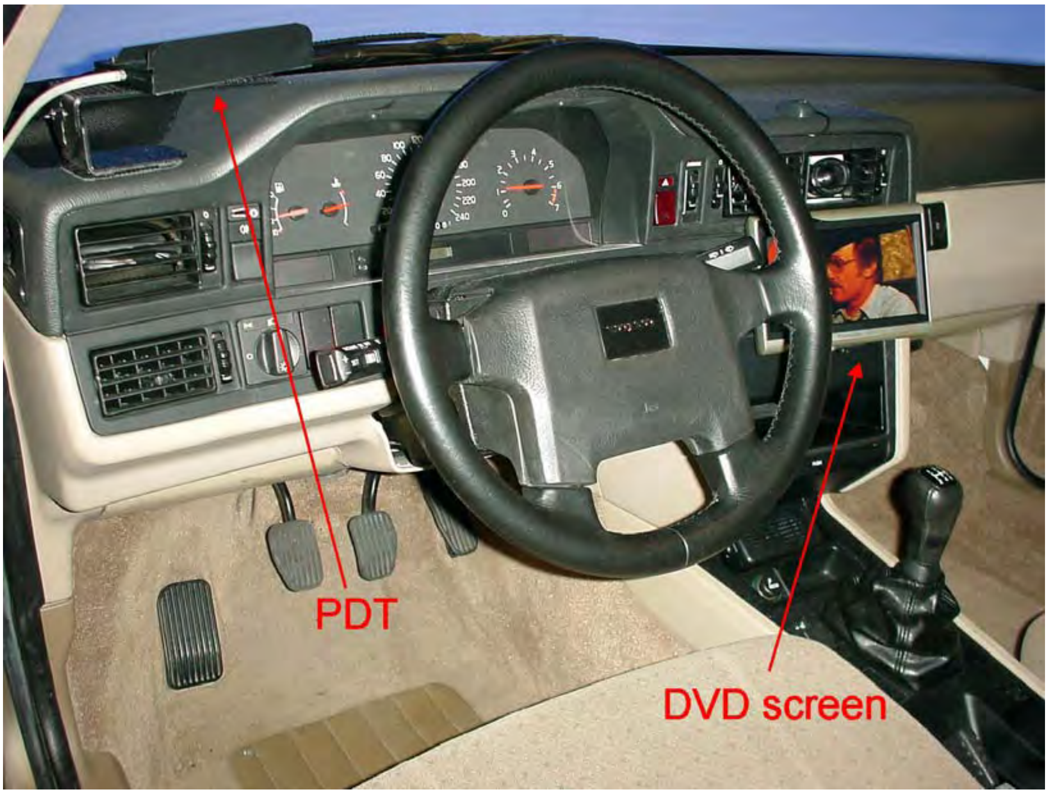


Figure 125 *Inside of the driving simulator with DVD screen and PDT visible.*

For choosing an appropriate DVD film the following requirements had to be met:

- The language should be Swedish or English.
- At least 40 minutes of film were needed.
- The film should be available on DVD or VHS.
- The film should not be very new to avoid a situation whereby some participants may have seen it recently at the cinema, and thus remember the plot very well, while others have not seen it at all.
- No violent, sexual or otherwise offensive content.
- The plot should not be too complicated to make sure that the participants could follow the film without having to look at the screen constantly.
- The level of suspense should be similar throughout the film rather than having one distinct culmination in order to avoid a distortion of the distribution of glances. This is important, because a culmination would be likely to appear during different traffic situations for different participants, due to different driving speeds.
- Distinct "events" that can be named reliably by the participants should occur several times throughout the film. Such an event could be a certain type of action of a certain character or the appearance of a certain object, for instance. The requirement was that the event should be clearly visible (the screen is relatively small) and easily recognisable.
- The events should not be recognisable by changes in the soundtrack.
- The event should occur around 5 to 10 times in half an hour. More frequent appearance might lead to a risk whereby the participant just names the event without watching the film, expecting that he/she will "score a hit". With less frequent occurrence the risk is that the participant misses all of the events, which would make it unclear whether or not the participant watched the film at all.
- The events should be around 10 to 30 seconds long. A shorter appearance would mean that the events can easily be missed, even though the participant watches the film intermittently, while a longer appearance would make the events detectable with only a few random glances.

Of several films considered, the road movie "Duel" by Steven Spielberg from 1970 was selected for closer examination, because it matched the requirements best. Most of the time the film features a passenger car and a truck engaged in a kind of competition, during which the truck threatens the car driver more and more. The part of the film chosen to be shown was 40 minutes long, from 00:42:44 to 01:22:30 of a total of 1:28:00. Two experimenters watched the film several times to collect possible events. It was decided to run a small scale qualitative pilot study to test whether the film was suitable and if so, which of the events was better suited. The two events tested are described in Table 4.

Table 4 *Description of the two events tested in the pilot study.*

Event	Description	Number of occurrences in 40 minutes
"Stop"	Main character stops his car	11
"Other vehicle"	Other vehicle than the main character's car and the truck appears	9

The “other vehicle” event occurred 9 times during the 40 minutes of film used (no other vehicle appeared in the last 9 minutes, therefore participants that needed approximately half an hour to complete the experimental route once had the chance to see all other vehicles). The vehicles that appeared were one school bus, three trains, four other passenger cars and one heap of car wrecks. The school bus was present for six and a half minutes, all other vehicles were present between 18 seconds and 1:15 minutes.

4.4 Pilot study preceding the DVD experiment

Two women and one man participated in the pilot study, which took about 45 minutes per participant. The participants were recruited among colleagues who were not familiar with the project within which the study was conducted.

The pilot study was kept at a low-cost level, therefore the film was not tested in the driving simulator but in a simpler setup. The participants were required to play Tetris while watching the film. Tetris is a computer game in which blocks of different shapes drop from above one after the other (cf. Figure 126). The player can turn the blocks and move them to the left and to the right to fit them into the pile below with the goal of not leaving any empty spaces. Each completely filled row is removed. For each removed row the player receives one point on the score, if two rows are removed at the same time, one extra point is received for each extra row. The falling speed of the blocks accelerates over time. The game is over when the pile of blocks reaches the upper end of the screen. Whenever the game was over during the experiment, the experimenter noted the achieved score, and the participant restarted the game.

Figure 126 *A screen-shot of an ongoing Tetris game as used in the pilot study. The sound was turned off and the level of difficulty was set to remain the same throughout the game, even though the speed of the falling blocks accelerated over time.*

Tetris was chosen because it demands more or less constant attention, even though it is possible to glance away for a second or two when a block is moved into the correct position and only needs to fall down. While playing Tetris, the participants had to watch the chosen 40 minutes of the film “Duel” and name one of the two “events” which were tested. Their Tetris scores were added to a score for naming the events correctly, and the participants were told that the one who reached the highest overall score would win a piece of cake, in order to heighten their motivation.

The participants were informed that they were participating in a pilot study for an experiment in which the influence of watching a DVD film on driving behaviour would be investigated, and that the aim of the pilot study was to find a suitable film and a suitable task for the main experiment. The first participant was asked to name all “other vehicles”, the second participant was asked to name all “stops”. Both named all events correctly, even though observation of the participants and questioning them afterwards revealed that the “other vehicles” task was better suited. This was mostly due to the fact that it was not always clear whether the main character’s car really stopped or only went very slowly, and whether the necessary brief stop between reversing and going forward counted as a stop. Additionally the stops could often be predicted by what was happening before, such that the necessary glance frequency was lower for finding the “stop” events than for finding the “other vehicles” events.

This led to a preliminary choice of the “other vehicles” event. A third participant was tested with this event. She agreed in a short interview afterwards that the event was easily recognisable and that she judged it to be better than the “stop” event, which was described to her. All three participants agreed that the film was able to interest a potential viewer, even though the film was not presented from the beginning, and that it was easy to follow the plot even though only intermittent glances were possible.

The conclusions from the pilot study were that the film “Duel” was suitable for the purpose at hand, and that the participants in the main experiment would be asked to name the event “other car” while driving the simulator.

4.5 Results DVD experiment – behavioural effects

The sample size was small; n = 8, and for one of the participants the data was incomplete for seven of the ten situations and therefore excluded from those particular analyses (car following, motorbike, urban complex no event, urban medium traffic light and no event, urban simple bus and no event) – the apparent reason behind quitting long before the end of the session was motion sickness. Still, statistical tests were performed in order to point out tendencies. This means that only very large and/or consistent effects become statistically significant. The results presented here cannot be considered to be very reliable, due to the small sample size.

Most of the behavioural effect measures that were analysed in the mobile phone experiment were analysed in the DVD experiment as well for the same traffic situations as in that experiment, those dealing with lateral position were excluded (see Table 4).

After the drive the participants answered two questionnaires including RSME – Rating Scale of Mental Effort (see above 1.6 Questionnaires).

4.5.1 Driving speed

Effect of DVD use on driving speed was analysed for the whole test route and for one of the traffic environments with events (car following) and each of the five traffic environments without events.

4.5.1.1 Average speed

No effects of DVD use were apparent for average speed (Table 138-Table 144).

4.5.1.2 Speed variance

Speed variance was reduced for the total route by DVD. No effects were found for the different traffic situations.

4.5.1.2.1 Total route

Average speed variance during the whole test run is presented in Figure 127. Speed variance decreased as an effect of DVD use (t(7)=3.784; p<.05) (Table 145).

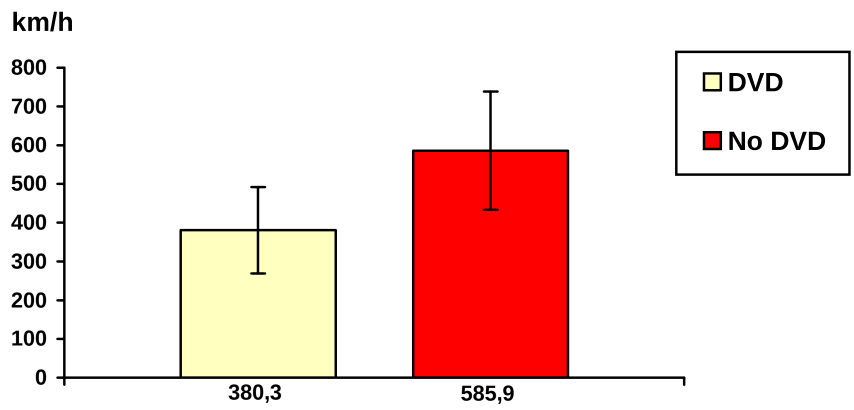


Figure 127 *Speed variance (± SD).*

4.5.1.2.2 90 km/h rural: car following

The average intra-individual speed variance at the *90 km/h rural: car following* situation is presented in Figure 128. According to a performed t-test, speed variance was not affected by DVD use (Table 146).

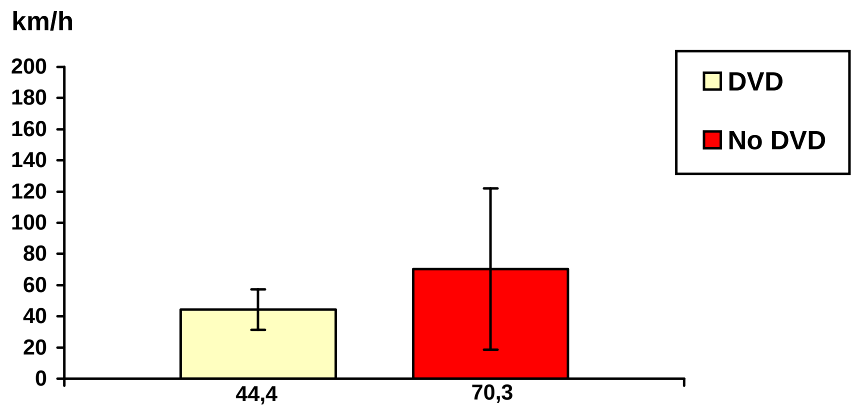


Figure 128 *Speed variance at car following situation (± SD), n=7.*

4.5.1.2.3 90 km/h rural: no event

The average intra-individual speed variance at the *90 km/h rural: no event* situation is presented in Figure 129. According to a performed t-test, speed variance was not affected by DVD use (Table 147).

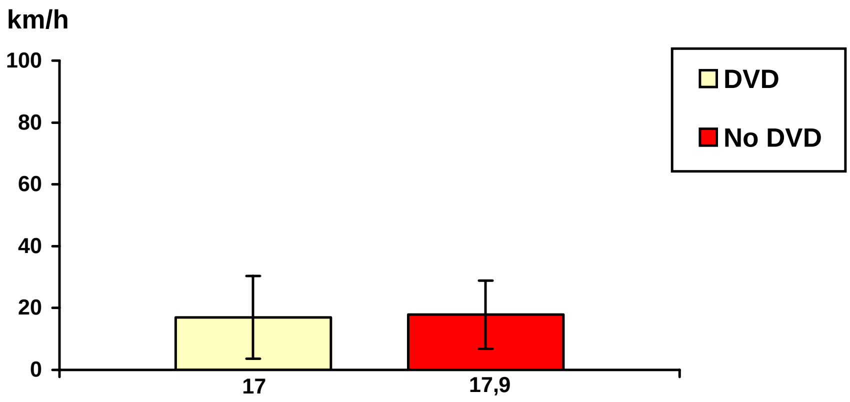


Figure 129 *Speed variance at 90 km/h rural: no event (± SD), n=8.*

4.5.1.2.4 70 km/h rural: no event

The average intra-individual speed variance at the *70 km/h rural: no event* situation is presented in Figure 130. According to a performed t-test, speed variance was not affected by DVD use (Table 148).

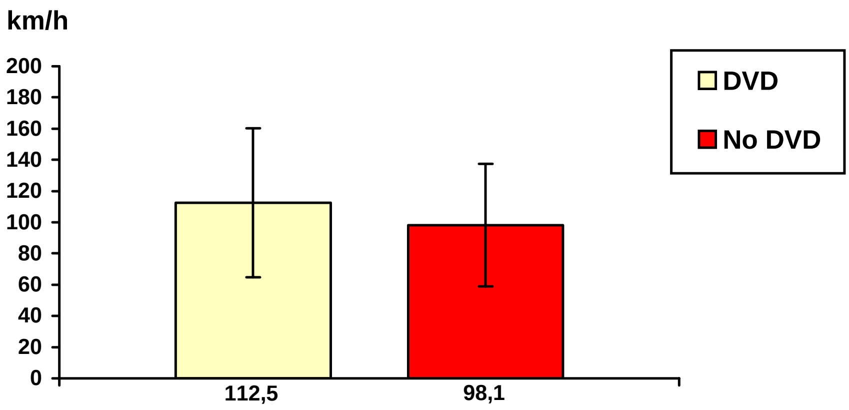


Figure 130 *Speed variance at 70 km/h rural: no event (± SD), n=8.*

4.5.1.2.5 50 km/h urban complex: no event

The average intra-individual speed variance at the *50 km/h urban complex: no event* situation is presented in Figure 131. According to a performed t-test, speed variance was not affected by DVD use (Table 149).

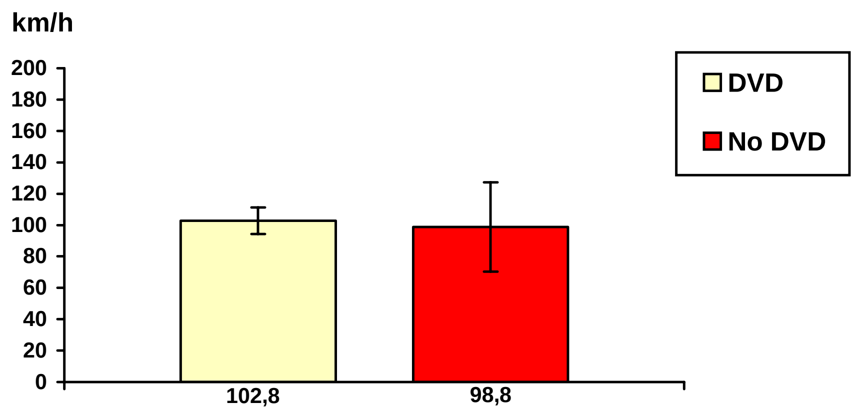


Figure 131 *Speed variance at 50 km/h urban complex: no event (± SD), n=3.*

4.5.1.2.7 50 km/h urban medium: no event

The average intra-individual speed variance at the *50 km/h urban medium: no event* situation is presented in Figure 132. According to a performed t-test, speed variance was not affected by DVD use (Table 150).

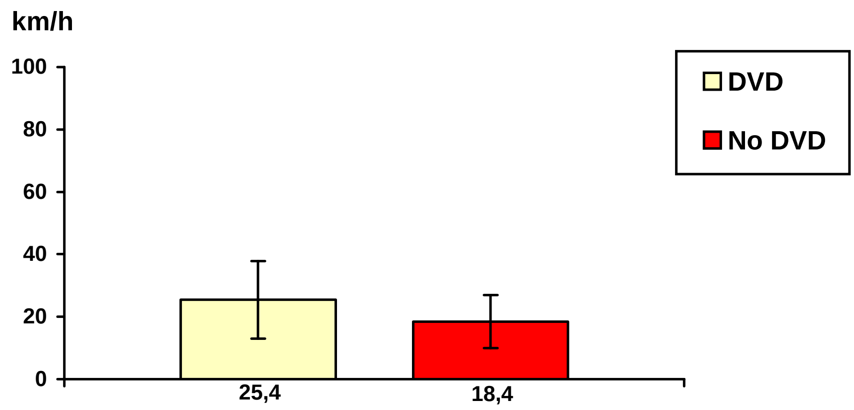


Figure 132 *Speed variance at 50 km/h urban medium: no event(± SD), n=7.*

4.5.1.2.7 50 km/h urban simple: no event

The average intra-individual speed variance at the *50 km/h urban simple: no event* situation is presented in Figure 133. According to a performed t-test, speed variance was not affected by DVD use (Table 151).

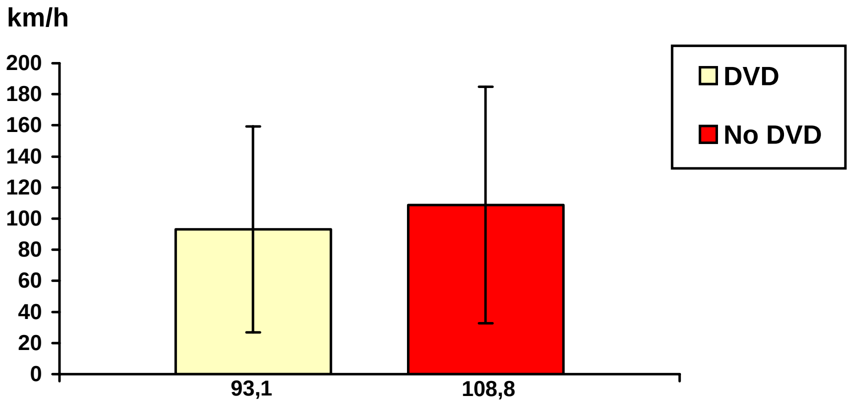


Figure 133 *Speed variance at 50 km/h urban simple: no event (± SD), n=7.*

4.5.1.3 Maximum speed

No effects of DVD use were found for average maximum speed (Table 152–Table 158).

4.5.2 Brake reaction time performance at events

Effect of DVD use on brake reaction times was analysed for each of four traffic environments with events (motorbike, bicycle, traffic light, bus). No effects of DVD use were apparent (Table 159–Table 162).

4.5.3 Maximum longitudinal deceleration

Effect of DVD use on maximum longitudinal deceleration was analysed for each of four traffic environments with events (motorbike, bicycle, traffic light, bus). No effects of DVD use were apparent (Table 163–Table 166).

4.5.4 Distance headway

4.5.4.1 Mean distance headway

Effect of DVD use on mean distance headway was analysed for one of the traffic environments with events (car following).

Mean distance headway increased as an effect of DVD at the car following situation.

4.5.4.1.1 90 km/h rural: car following

The average mean distance headway at the *90 km/h rural: car following situation* is presented in Figure 134. According to a performed t-test, mean distance headway increased as an effect of DVD use (t(6)=2.872; p<.05). The increase in distance was 15.4 m (Table 167).

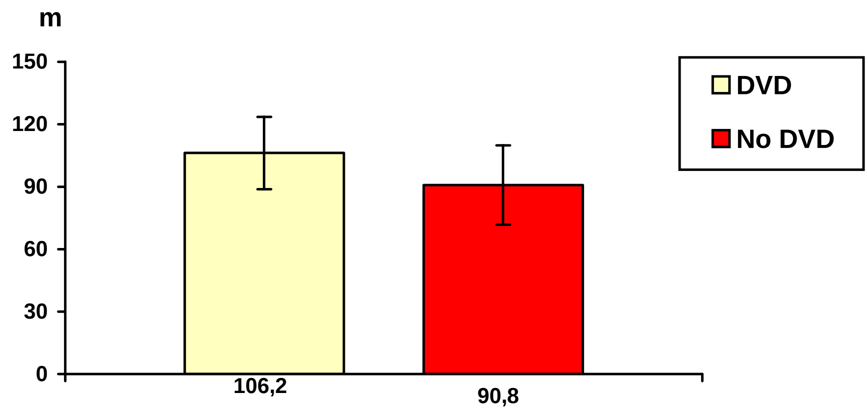


Figure 134 *Mean distance headway at car following situation (± SD), n=7.*

4.5.4.2 Distance headway variance

Effect of DVD use on distance headway variance was analysed for one of the traffic environments with events (car following). No effect of DVD use emerged (Table 168).

4.5.4.3 Minimum distance headway

Effect of DVD use on minimum distance headway was analysed for each of two traffic environments with events (car following, bus).

Minimum distance headway increased as an effect of DVD use at the car following situation.

4.5.4.3.1 90 km/h rural: car following

The average minimum distance headway at the *90 km/h rural: car following* situation is presented in Figure 135. According to a performed t-test, minimum distance headway increased by 16.1 m as an effect of DVD use ($t(6)=3.278$; $p<.05$) (Table 169).

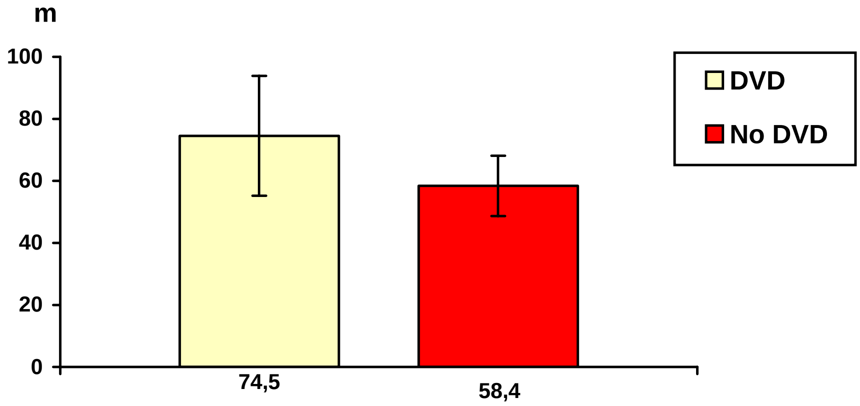


Figure 135 *Minimum distance headway at car following situation (± SD), n=7.*

4.5.4.3.2 50 km/h urban simple: bus

The average minimum distance headway at the *50 km/h urban simple: bus* situation is presented in Figure 136. According to a performed t-test, no effect emerged (Table 170).

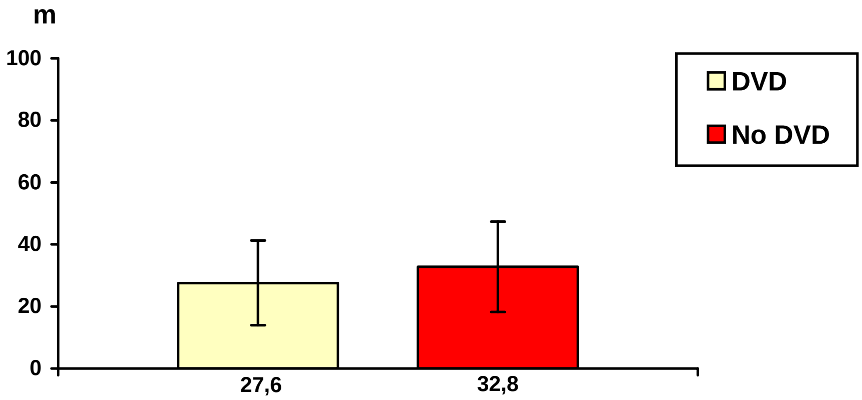


Figure 136 *Minimum distance headway at bus situation (± SD), n=7.*

4.5.5 Minimum time headway

Effect of DVD use on minimum time headway was analysed for each of two traffic environments with events (car following, bus).

Minimum time headway increased as an effect of DVD at the car following situation.

4.5.5.1.1 90 km/h rural: car following

The average minimum time headway at the *90 km/h rural: car following* situation is presented in Figure 137. According to a performed t-test, minimum time headway increased as an effect of DVD use ($t(6)=3.996$; $p<.01$). The difference in time headway was .26 s (Table 171).

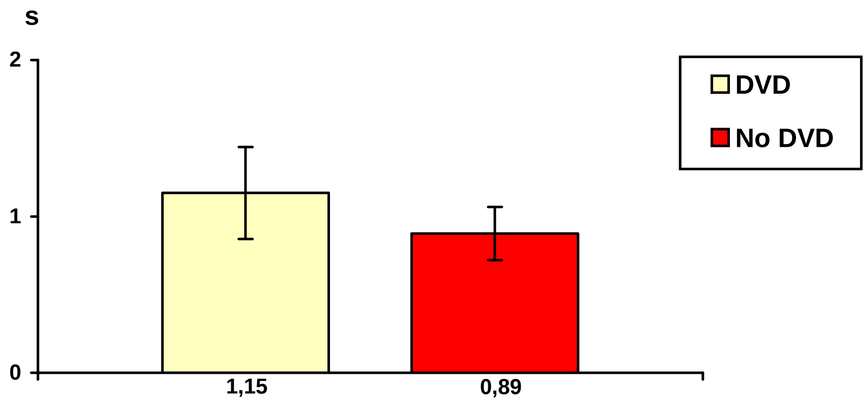


Figure 137 *Minimum time headway at car following situation (± SD), n=7.*

4.5.5.1.2 50 km/h urban simple: Bus

The average minimum time headway at the *50 km/h urban simple: bus* situation is presented in Figure 138. According to a performed t-test, no effect emerged (Table 172).

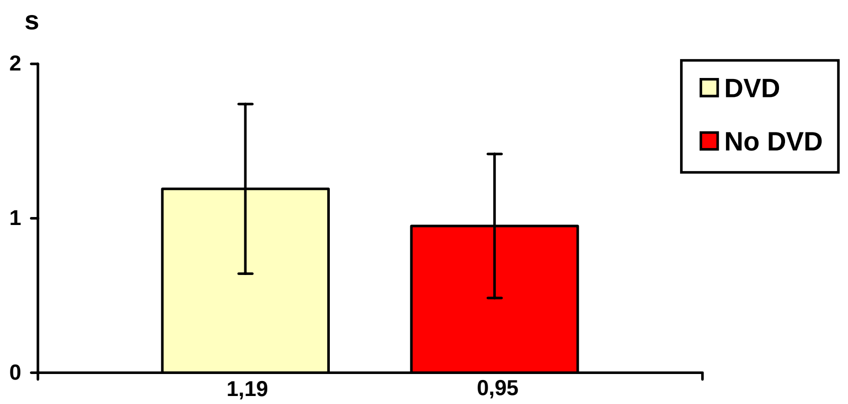


Figure 138 *Minimum time headway at bus situation (± SD), n=7.*

4.5.6 Minimum time to collision

Effect of DVD use on minimum time to collision was analysed for each of two traffic environments with events (car following, bus). No effects of DVD use emerged (Table 173, Table 174).

4.5.7 Number of participants stopping at events

Effects of DVD use on number of participants stopping at three events (bicycle, traffic light, bus) were analysed. No effect of DVD use was found (Table 176).

4.5.8 PDT performance

PDT performance was analysed with respect to average reaction times and percentage of missed PDT signals.

4.5.8.1 Reaction time

Effect of DVD use on PDT reaction time was analysed for the whole test route and for each of the five traffic environments with events and the corresponding traffic environments without events.

> PDT reaction time performance was impaired at six of the ten traffic situations – rural 90 km/h without event, rural 70 km/h without event, urban complex without event, urban medium complexity without event, urban simple with and without event. For the total route, however, no effects of DVD were found.

4.5.8.1.1 Total route

Figure 139 shows the average PDT reaction time for the whole test drive. The reaction time was not influenced by DVD use (Table 176).

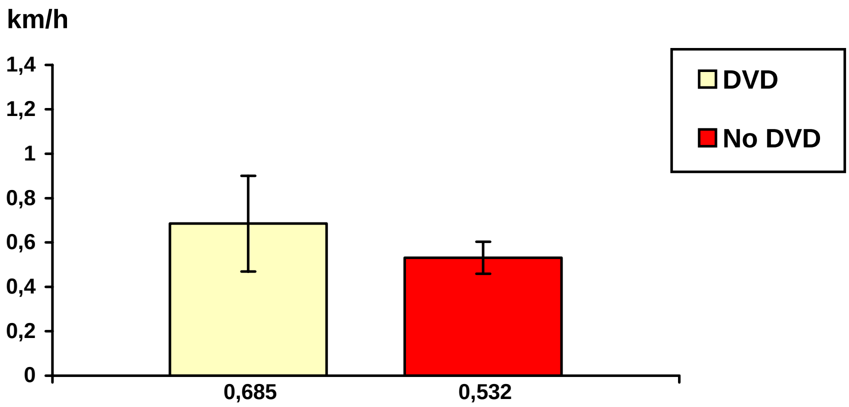


Figure 139 *PDT reaction time (± SD), n=8.*

4.5.8.1.2 90 km/h rural: car following and no event

The average reaction times at the *90 km/h rural: car following* and *no event* situations are presented in Figure 140 and Figure 141. According to performed t-tests, reaction time performance was impaired by DVD use, but only at the *no event* situation (t(6)=4.129; p<.01). The difference in reaction time was 135 ms (Table 177).

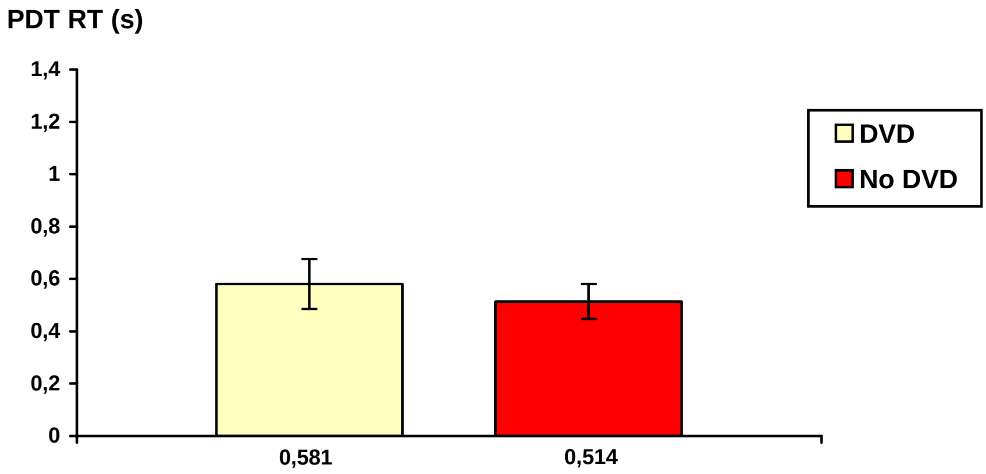


Figure 140 *PDT reaction time at 90 km/h rural: car following (± SD), n=6.*

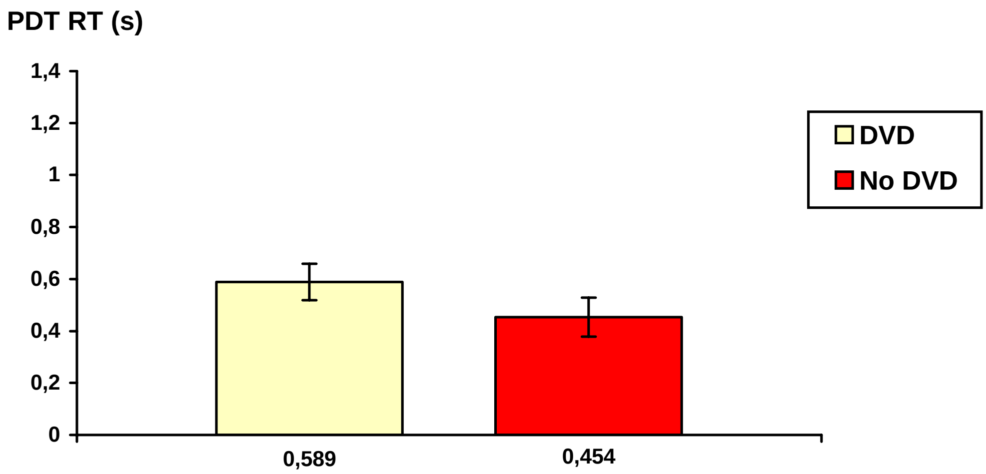


Figure 141 *PDT reaction time at 90 km/h rural: no event (± SD), n=7.*

4.5.8.1.3 70 km/h rural: motorbike and no event

The average reaction times at the *70 km/h rural: motorbike* and *no event* situations are presented in Figure 142 and Figure 143. According to performed t-tests, reaction time performance was impaired by DVD use at the *no event* situation (t(6)=3.719; p<.05). The difference in reaction time was 88 ms (Table 178).

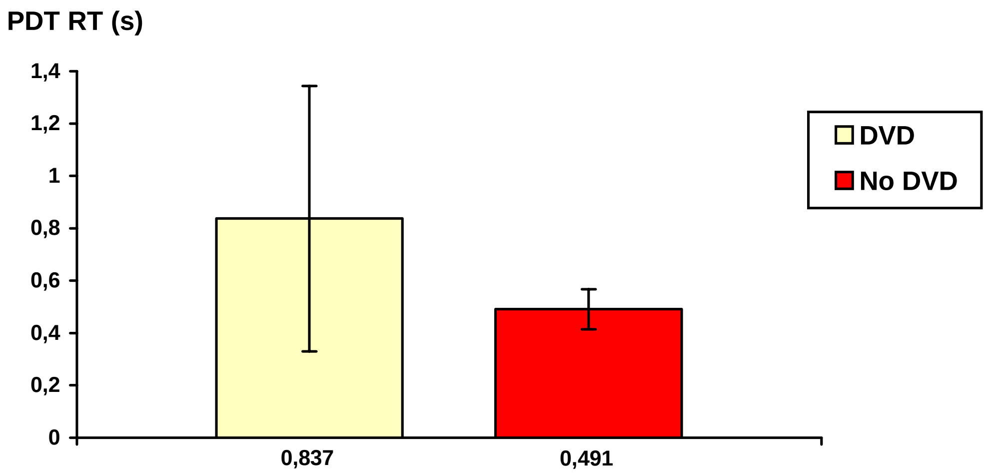


Figure 142 *PDT reaction time at 70 km/h rural: motorbike (± SD), n=7.*

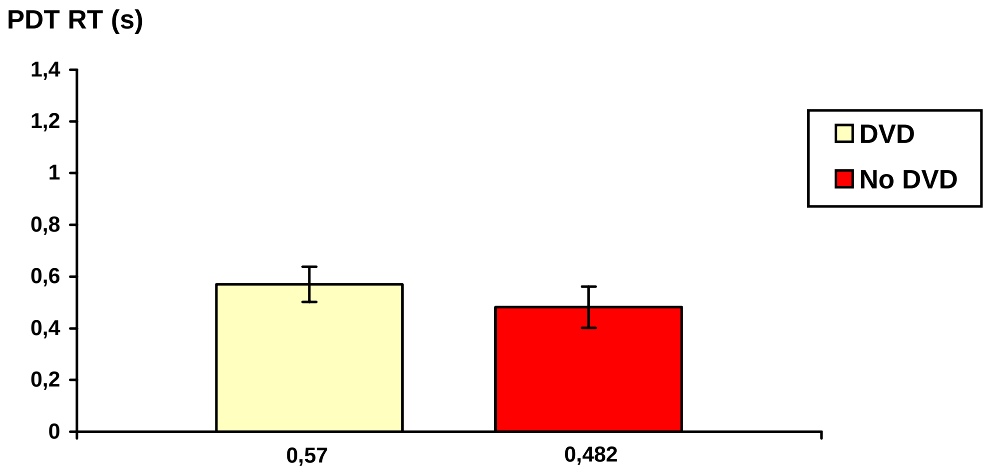


Figure 143 *PDT reaction time at 70 km/h rural: no event (± SD), n=7.*

4.5.8.1.4 *50 km/h urban complex: bicycle and no event*

The average reaction times at the *50 km/h urban complex: bicycle* and *no event* situations are presented in Figure 144 and Figure 145. According to performed t-tests, reaction time performance was impaired by DVD use at the *no event* situation (t(5)=5.623; p<.05). The difference in reaction time was 56 ms (Table 179).

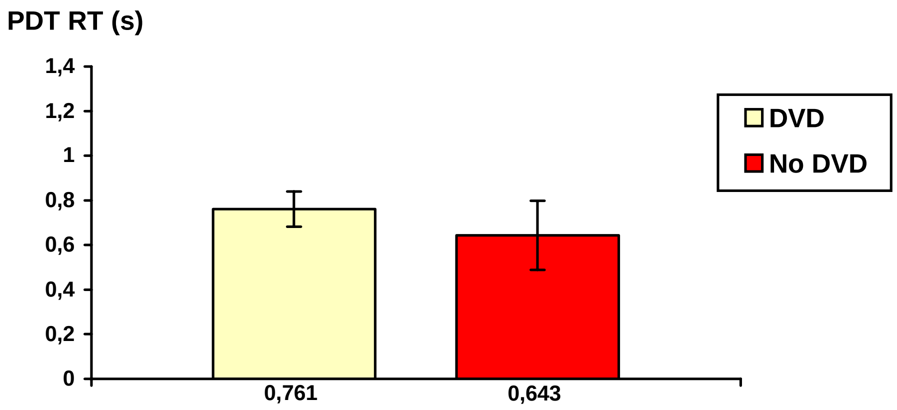


Figure 144 *PDT reaction time at 50 km/h urban complex: bicycle (± SD), n=7.*

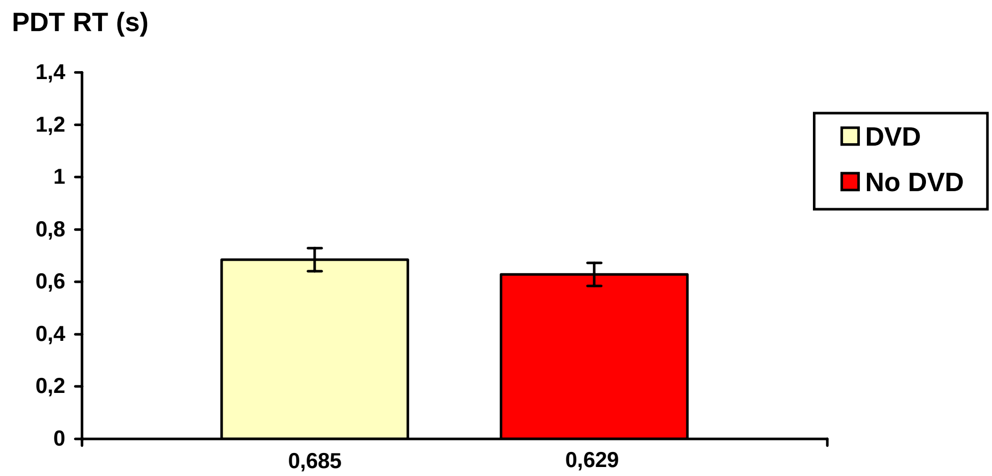


Figure 145 *PDT reaction time at 50 km/h urban complex: no event (± SD), n=6.*

4.5.8.1.5 50 km/h urban medium: traffic light and no event

The average reaction times at the *50 km/h urban medium: traffic light* and *no event* situations are presented in Figure 146 and Figure 147. According to performed t-tests, reaction time performance was impaired by DVD use at the *no event* situation (t(5)=5.264; p<.05). The difference in reaction time was 163 ms (Table 180).

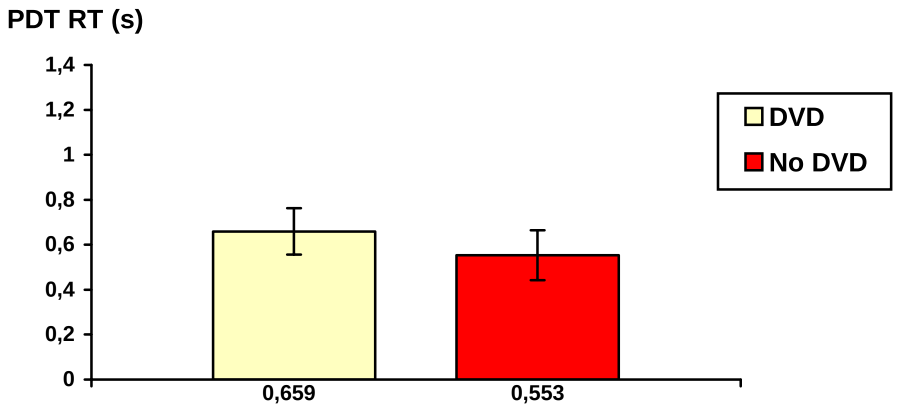


Figure 146 *PDT reaction time at 50 km/h urban medium: traffic light (± SD), n=6.*

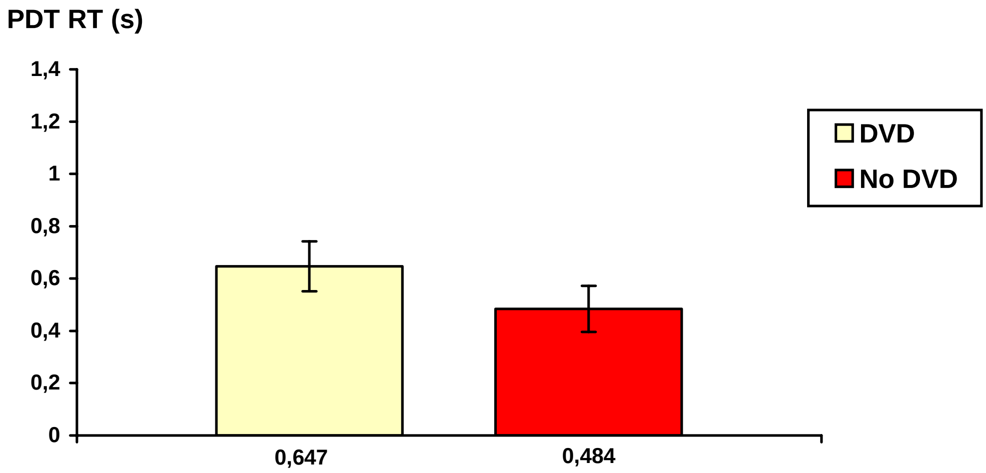


Figure 147 *PDT reaction time at 50 km/h urban medium: no event(± SD), n=6.*

4.5.8.1.6 *50 km/h urban simple: bus and no event*

The average reaction times at the *50 km/h urban simple: bus* and *no event* situations are presented in Figure 148 and Figure 149. According to performed t-tests, reaction time performance was impaired by DVD use at both situations. The difference in reaction time was 148 ms at the *bus* situation (t(5)=2.883; p<.05) and 122 ms at the other situation (t(5)=5.264; p<.01) (Table 181).

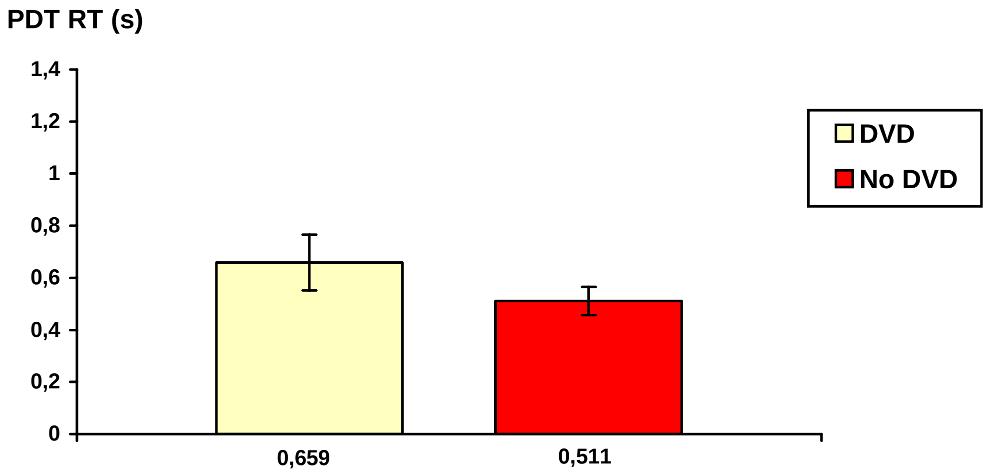


Figure 148 *PDT reaction time at 50 km/h urban simple: bus (± SD), n=6.*

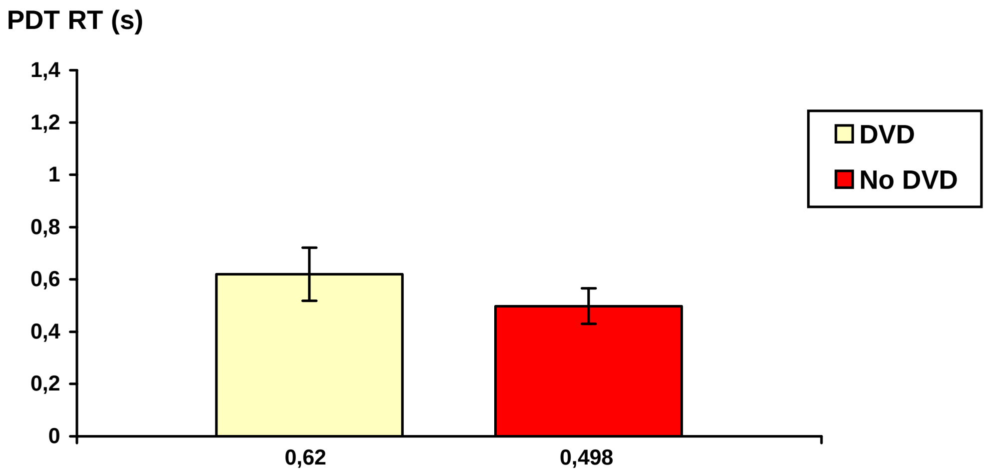


Figure 149 *PDT reaction time at 50 km/h urban simple: no event (± SD), n=6.*

4.5.8.2 Missed signals

Effect of DVD use on percentage of missed signals was analysed for the whole test route and for each of the five traffic environments with events and the corresponding traffic environments without events.

No effects of DVD use emerged (Table 182–Table 187).

4.6 Plots

In this chapter some data plots of the DVD experiment are shown. This is believed to allow a more qualitative look at the data than the results of the statistical analyses permit.

Figure 150 shows the speed development and the average speed for all drivers (motorbike event). The average speed is somewhat lower when the DVD film is on. Figure 151 shows the speed development and the average speed for the bus event. Here some drivers with DVD film on do not stop for the bus. In Figure 152 the speed development and the average speed are plotted for a longer urban section, also containing the bicycle event.

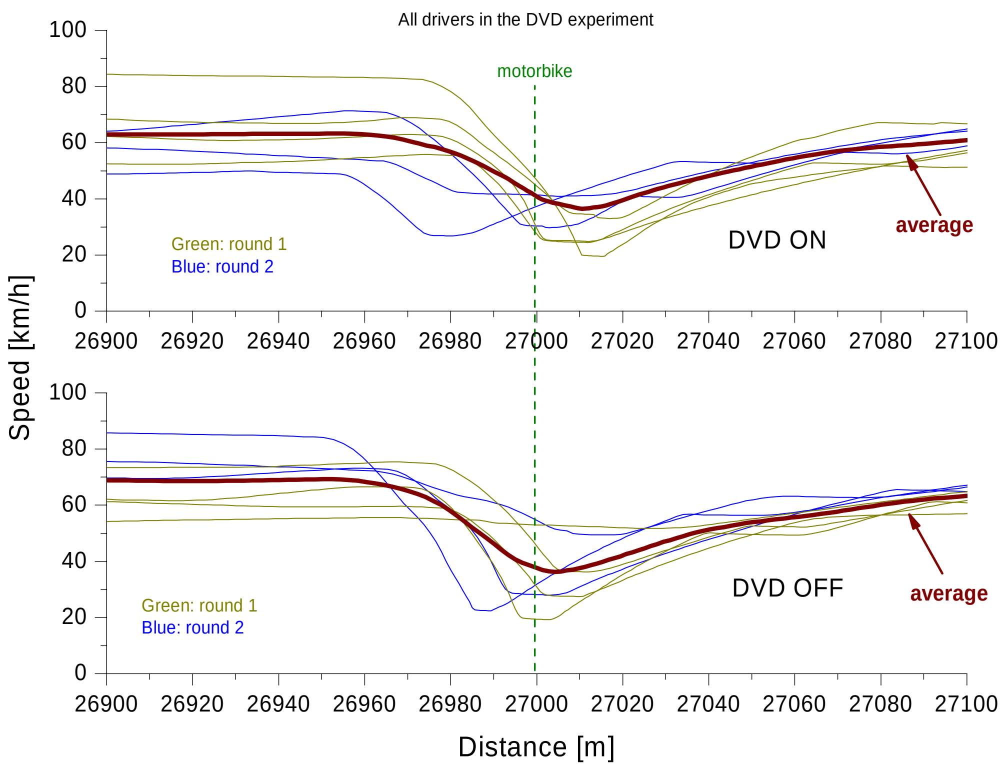


Figure 150 *Speed development and average speed for all drivers in the DVD experiment for the motorbike event.*

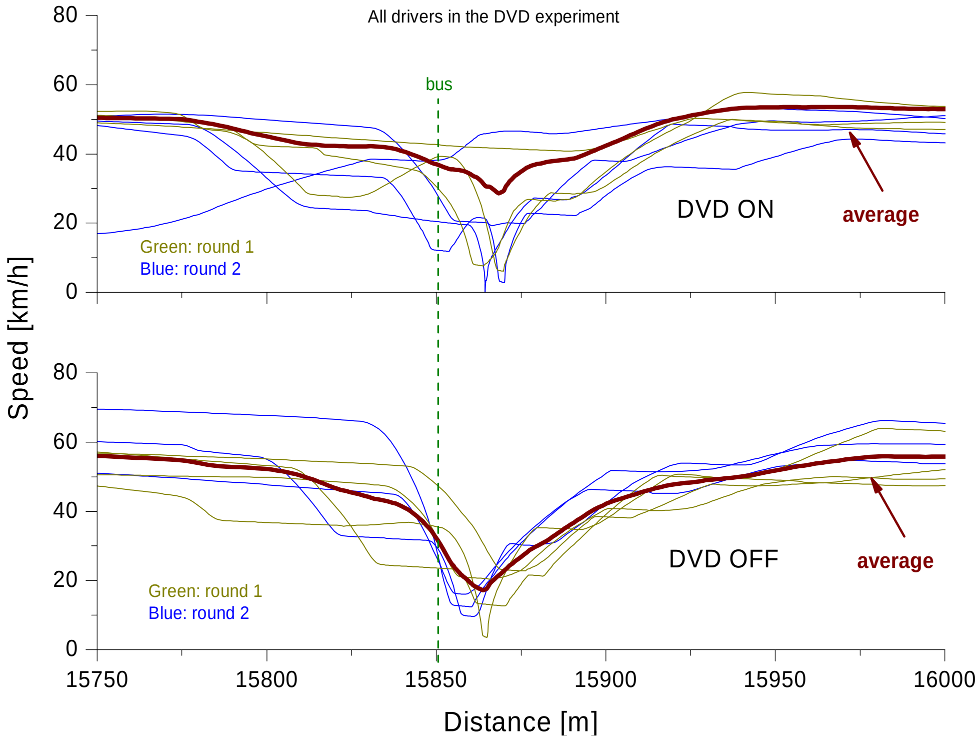


Figure 151 *Speed development and average speed for all drivers in the DVD experiment for the bus event.*

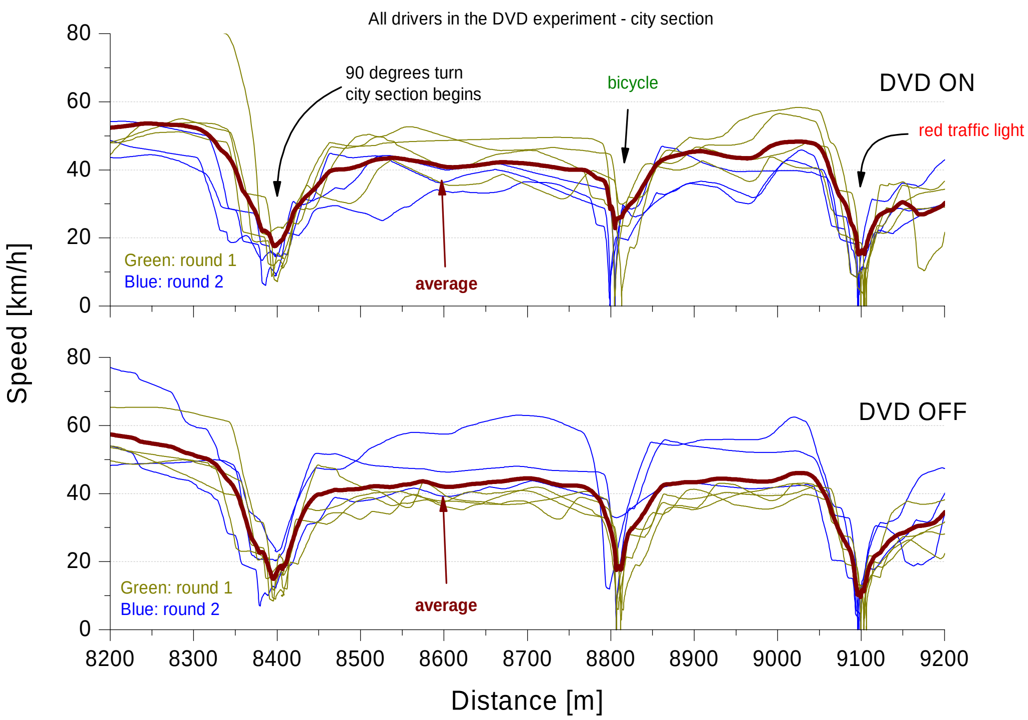


Figure 152 *Speed development and average speed in the complex urban environment.*

4.7 Results DVD experiment – subjective effects

4.7.1 Perceived mental effort

Perceived mental effort is measured on the RSME scale, 0–150, where 0 represents "no effort" and 110 "very great effort".

On average the perceived mental effort for all 8 participants was 72.9±21.9.

4.7.2 Perceived mental effort (DVD during last motorbike situation)

Half of the participants watched DVD during the last motorbike situation, and the remaining participants did not. Data were available for four participants who watched DVD at the situation, and for three participants who did not watch DVD at the situation. The average perceived mental effort is shown in Figure 153. According to a performed t-test, the perceived mental effort was not affected by DVD use (t(5)=1.534; n.s.).

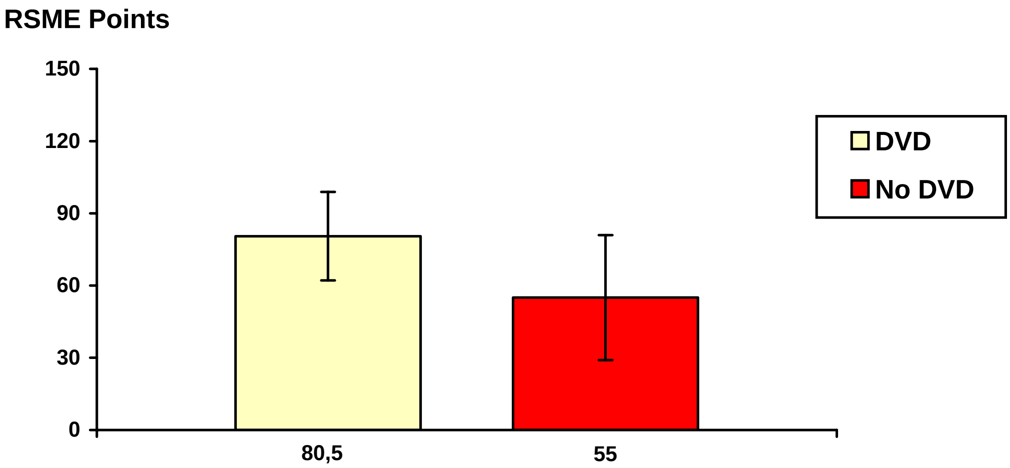


Figure 153 *Perceived mental effort at last motorbike situation (± SD).*

4.7.3 Opinion of DVD

Question: *What is your opinion of watching DVD while driving?*

Scale 0–100, where 0 represents "very negative" and 100 "very positive".

The average rating was 11.6±16.5. The opinion of watching DVD while driving was very negative.

4.7.4 DVD use

4.7.4.1 Frequency of watching DVD in car

Question: *How often do you watch DVD in the car for entertainment (for example watch a movie) while you drive (0=never, 100=always)?*

5 participants reported that they never do watch DVD while driving. Of the remaining 3 participants, one reported "5" and two "1" (that is, practically never).

4.7.4.2 Watching the actual movie

Question: *Had you seen the movie before?*

Two participants reported that they had seen the movie before.

Question: *How interested were you in the movie (0=not at all, 100=very)?*

The answers ranged from 3 to 99 with 49 as the average.

Question: *How much did you see of the movie (0=nothing, 100=all of it)?*

The answers ranged from 25 to 99 with 63 as the average.

4.7.4.3 Perceived required effort when watching DVD

Question 3: *How much effort did it require to watch the movie while driving?*

Scale 0–100, where 0 represents “no effort” and 100 represents “very great effort”.

The average perceived effort when watching DVD while driving was 73.1±20.6. The scale was 0 to 100, where 0 represents “no effort” and 100 represents “very great effort”.

4.7.4.4 Concentration while watching the movie

Question: *Did you miss other vehicles (none, some, many)?*

Three participants reported that they had missed none. The remaining participants reported “some”.

Question: *Were you just trying to detect “other vehicles”, or did you follow the plot of the movie?*

Four participants reported that they had followed the plot of the movie, whereas the remaining participants reported that they concentrated on detecting other vehicles.

Question: *What did you concentrate on while watching the movie (the movie, driving, no difference)?*

Three participants reported that they were mostly concentrated on watching the movie, whereas the remaining five participants reported that they were mostly concentrated on driving.

4.7.5 Effects of watching DVD while driving

4.7.5.1 Speed change

Question 6: *Did the fact that you were watching the movie while driving affect your speed?*

Data were obtained for all 8 participants. Four participants reported that they had reduced their speed. Two of them reported that their speed had not been influenced by watching the movie (see Figure 154).

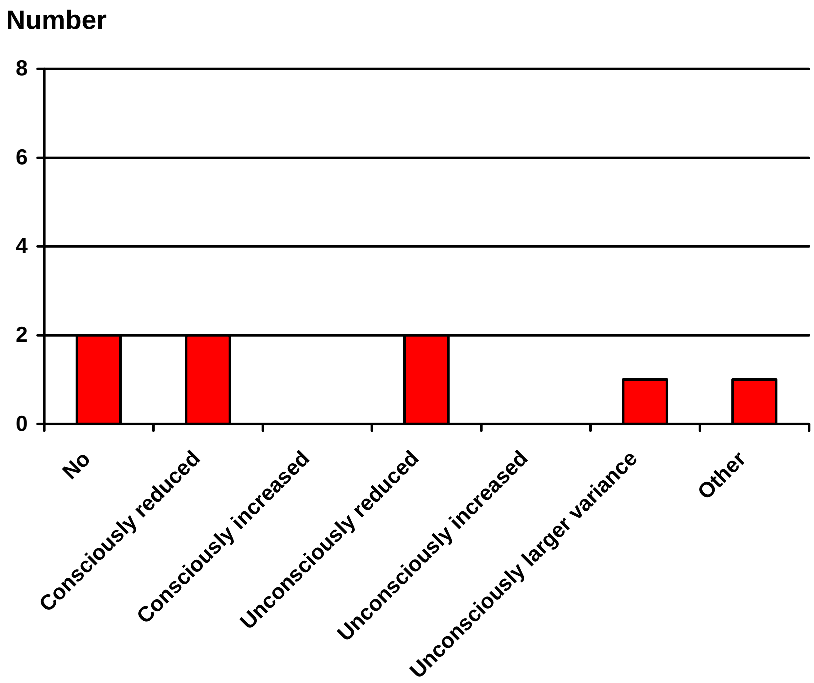


Figure 154 *Reported speed change as a result of watching DVD.*

4.7.5.2 Headway change

Question 7: *Did the fact that you were watching the movie while driving affect your distance to the car in front of you?*

Five of the participants reported that headway was not affected by watching the movie (see Figure 155).

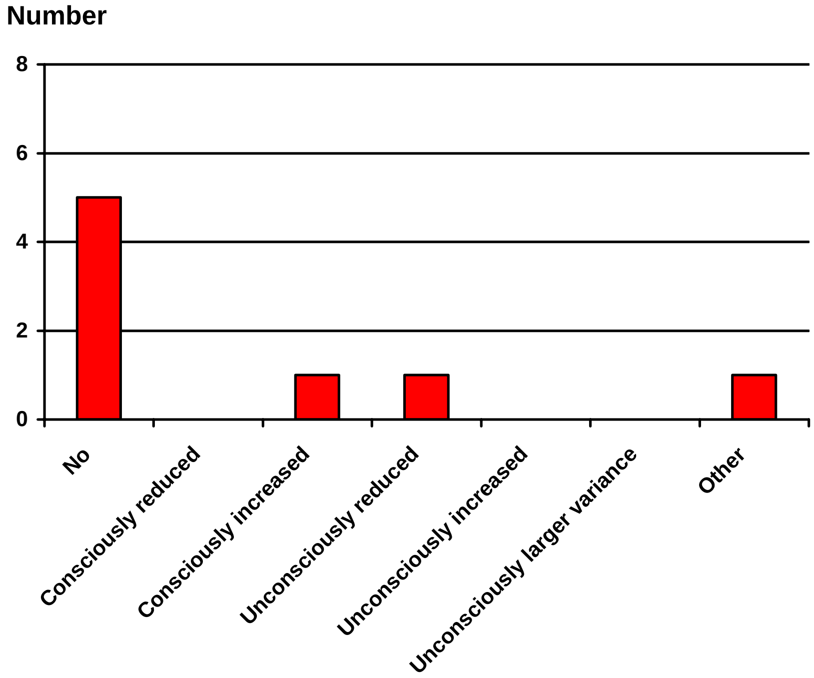


Figure 155 *Headway change as a result of watching the DVD movie.*

4.7.5.3 Change of lateral position

Question 8: *Did the fact that you were watching the movie while driving affect your lateral position?*

Four participants reported that they kept to the left – unconsciously (see Figure 156).

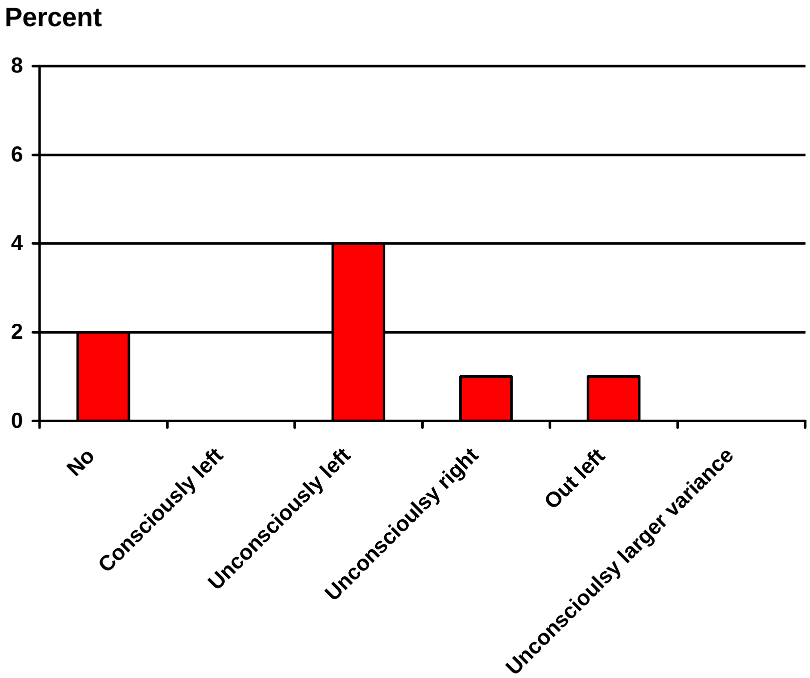


Figure 156 *Change of lateral position as a result of watching the DVD movie.*

4.7.6 Performance

Question 10: *Do you think your driving performance was better or worse than normal when watching the movie?*

The eight participants answered on a scale of 0 to 100, where 0 represents "much worse", 50 represents "equal performance" and 100 represents "much better". The average perceived driving performance is 22.5±14.9.

4.7.7 Traffic environment

Question 12: *In which traffic environment do you think it was easiest to watch the movie?*

All participants thought it was easiest to watch the movie when driving in rural traffic environment.

4.7.8 Summary of results – subjective effects

Perceived mental effort (RSME) was analysed for the last motorbike situation. No effect of DVD was apparent.

The opinion of watching DVD while driving was rated negative.

Four of eight reported a speed reduction as an effect of DVD.

Five of eight reported no change in headway as an effect of DVD.

Six of eight reported no change in lateral position as an effect of DVD.

Driving performance was rated rather low.

DVD was rated easiest to use in rural areas.

5 Dialling experiment

The scope of the experiment was to investigate the implications of a particular moment in a mobile phone conversation: when the driver dials a number. It is believed that the ringup moment is particularly critical since it requires the driver to handle the mobile phone physically and to look away from the road. Ringing up was done in handsfree mode (with the phone placed in the holder precisely as in the handsfree part of the mobile phone experiment) and in handheld mode (where the driver was required to pick the mobile phone from the holder and have it in his/her hand).

Figure 157 *Mobile phone for the dialling experiment.*

5.1 Participants

The participants for the dialling experiment were the same as those for the mobile phone conversation experiment. Some participants felt dizzy after the first drive, so they chose not to take part in the ring up experiment. In total 42 out of 48 participants completed the ring up experiment. The mean age was 33.2±8.5 years; 24 were males and 18 females. They had held a driving licence for 14.8±8.4 years.

5.2 Dialling task

The following requirements are set on the number the participants have to dial: The number dialled by the participants should be the same for every participant, to keep the level of difficulty constant. It should be an existing number that can be answered by the experimenter in order to allow control of whether the participant has dialled correctly or not. The participants should not be required to remember the number without external aid. The external aid, however, should not require that the participants have to look to a third location (apart from the road and the telephone) to retrieve the number.

The same setting as in the mobile phone experiment was used (simulator, technical equipment, etc.). As mentioned above, the 42 of the 48 participants from the two phone conditions performed the dialling task on a different road stretch than in the main experiment. The driving distance was about 15 km. Those participants who had used the “handheld” modus before also used the “handheld” modus during the dialling task and those participants who had used the “handsfree” modus before also used the “handsfree” modus during the dialling task. There was little traffic on the road. The instruction was to drive as the participants usually would in a similar situation in real traffic (Appendix 10.1.5, 10.1.6).

At three times the drivers were requested to make a phone call, this took place by projecting the word “Ring” in large yellow letters in the centre of the simulator screen. The chosen number to be dialled belonged to the standard phone network and was connected to a telephone in the simulator hall. The number consisted of nine digits – an area code consisting of three digits, and a phone extension consisting of six digits (013-20 40 22). The number was glued to the telephone (see Figure 157). The keys of the telephone were set to beep each time a button was pressed, the screen was always lit. In a certain location on the route the word “RING!” appeared on the simulator screen. It remained there until the participant started placing the call (i.e. took out the telephone from the holder in the handheld condition or pressed the first button in the handsfree condition). As soon as the call got through to the experimenter, he or she picked up the phone and said: “Hello, you can hang up now”, whereupon both the experimenter and the participant ended the call. After the driving the participants filled in a brief questionnaire.

The choice of the way to present the phone number to dial is evidenced below (Table 5).

Table 5 *Different possibilities to present the phone number for the ring up experiment.*

Position	Advantages	Disadvantages
number written on the phone itself	simple to implement	unrealistic perhaps low visibility of the number in rather dark simulator
use number stored in the mobile phone	realistic simple to implement	not sure that all participants will be able to use the function no dialling task, just select from list
outside in the simulator scene (centre or corner...)	easy to present possible to control via computer	might be too "friendly", because it forces the participants to look on the road (otherwise they might disregard the road more)
voice that tells number	simple to implement	unrealistic understanding the number may be difficult
on the steering wheel	simple to implement easy to see,	unrealistic 3rd location to look at
on a paper slip on the passenger seat	relatively realistic	paper slip might fall down additional task "search for note and look at it" (many sources of variance) 3rd location to look at
remembered by participant	participant can choose freely when to look at the road and when to look at the phone, does not need to read the number somewhere	participants might forget the number

5.3 Questionnaire

As in the other parts of the study, here too the participants filled in a questionnaire (Appendix 10.2.5 Questionnaire Dialling). It was concerned with:

- Mental effort (scale used: RSME – Rating Scale Mental Effort) for the whole route.
- Own use of mobile phone in cars.
- Effort in dialling.
- Number of times it was necessary to look at the phone while dialling.
- Number of times they dialled wrongly.
- Concentration on dialling or driving.
- Influence of mobile phone on speed and lateral position.
- Opinion about driving "quality" while dialling.

Each driver filled also in a demographic questionnaire covering: age, driving licence, gender, mileage, handedness and experienced motion sickness.

5.4 Results dialling experiment – behavioural effects

5.4.1 Analyses

Behavioural data were analysed for 42 drivers, 23 in handsfree mode and 19 in handheld mode. The road stretch where the drivers still accelerated to reach cruise speed and the part at the end of the drive where the drivers decelerated were excluded from the analyses. The experiment leader marked when the drivers rang up: in the case of handheld phone use this was when the phone was picked from the holder until it was replaced in the holder after the phone call. For the handsfree mode it was from the point the driver pushed the first button on the phone until he or she pushed the hang up button after the call. The variables analysed were speed, lateral position variance, and PDT reaction time and miss rate (number of misses to number of total PDT stimuli in percent).

5.4.2 Driving speed

For each driver the mean speed was calculated both for while ringing up and for normal drive (see Figure 158).

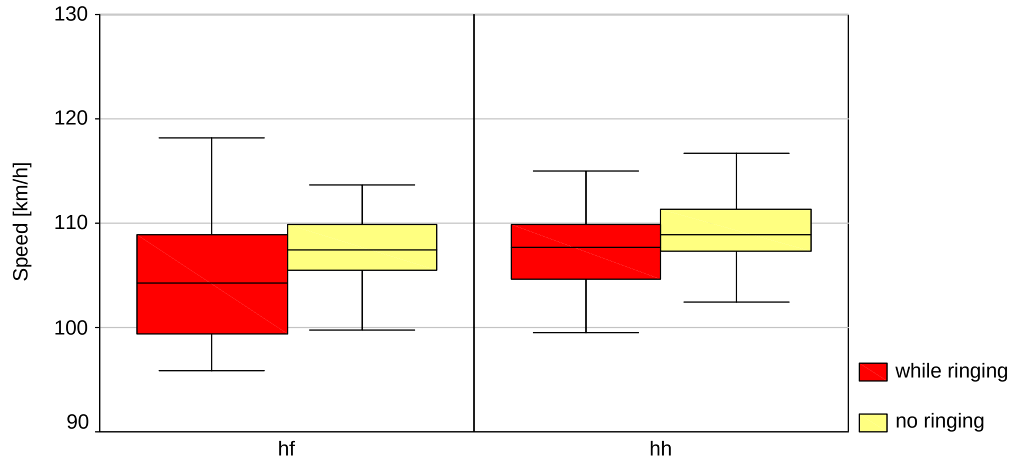


Figure 158 *Box plot of the mean speed for handsfree and handheld mode.*

Mean speed handsfree drive
The mean speed was reduced when the driver rang up. The mean speed while ringing up was 104.5±7.1 km/h and for normal drive 108.3±5.9 km/h. The difference is statistically significant ($t(22)=-5.92$, $p<.001$).

Mean speed handheld drive
The mean speed was reduced when the driver rang up. The mean speed while ringing up was 107.2±4.9 km/h and for normal drive 109.2±4 km/h. The difference is statistically significant ($t(18)=-4.22$, $p<.001$).

Comparisons handsfree – handheld drive

The difference between handsfree and handheld phone regarding mean speed during phone use was not significant (t(40)=1.357; n.s.). The effect of phone use was, however, greater for handsfree mode (t(40)=2.069; p<.05). The difference was 1.8 km/h.

5.4.2.1 Summary speed

The speed was decreased when ringing up both in handsfree (difference 3.8 km/h) and in handheld mode (difference 2 km/h). The effect was, however, greater for the handsfree mode. The results are also summarised in the following graphs: Figure 159 compares the mean speed for all drivers over the whole 15 km drive, Figure 160 shows the speed development for all drivers in handsfree condition, and Figure 161 for all drivers in handheld condition.

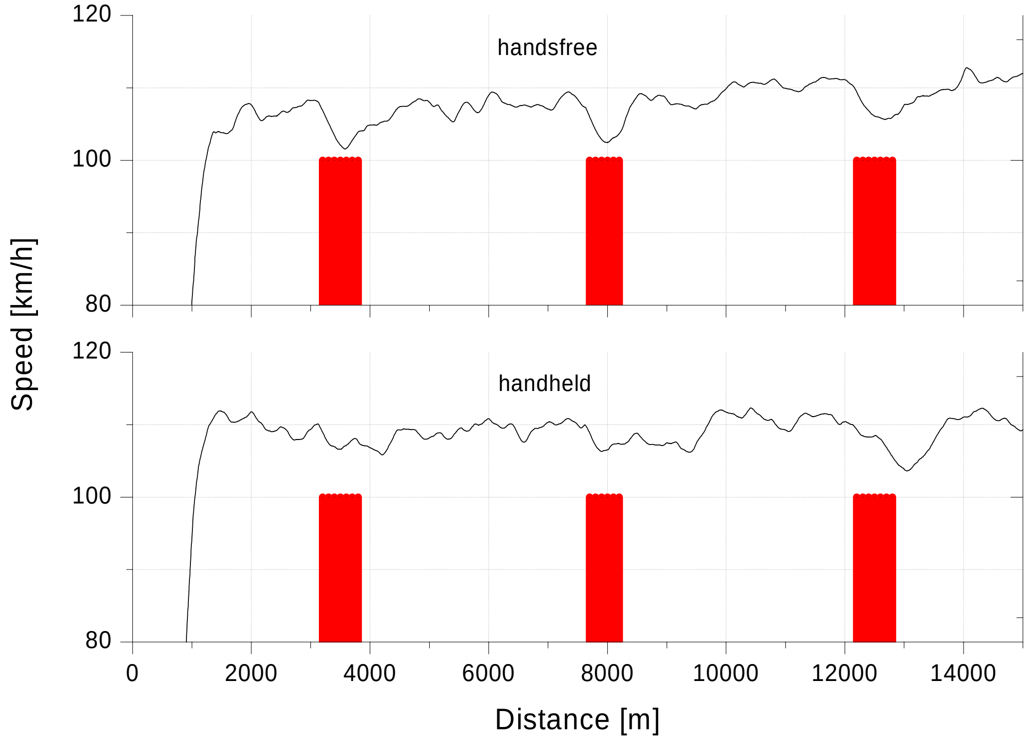


Figure 159 *Comparison mean speed for handsfree and handheld condition in the dialling experiment. The red boxes represent where the drivers ring up. Note that the y axis (speed) does not start at zero.*

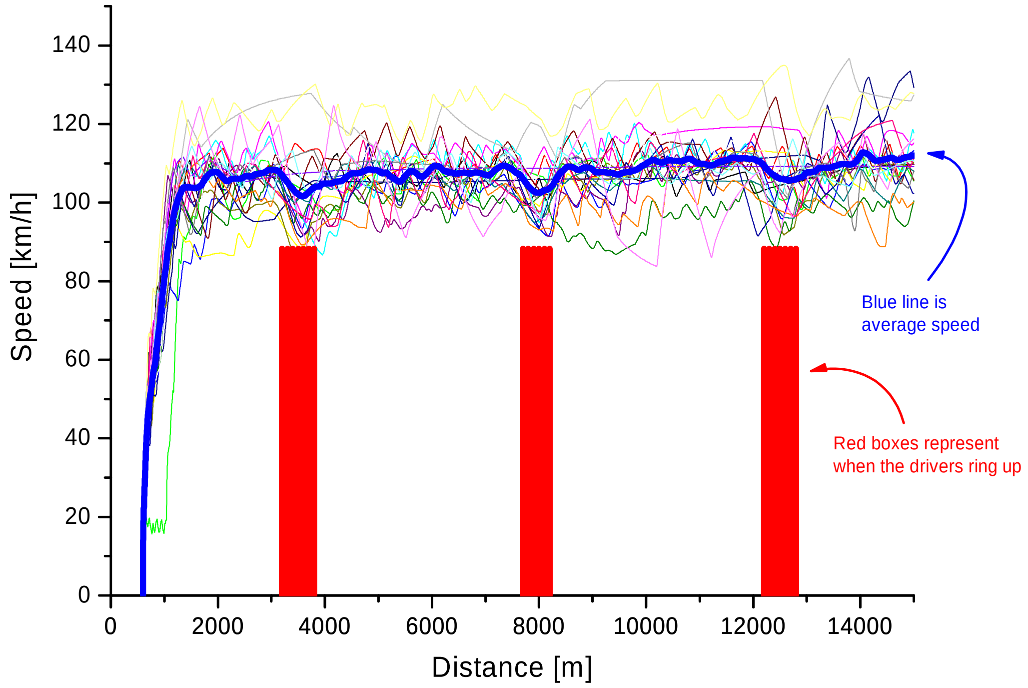


Figure 160 *Speed development in the handsfree condition for all drivers and averaged curve.*

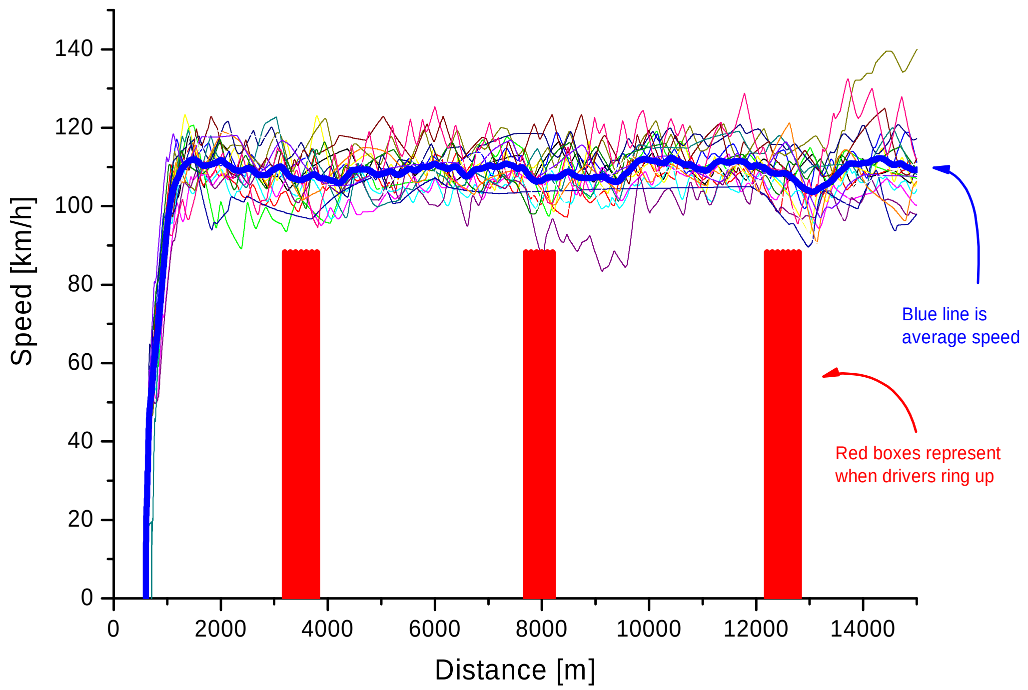


Figure 161 *Speed development in the handheld condition for all drivers and averaged curve.*

Each line in the graphs above represents the speed for a single driver. The average speed for all drivers in the plot is shown as a thick blue line. The period when the drivers ring up is marked by the red boxes. The measurements began after a few hundred metres, which is why the speed measurements do not start at distance zero. From the graph of the handsfree condition a speed reduction when ringing up is clearly noticeable; the handheld condition does not display this clear speed reduction.

5.4.3 Lateral position variance

For each driver the variance of lateral vehicle position on road was calculated for the time while ringing up and for normal drive. Figure 162 shows a box plot of the variance of the lateral position for handsfree and handheld mode.

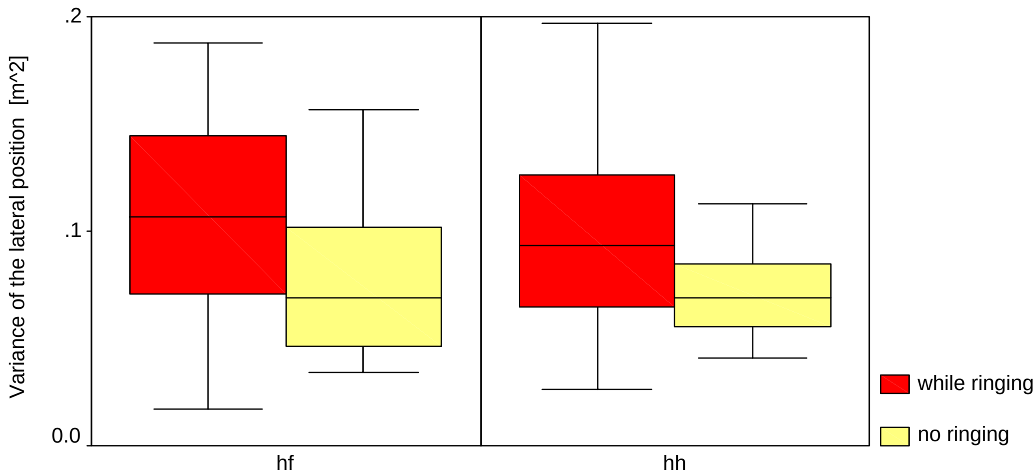


***Figure 162** Variance of lateral vehicle position for handsfree and handheld situation.*

Variance of the lateral position handsfree drive

The variance of the lateral position was increased when the driver rang up. The variance while ringing up was 0.118±0.077 and for normal drive 0.077±0.037. The difference is statistically significant ($t(22)=3.38$, $p<.005$).

Variance of the lateral position handheld drive

The variance of the lateral position was increased when the driver rang up. The variance while ringing up was 0.130±0.128 and for normal drive 0.070±0.020. The difference is not statistically significant.

Comparisons handsfree – handheld drive

The difference between handsfree and handheld phone regarding variance of lateral position during phone use was not significant ($t(40)=.377$; $p>.05$). The effect of phone use was not significantly different either ($t(40)=.640$; $p>.05$).

5.4.3.1 Summary lateral position variance

The trend was that the variance of the lateral position was increased when ringing up both in handsfree and in handheld mode; this result was however statistically significant only for the handsfree mode. There was no statistically significant difference between the handsfree and the handheld mode.

5.4.4 Results for PDT

For each driver the mean PDT reaction time and the percentage of missed stimuli were calculated for the time while ringing up and for normal driving.

The *percentage of PDT misses* variable was not normally distributed, thus nonparametric test were used in the statistical analyses. For the mean reaction time t-test were used. The results are summarised in Figure 163 and Figure 164 below.

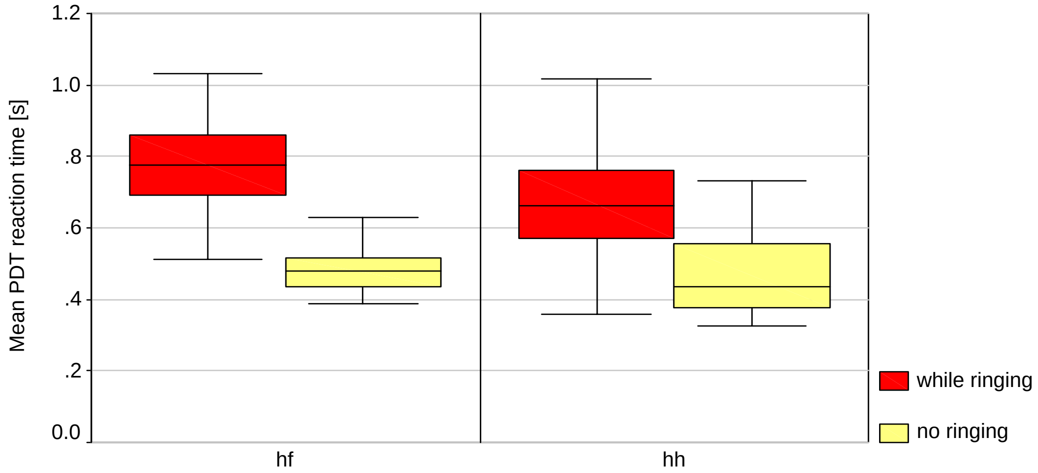


Figure 163 *Box plot showing mean PDT reaction time for handsfree and handheld mode.*

Note: Box plots are summary plot based on the median, quartiles and extreme values. The box represents the interquartile range which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. A line across the box indicates the median. Outliers are cases with values between 1.5 and 3 times the interquartile range.

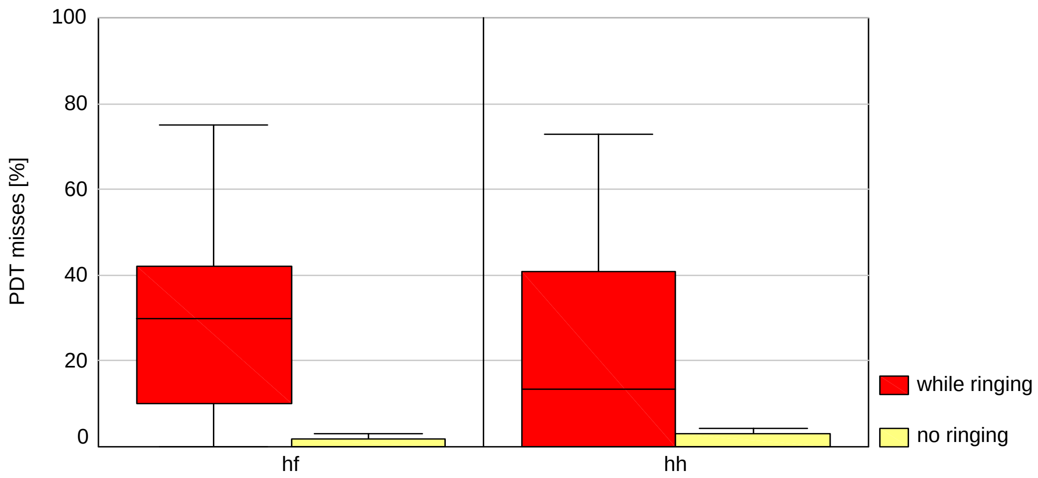


Figure 164 *Box plots showing the number of PDT misses [%] for handsfree and handheld mode.*

Mean PDT reaction time handsfree drive

The mean PDT reaction time was 0.779±0.148 seconds when ringing up and 0.480±0.076 seconds during normal drive ($t(22)=9.59$, $p<.001$). Thus there is an increase of 0.299 seconds in mean PDT reaction time when ringing up (which corresponds to an increase of 62.35%).

Percentage of PDT misses handsfree drive

The drivers had a much higher number of PDT misses when ringing up. During the normal drive the mean percentual number of PDT misses was 1.1±2.3% (the median value was 0), and when ringing up 29.3±21.7% (the median value was 30). The difference was statistically significant ($Z=-3.84$, $p<.001$).

Mean PDT reaction time handheld drive

The mean PDT reaction time was 0.711±0.240 seconds when ringing up and 0.477±0.117 seconds during normal drive ($t(18)=4.15$, $p<.001$). Thus there is an increase of 0.234 seconds in mean PDT reaction time when ringing up (which corresponds to an increase of 49.1%).

Percentage of PDT misses handheld drive

The drivers had a much higher number of PDT misses when ringing up. During the normal drive the mean percentual number of PDT misses was 2.8±5.0% (the median value was 0), and when ringing up 22.4±24.8% (the median value was 13.3). The difference was statistically significant ($Z=-3.18$, $p<.005$).

Differences in handheld and handsfree condition

a) Mean PDT reaction time

The difference between handsfree and handheld phone regarding mean PDT reaction time during phone use was not significant ($t(40)=1.119$; n.s.). The effect of phone use was not significantly different for the two phone modes either ($t(40)=1.053$; n.s.).

b) Percentage of PDT misses

The difference between handsfree and handheld phone regarding percentage of PDT misses during phone use was not significant (Mann Whitney U test: $z=1.146$; n.s.). The effect of phone use was not significantly different for the two phone modes either ($z=1.361$; n.s.).

5.4.4.1 Summary PDT

It is clearly visible that the PDT performance was much worse while ringing up as compared to normal driving. This displays that there is a significant increase in mental workload when ringing up. No difference between the handsfree and the handheld condition were found. The following graph (Figure 165) summarises the results of the statistical analyses. (Note: in the graph the PDT misses were recoded as PDT reaction time of 2 seconds and plotted together with the reaction time for the PDT hits, thus the y axis is defined as “average PDT reaction in the graph”.)

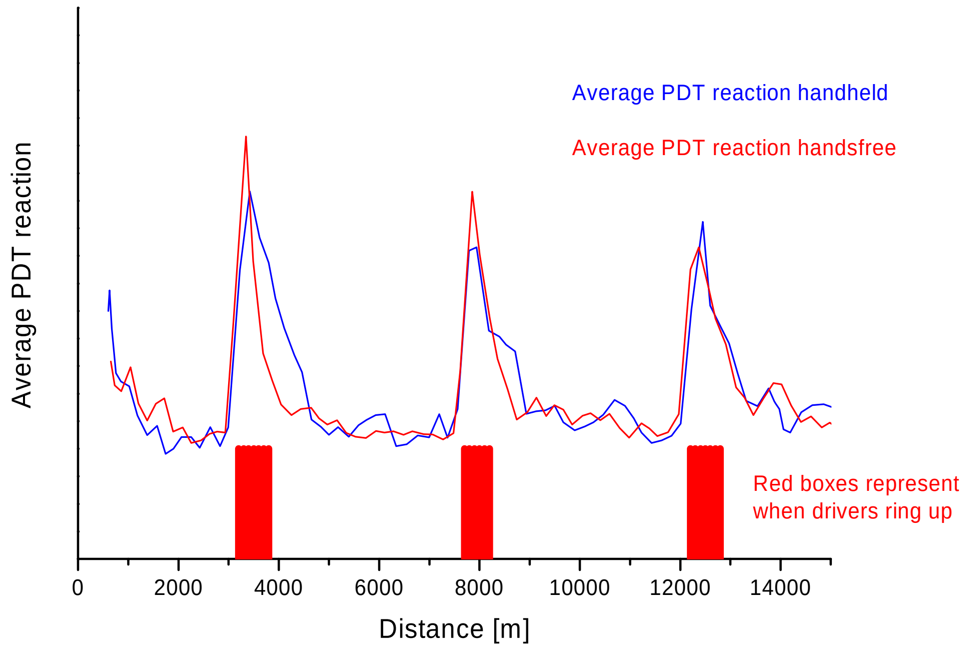


Figure 165 *Average PDT reaction over the whole 15 km drive. The boxes represent when “most” of the drivers ring up, some drivers took longer time to ring up, which explains why the average PDT reaction is longer also after the red boxes.*

5.5 Results dialling experiment – subjective effects

Questionnaire data were collected for 44 participants, 23 with handsfree and 21 with handheld phone mode.

5.5.1 Perceived mental effort

Perceived mental effort is measured on the RSME scale, 0–150, where 0 represents "no effort" and 110 "very great effort".

Figure 166 shows the average mental effort for 23 participants using a hands-free phone and 20 participants using a handheld phone. There was no difference between the two groups (t(41)=.230; n.s.).

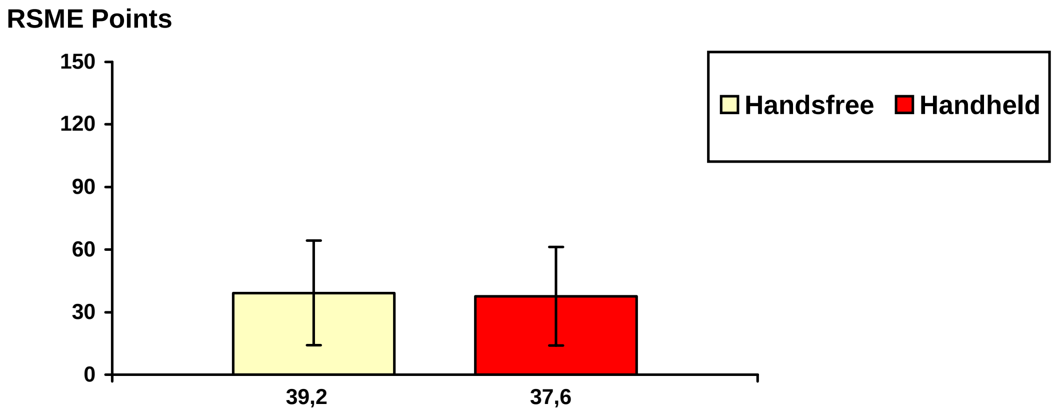


Figure 166 *Perceived mental effort (± SD).*

5.5.2 Mobile phone use for dialling

5.5.2.1 Dialling while driving

More than 86% of the 44 participants asked usually dial while driving. Most common was to use the short number function (Figure 167).

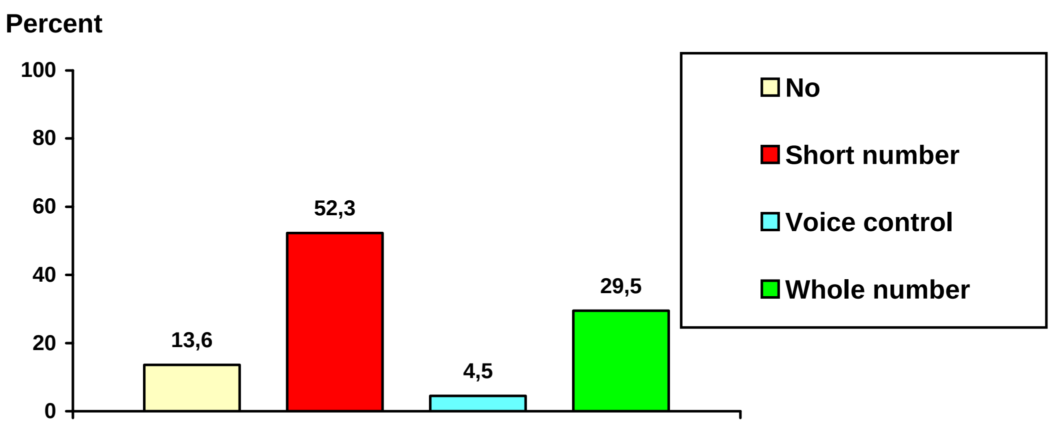


Figure 167 *Dialling while driving.*

5.5.2.2 Frequency of phone use

Question 1b: *If you dial while driving, how often do you do this?*

Scale 0–100, where 0 represents "very rarely" and 100 represents "very often".

Figure 168 shows the result. It was most common to dial while driving for those who use short number.

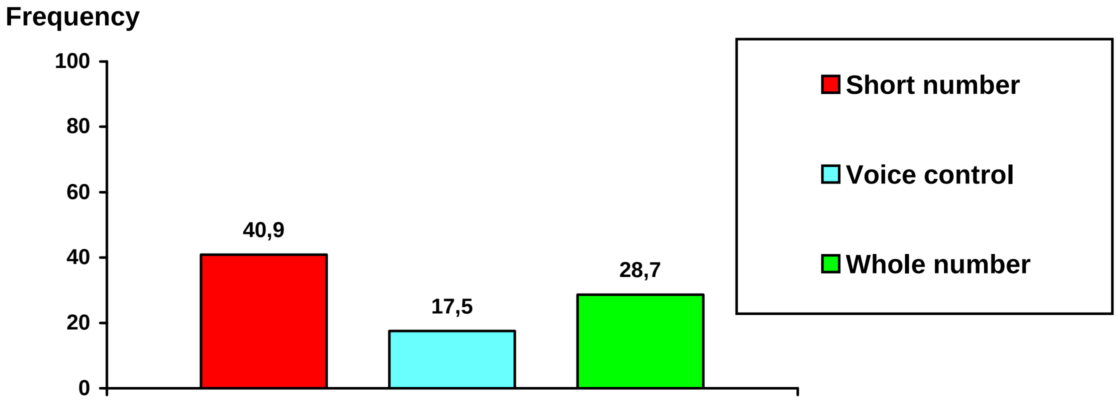


Figure 168 *Frequency of dialling.*

5.5.2.3 Perceived required effort when talking on the mobile phone

Question 2: *How much effort did it require to dial while driving?*

Scale 0–100, where 0 represents "no effort" and 100 represents "very great effort".

Figure 169 shows the average perceived effort when dialling while driving. Perceived effort was not affected by phone mode (t(41)=.016; n.s.).

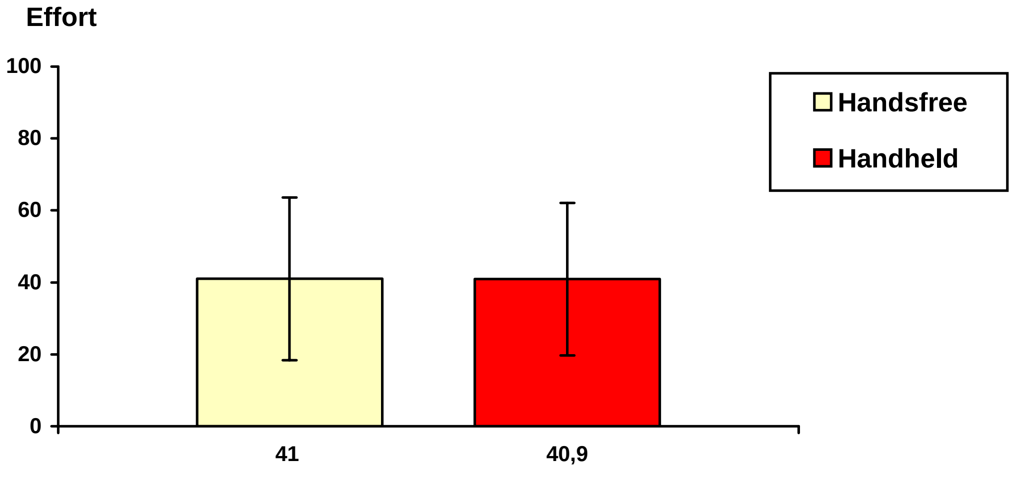


Figure 169 *Perceived effort (0–100) when talking on the phone (± SD).*

5.5.2.4 Looking at the phone while dialling

Question 3: *How often did you look at the phone while dialling?*

Scale 0–100, where 0 represents "very rarely" and 100 represents "very often".

Figure 170 shows the result. How often one looked at the phone while dialling was not influenced by phone mode (t(42)=.765; n.s.).

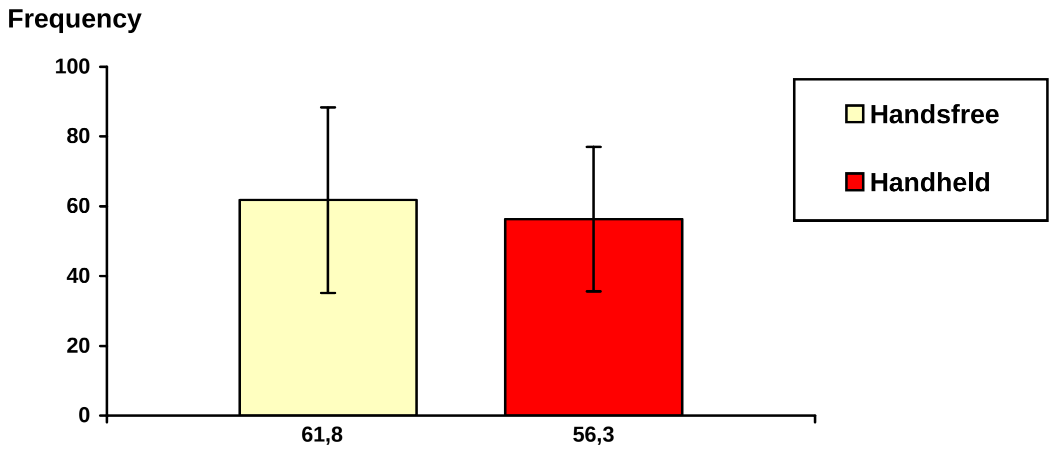


***Figure 170** Frequency of looking at the phone while dialling.*

5.5.2.5 Dialling errors

Question 4: *Did you make dialling errors and have to make corrections?*

Scale 0–100, where 0 represents "never" and 100 represents "often".

The frequency of dialling errors was not influenced by phone mode (t(42)=.427; n.s.) (Figure 171).

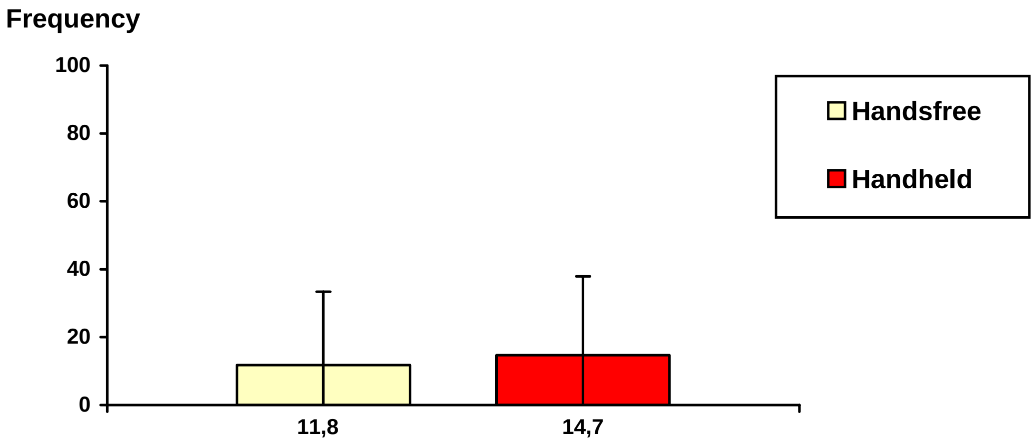


***Figure 171** Frequency of dialling errors.*

5.5.2.6 Frequency of looking at the road while dialling

Question 5: *How often did you look at the road while dialling?*

Scale 0–100, where 0 represents "not at all" and 100 represents "after each figure".

The frequency of looking at the road was not influenced by phone mode (t(42)=1.223; n.s.) (Figure 172).

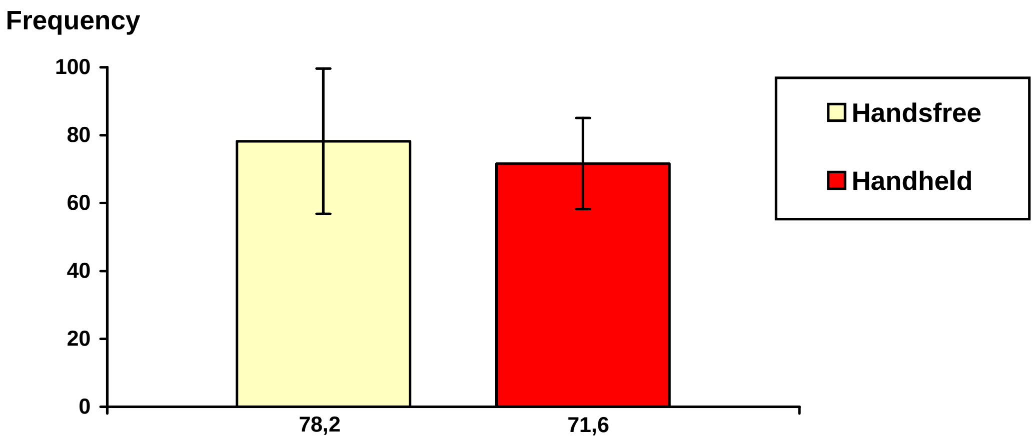


***Figure 172** Frequency of looking at the road while dialling.*

5.5.2.7 Concentration during the phone calls

Question 6: *What did you concentrate on during the dialling?*

More than half of all participants reported they were mostly concentrated on the driving task during dialling (Figure 173). However, about one quarter of the participants stated that they were mostly concentrated on the phone.

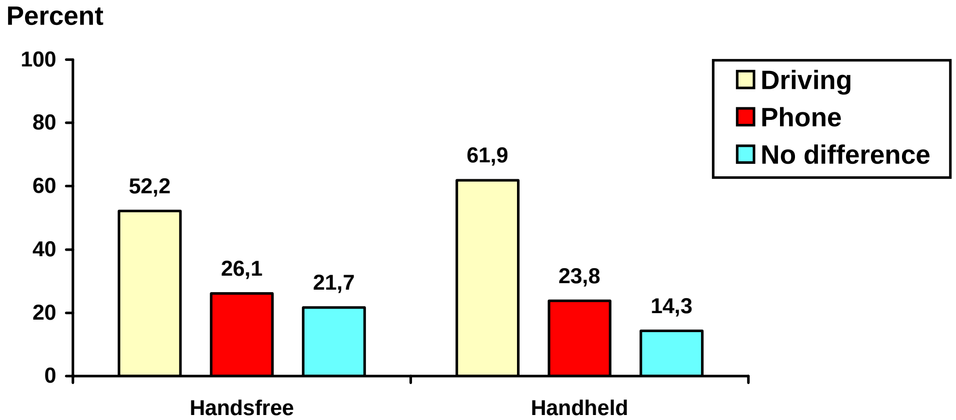


***Figure 173** Concentration during dialling.*

5.5.3 Effects of using mobile phone while driving

5.5.3.1 Speed change

Question 7: *Did the fact that you were dialling while driving affect your speed?*

The most common answer was an unconscious reduction of speed when talking on the phone (Figure 174).

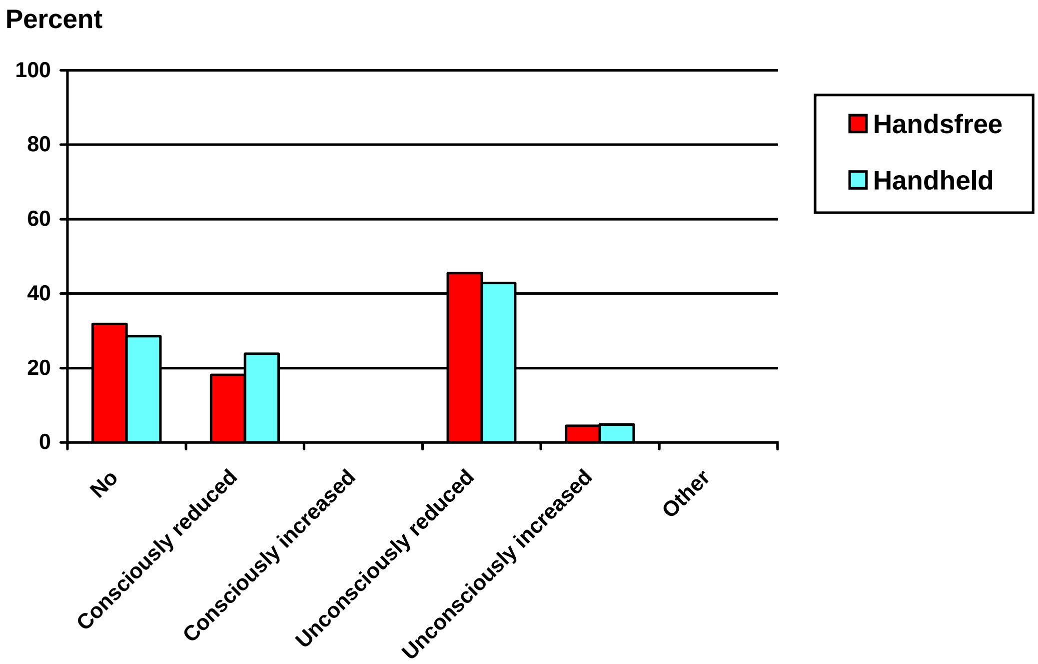


Figure 174 *Reported speed change as a result of dialling.*

5.5.3.2 Change of lateral position

Question 8: *Did the fact that you were dialling while driving affect your lateral position?*

The most common answer from the participants using the handheld phone was that dialling did not affect their lateral position (Figure 175). This answer was also very common for the handheld group. About 20% of the participants in both groups reported an unconscious change to the left.

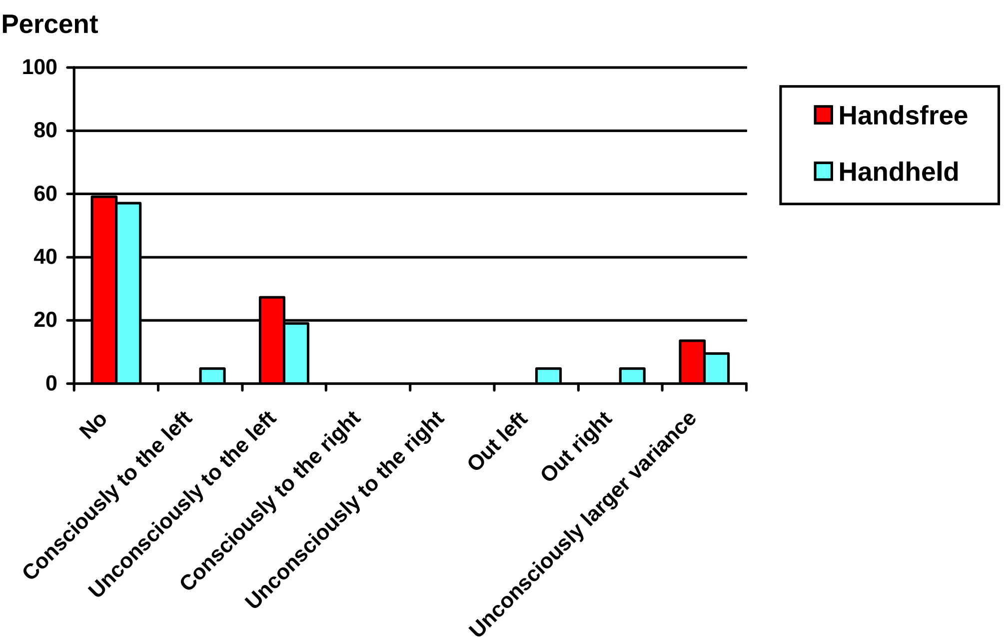


Figure 175 *Change of lateral position as a result of dialling.*

5.5.4 Performance

Question 10: *Do you think your driving performance was better or worse than normal when dialling?*

All 48 participants answered on a scale of 0 to 100, where 0 represents "much worse", 50 represents "equal performance" and 100 represents "much better". The average perceived driving performance is shown in Figure 176. There was no difference in perceived performance between participants using a handsfree phone and participants using a handheld phone, (t(41)=1.280; n.s.).

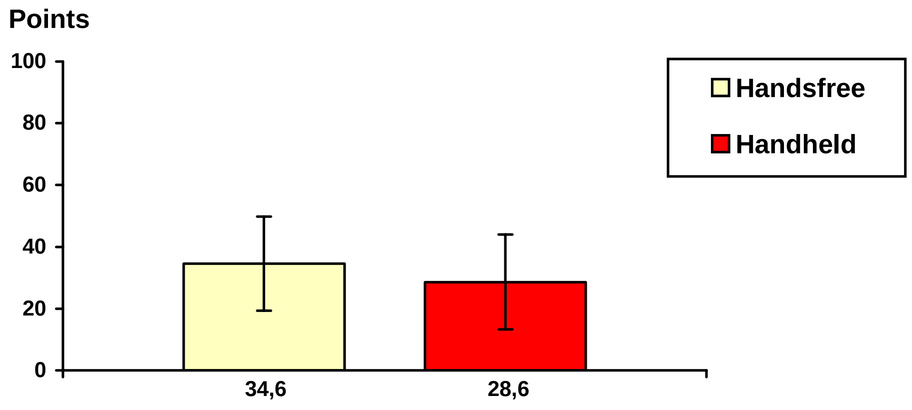


Figure 176 *Perceived driving performance (± SD).*

5.5.5 Validity

Question 11: *Would you use the mobile phone the same way in real traffic?*

The majority of the participants reported that they would use the phone the same way in real traffic (see Figure 177).

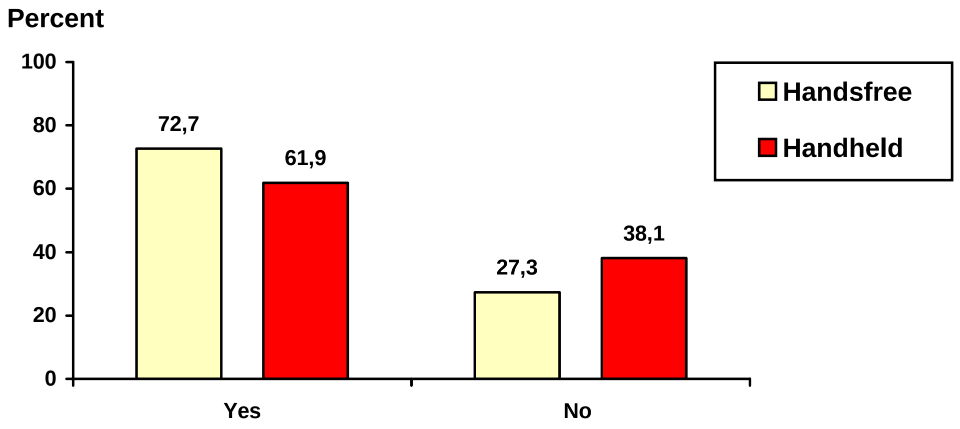


Figure 177 *Reported validity.*

5.5.6 Summary of results – Subjective effects

No difference in perceived mental effort (RSME) was apparent between handsfree and handheld phone. Similarly, there was no clear difference between the two phone modes regarding perceived effort (effort scale) when dialling.

More than 86% reported that they usually dial while driving. Use of short numbers was the most common.

About 60% looked at the phone and about ¾ looked at the road while dialling with no difference between modes. Few errors in dialling were reported.

More than 60% reported a speed reduction as an effect of phone use.

More than 40% reported a change in lateral position as an effect of phone use.

Driving performance was not affected by phone mode.

6 Comparison between HH, HF, SMS and DVD experiments

In this short chapter some comparisons across the different experiments that make up the study are shown for the PDT reaction time and the questionnaires. The comparisons between the experiments have not been tested with respect to statistical significance, but are based solely on visual inspection of the figures.

6.1 PDT reaction time

Figure 178 presents an overview of the result for average PDT reaction time at all ten traffic situations when engaged in mobile phone conversation or watching a DVD film. The drivers using a phone appeared to have longer average reaction times than drivers watching a DVD movie.

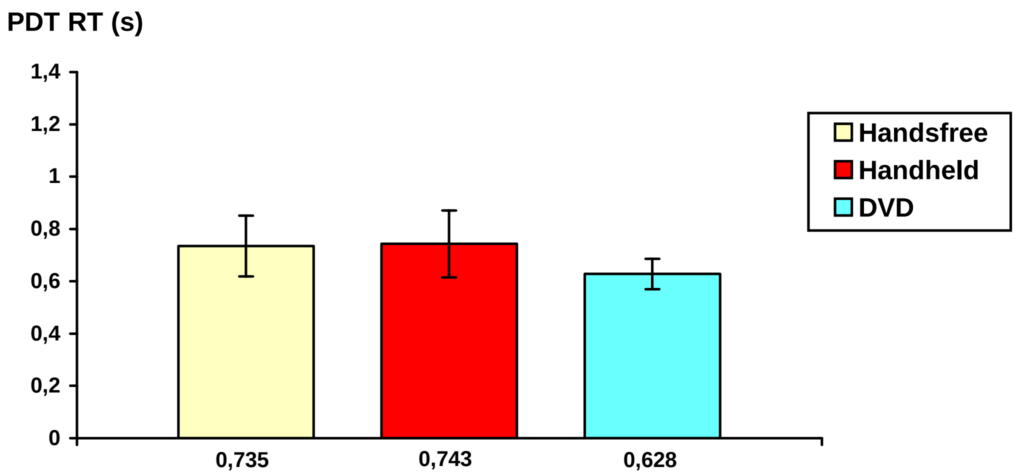


Figure 178 *Mean PDT reaction time in two experiments in the study – phone conversation (handsfree vs. handheld phone), DVD (± SD).*

6.2 Perceived mental effort

Perceived mental effort was measured on the RSME scale, 0–150, where 0 represents "no effort" and 110 "very great effort".

6.2.1 Perceived mental effort – total route

Figure 179 shows the average mental effort for 24 participants using a handsfree phone, for 24 participants using a handheld phone, for ten participants receiving SMS, and for 7 participants watching a DVD movie. The result is for driving both with and without use of the device. The mental effort appears to be highest in the DVD experiment.

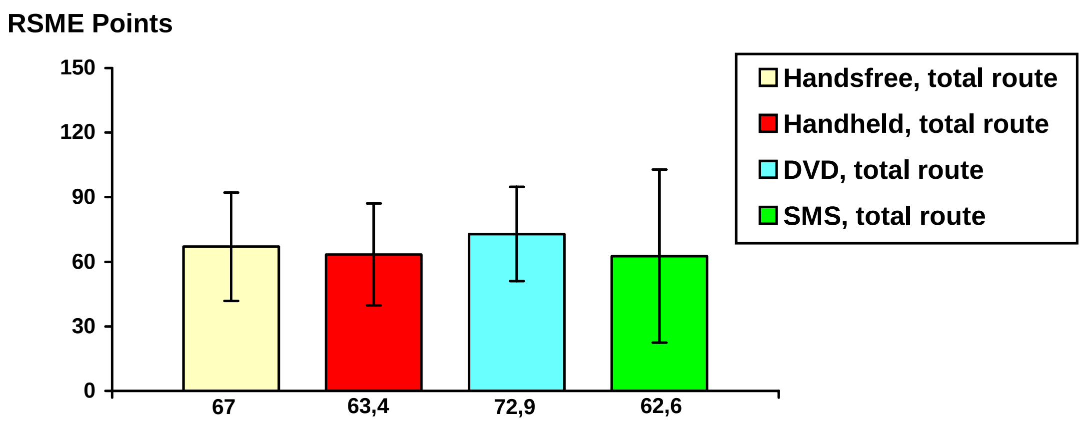


Figure 179 *Perceived mental effort during total route (± SD).*

6.2.2 Perceived mental effort at motorbike situation

Figure 180 shows the average mental effort at the motorbike situation. No significant effects of any of the devices emerged. However, the suggestion that the effect could be greatest for DVD and SMS is noticeable.

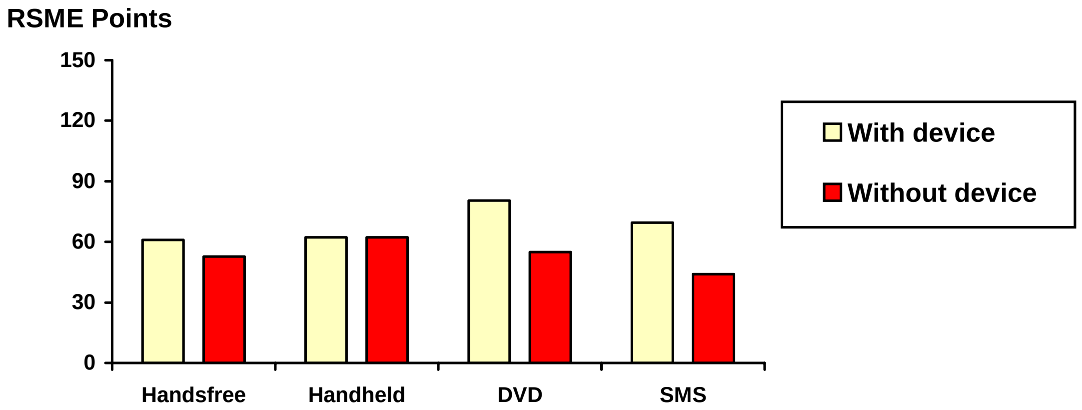


Figure 180 *Perceived mental effort at motorbike situation (± SD).*

6.3 Reported effort

Figure 181 summarises the answers to the question: "*Hur ansträngande var det att prata i telefon och köra samtidigt*? (How much effort did it require to talk on the phone and drive at the same time?)". For the SMS experiment and DVD experiment, the question was of course related to their device. The drivers with SMS appear to have experienced the lowest effort, while the drivers with DVD appear to have experienced the highest effort.

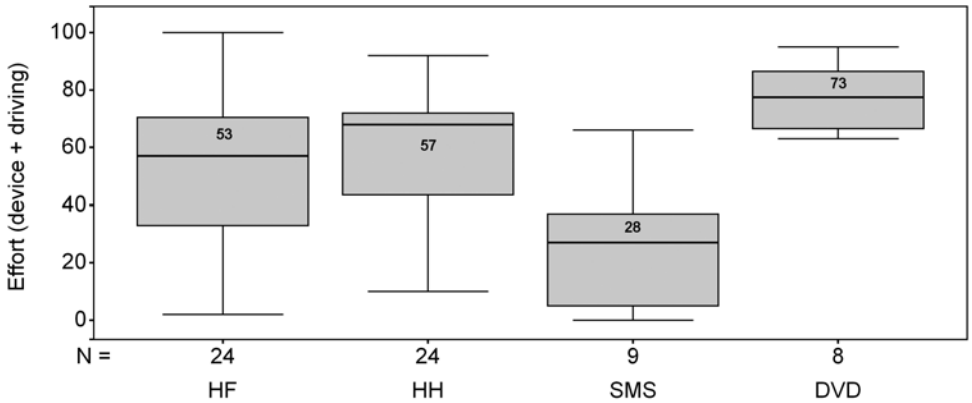


***Figure 181** Box plots of reported effort for mobile phone conversation, SMS and DVD experiments. The mean values are written in each box [0 = very low, 100 = very high].*

6.4 Reported opinion about the device

Figure 182 shows the drivers' opinion about the device used. The question was: "*Vad är din inställning till att använda mobiltelefon under bilkörning*? (What is your attitude towards using a mobile phone while driving?)". All drivers in the mobile phone conversation experiment were asked both for handheld and hands-free mode, the drivers in the SMS experiment answered for sending and receiving SMS, and those in the DVD experiment for watching a DVD film while driving.

Handsfree mobile phone appears to have been rated as the most positive device, and DVD the most negative device.

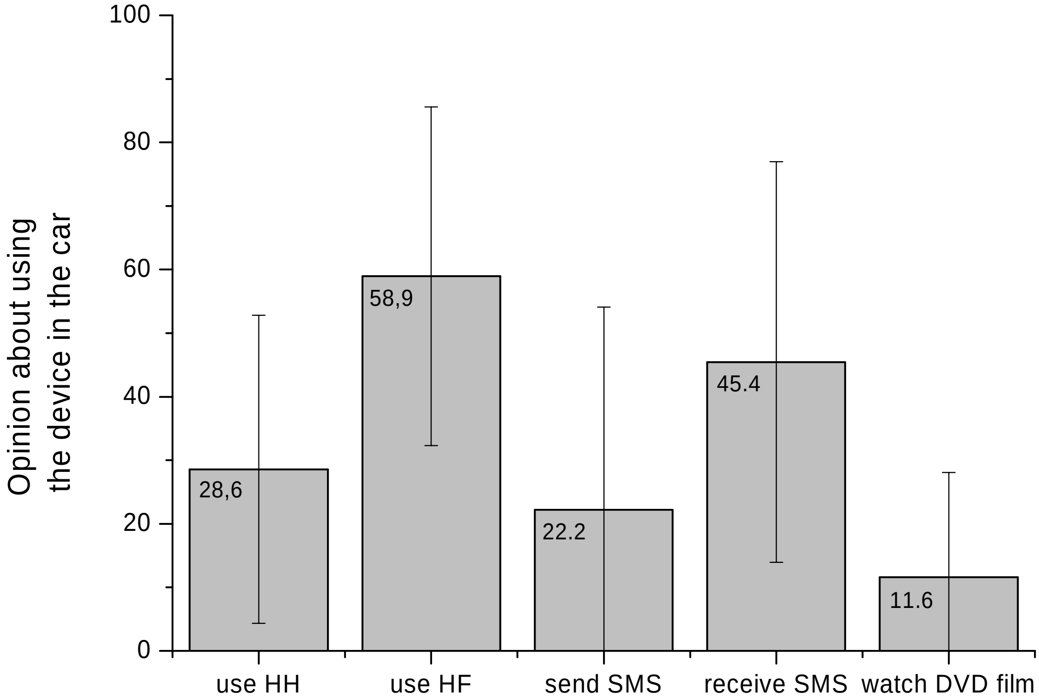


Figure 182 *Participants' opinion about the devices studied [0 = very negative, 100 = very positive].*

6.5 Reported driving style change while using the device

Figure 183 shows the answers to the question: "*Tycker du att du körde sämre eller bättre än normalt när du pratade i mobiltelefon?* (Do you think you drove worse or better than normal when you where talking on the phone?)". The drivers in the SMS and DVD experiments were asked about using SMS and watching DVD.

SMS appears to have been given the most positive rating regarding driving style, and DVD the most negative.

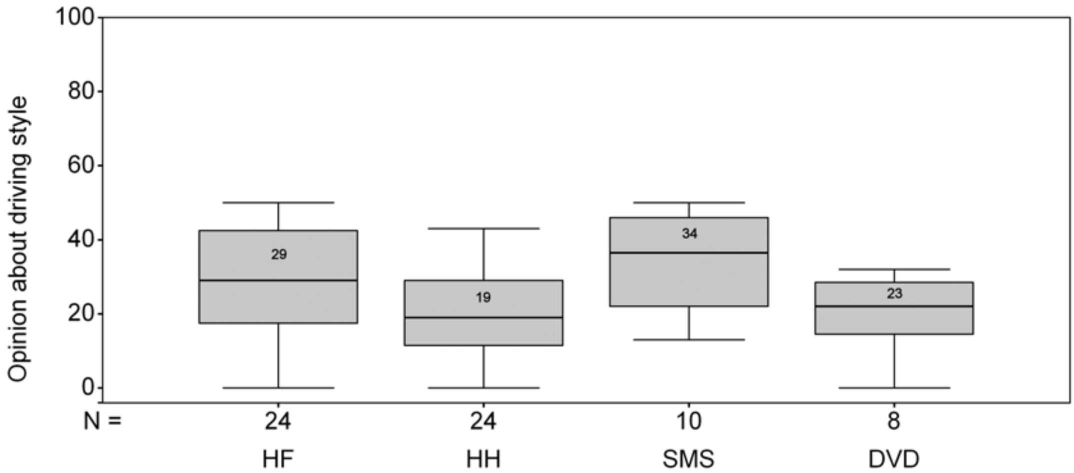


Figure 183 *Box plots of the participants' opinion of how well they drove. The mean values are written in each box (0 = much worse than without device, 50 = equal to without device, 100 = much better than without device).*

7 Discussion

The discussion of the results is divided into the experiments constituting the study: mobile phone conversation experiment (handsfree and handheld), SMS experiment, DVD experiment and mobile phone dialling experiment.

7.1 Mobile phone conversation experiment

The main question was if a demanding mobile phone conversation while driving had any effects on driving performance. This question can be answered positively, as various variables were affected by the mobile phone call.

The effects can be assigned to two main categories: effects that may have negative consequences on traffic safety, and compensatory behaviours that may counteract the negative effects. The net effect of these two opposing tendencies will probably determine the actual effect on traffic safety.

As expected, measures of mental workload were affected by mobile phone use. PDT showed strong effects of mobile phone conversation for both handheld and handsfree mode in all traffic environments and in all events; recorded PDT performance when talking on the phone was impaired (slower reaction time and higher miss rate). The effects were very similar for the two phone modes, a result that closely corresponds to the results found by Patten et al. (2003) in real traffic. Similar effects on self-reported mental workload have been demonstrated for handsfree phones in simulated driving (Alm and Nilsson, 1990) and for handheld phones (de Waard, Hernández-Gress and Brookhuis, 2001; Burns et al., 2002). It is reasonable to assume that impaired PDT performance implies a reduced readiness to respond to traffic situations that require a fast and accurate response from the driver, and should consequently be interpreted as a negative effect from a traffic safety point of view.

The major results regarding driving behaviour are summarised in Table 126 and Table 127 on pages 238 and 239 in the Appendix, which the reader is recommended to study. An important measure from a traffic safety perspective is the lateral control of the vehicle. The result was that the lateral position variance decreased for both handsfree and handheld modes on the rural road with speed limit 90 km/h. Similar tendencies also appeared for other situations. When the average performance across all situations was analysed, the lateral position variance decreased for handsfree mode only, although the non-significant result for handheld mode pointed in the same direction. These findings are quite the opposite to what most other researchers have found: that the variation in lateral position instead increases as an effect of mobile phone use. The latter result has been demonstrated for both phone modes on tracking performance (Strayer and Johnston, 2001), and for handheld mode in real or simulated driving (Salvucci and Macuga, 2002; Reed and Green, 1999; de Waard, Hernández-Gress and Brookhuis, 2001). Haigney et al. (2000) also found impaired lateral control with handheld phone in simulated driving. These results have been interpreted as negative effects from a traffic safety point of view. A couple of other studies did not, however, demonstrate any effects of phone use on variation in lateral position; for handsfree phone (Alm and Nilsson, 1990), and for both phone modes (Burns et al., 2002).

A similar effect to what was found in the present experiment, decreased variation in lateral position, has been described for car following in real traffic (Brookhuis, de Vries and de Waard, 1991). An interpretation of this finding has been suggested by van der Hulst (1999). Drivers adopt "virtual" safety margins in lateral position when driving. This can be seen as an invisible line to the left and to the right of the vehicle, and the driver wants to keep the vehicle inside this "tunnel", where he or she feels safe. The driver accepts a certain variation in lateral position as long as the vehicle does not cross the safety margins. In a situation with higher workload (for example high speed, a complex traffic environment or mobile phone conversation) the driver positions the safety margins closer to the vehicle, which means that the variation in lateral position will decrease since he or she wants to keep the car inside the margins. In other words it can be interpreted as a compensation for the higher workload. An alternative interpretation, suggested by Brookhuis, de Vries and de Waard (1991) is that the decreased variation in lateral position is an effect of increased driver alertness. Other explanations also seem plausible, however. It might be related to the reduced driving speed, or it might be an effect of the steering becoming less prioritised during the phone conversation.

Another measure of lateral control, lateral acceleration, was also affected by phone use. Maximal lateral acceleration decreased in two situations (motorbike, car following) for handsfree mode. The tendency was the same for two more of the remaining situations. The result could be given the same interpretation as the results for the variation in lateral position, since the two measures can be assumed to be affected in a similar way by the driver's steering pattern. Similar tendencies also appeared partly for the handheld mode. However, the only significant outcome was that the maximal lateral acceleration, on the contrary, increased at one of the situations, the bus situation, but only for handheld mode. The effect was most certainly linked to the slow reaction caused by handheld phone use.

Longitudinal control was also affected by phone use. The speed reducing effect of mobile phone conversation was evident for both phone modes in the two traffic situations appearing to be the most demanding according to mental workload: the rural environment with the highest speed limit (90 km/h) and the urban environment with the highest complexity. Speed was also reduced in the handheld phone mode in two other traffic environments. Similar tendencies appeared in most of the remaining situations for both modes, although stronger for the handheld mode. Speed reduction caused by talking on the phone while driving a car has been demonstrated in other simulator studies as well: for handsfree phones when driving on a rather straight route (Alm and Nilsson, 1990) and in another study for both phone modes (Haigney, Taylor and Westerman, 2000), whereas Burns et al. (2002) found a speed reducing effect for handheld phones only. The speed reduction could be interpreted as an attempt to compensate for the increased workload caused by the phone conversation.

Although the speed-reducing effect was not significantly different for the two phone modes for any of the traffic situations analysed separately, the speed reduction across all studied traffic environments was different for the two phone modes – it was greater for handheld phone mode. Handheld phone mode seems to trigger a larger compensatory effect than handsfree mode, an effect also found in a field study by Patten et al. (2003) where drivers with handheld phone reduced their speed while no effect on driving speed was apparent for handsfree mode. Similarly, in a field study by Parkes, Fairclough and Ashby (1993) no effects on driving speed were found for handsfree phones. The result is intriguing since no difference in PDT performance was apparent between the two phone modes. It cannot be ruled out that the drivers using a handheld phone to some extent made the driving task less mentally loading by slowing down (more so than the handsfree drivers). This way, the mental workload might have been made rather similar to the workload in the handsfree condition.

The result for speed variance was mixed. Phone use caused reduced speed variance in one situation for handsfree mode, whereas effects in different directions (decrease, increase) were apparent for handheld mode in two different situations. Speed variance across all analysed traffic environments decreased for handsfree mode only. To explain these effects is not a simple matter. When the speed variance is reduced, one possibility might be that drivers pay less attention to the driving task, get “locked” at a certain speed and fail to flexibly adapt the speed to the prevailing traffic situation, or that they overcompensate in keeping the speed constant.

Longitudinal interaction with other road users was also affected by phone use. One such result was that the reaction time for braking at one event, the bus event, was increased by phone use in the handheld mode. This result goes well in hand with the increased lateral acceleration in this situation. It should be noted, however, that no similar effects were found for the other events that required a reaction from the driver, a result which may be related to reduced speeds in these situations when being engaged in phone conversation, thus giving the driver more time to react to prevent a collision.

Burns et al. (2002) also demonstrated increased brake reaction time for handheld phone but not for handsfree phone. Other studies have, however, found prolonged reaction times to different traffic events for handsfree phone: on a tracking task (Strayer and Johnston, 2001) and in simulated driving (Alm and Nilsson, 1990; 1995; Strayer et al., 2002) or in real car driving (Brookhuis, de Vries and de Waard, 1991; Tokunaga et al., 2001). Still, it appears that the effects will be accentuated with the handheld mode.

Minimum time headway and minimum distance headway, measures of longitudinal risk margin, increased as an effect of phone use in the car following situation, for both phone modes. The result can be interpreted as a compensatory behaviour by the drivers. The tendency was the same for the other situation that was analysed. The result for minimum time headway, however, contrasts with the results from the simulator study by Alm and Nilsson (1995) where minimum time headway was reduced by handsfree phone use in car following, implying increased risk of a collision. Another measure of longitudinal risk margin, minimum time to collision (where consideration is taken to the speed difference between lead car and following car) showed no effects of phone use, however.

Let us return to the second question of the mobile phone conversation experiment: if driving in handsfree mobile phone mode differed from driving in handheld mode. Though effects of mobile phone conversation on some variables were found only in one phone mode (handheld or handsfree) and not in the other, it can be concluded that in the direct comparisons between phone modes most effects were quite similar.

The answers to the questionnaire did not reveal any differences in perceived mental effort between the handsfree and handheld phone modes, an outcome which of course supports the PDT results showing no difference between the two modes. Figure 182 shows that the opinion of the participants was much more positive towards handsfree phone use than handheld phone use. The driver also perceived driving performance as being more influenced/impaired by handheld than by handsfree (see Figure 183), a result which, however, hardly resembles the results for actual driving performance.

It can be discussed whether the effects found in the experiment were safety critical from a traffic perspective. As the PDT is meant to measure mental workload, and effects of impaired PDT performance were very clear during mobile phone conversation, it can be concluded that the conversation was demanding in terms of mental workload, which moreover means that the driver had less mental capacity left to attend to traffic during the conversation. Driving behaviour data do not give any strong indications for reduced traffic safety as an effect of phone use. However, it can be concluded with reasonable certainty that the drivers tried to compensate for the increased workload caused by the mobile phone conversation: by speed reduction (more so for handheld than for handsfree mode) and headway increase. In spite of these compensatory behaviours, mental workload was still markedly increased by phone use. It can be assumed that the increased mental workload caused by the phone conversation would have negative effects from a traffic safety perspective in terms of reduced readiness to respond if a risky situation were suddenly to appear. To what extent the reduced speed and/or increased headway would compensate for the reduced readiness is unclear. The crash risk may be reduced to some extent, but probably not enough considering the large increase in mental workload.

7.2 SMS experiment

When discussing the effects that were found in the experiment, one should keep in mind that the limited number of participants (10) made it difficult to find effects of the independent variables.

Even though the transmission of the SMS message was of short duration, it can be assumed that it was quite distracting to the driver.

The principal results regarding driving behaviour are summarised in Table 137 on page 242 in the Appendix.

The brake reaction times at four situations were analysed. The results show that the reaction time for braking at the motorbike event was more than 35% longer when the driver was reading the SMS. This result is important in terms of traffic safety, since the risk of a collision with the motorbike is higher when the car driver brakes later. The large effect may be related to a low expectancy by the driver for something to occur that requires a fast reaction in the otherwise quiet rural environment. Similar tendencies appeared in a couple of other situations.

The questionnaire showed that the participants had a negative opinion of sending SMS from mobile phones in cars (not tested in the experiment), but were more positive to receiving SMS (see Figure 182). Receiving SMS was scored the lowest effort of the devices in the study (see Figure 181). Probably in hand with this, the participants' opinion about how well they drove in the SMS experiment was the most positive but still worse than only driving (see Figure 183).

It was observed that the time needed for reading the SMS message varied greatly across participants. This makes the effects of SMS reading somewhat difficult to analyse. The strategy for reading the SMS varied as well: some participants took the phone as soon as the SMS message arrived and read it, while others waited to read the SMS until they were in a less demanding situation (for example after a crossing). It is believed that the strategy for reading the SMS is very important in terms of traffic safety: if the driver waits until after a complex situation to take the phone, or if he or she feels urged to read the message as soon as it arrives independently of the prevailing traffic situation.

7.3 DVD experiment

There were only eight participants in the DVD experiment which of course made it difficult to find effects of the independent variables.

The principal results regarding driving behaviour are summarised in Table 188 on page 255 in the Appendix.

In most traffic environments, the PDT reaction time was slower when watching the DVD film. This can be interpreted as showing that watching the film increased the mental workload of the drivers.

Longitudinal control was affected by watching the DVD movie. Speed variance over the whole route decreased as an effect of watching the film. The mean speed did not, however, show any effects of watching the movie. There was not even a tendency in this direction when the result for the whole route was analysed.

Some effects were also found for longitudinal interaction with other vehicles. The mean distance headway and the minimal distance headway in the car following event increased when watching the film. Of course this effect goes in hand with the increase of the time headway, since at a given speed a longer distance headway also means a longer time headway. The result can be interpreted as a compensatory behaviour by the drivers.

The decrease in speed variance is not seen as safety critical, but the impaired PDT reaction time performance (whole route) may be related to reduced safety, which, however, is counteracted by the increased distance headway in one of the situations.

The questionnaires did not reveal any effect of watching the DVD film when driving on the perceived subjective mental effort. The participants had a very negative opinion about watching films and driving, in fact the DVD movie scored the most negative opinion of all devices, as Figure 182 on page 171 shows. The participants also reported that their driving performance was impaired when watching the DVD movie (see Figure 183 on page 172), although not more so than when using a handheld phone.

It is interesting to note that the questionnaire pointed out that the participants in the DVD experiment reported the greatest effort of all four experiments in the study (see Figure 181 on page 170). More research is needed to study the effects of in-car devices such as DVD players. The present experiment suffered from a small sample size, although it does point out that there are effects which may be safety critical when using such devices. It may be considered particularly alarming that the participants did not reduce their driving speed in an attempt to compensate for the increased workload.

7.4 Dialling experiment

The principal results regarding driving behaviour are summarised in Table 189 on page 256 in the Appendix.

The mental workload as measured by the PDT increased when interacting with the in-vehicle device.

Lateral and longitudinal control were affected by dialling a phone number.

Lateral position variance increased in the handsfree mode, and a similar (non-significant) trend appeared in the handheld mode. In direct comparison between the two modes, however, no difference in lateral position variance was apparent. The result is an indication of reduced safety – in contrast to the result from the mobile phone conversation experiment, where the participants instead reduced their lateral deviation. This lends support to the belief that dialling is a more critical phase than the conversation part of the phoning sequence.

Dialling a phone number has also in a number of other studies been shown to have potentially negative effects from a traffic safety point of view: prolonged eyes-off-the-road episodes (Zwahlen, Adams and Schwarz, 1988), impaired ability to follow the road in an optimal way (California Highway Patrol, 1987), changed steering wheel movement pattern resulting in increased variation in lateral position (Reed and Green, 1999), and impaired detection and time to collision performance (Lamble et al., 1999).

Handsfree mobile phone use is commonly supposed to be more "user friendly" since the driver does not have to hold the phone in the hand. Conversely, the results of the analyses clearly show that the handsfree and the handheld mode are rather equivalent in terms of increased workload. The drivers reduced their speed when interacting with the in-vehicle device. The speed reduction was, however, greater for the handsfree mode, which could be interpreted in terms of different degrees of compensation. The reason for the results can be supposed to lie in the fact that for dialling the number in handsfree mode the drivers had to look away from the road for a longer time period than in handheld mode (the mobile phone holder position can be seen in Figure 3 on page 39). A typical position for holding the phone in handheld mode can be seen in Figure 184 below. When ringing up in handheld mode the drivers grabbed the mobile phone from the holder (which hardly ever required the driver to look away from the road, as seen in the video recording of the drives), and then held the phone close to the upmost part of the steering wheel while dialling. From this position the mobile phone was much closer to the frontal view of the driver than in the handsfree mode.

Figure 184 *Typical position in which the mobile phone was held for dialling (handheld situation).*

7.5 General points

The selection of participants in the study could be discussed. Even though one of the requirements for participation in the study was that the person did not easily suffer from motion sickness, a significant number of participants nevertheless met with such problems during the test session, and had to be replaced by other participants fulfilling the requirements. The results of the experiments are cones-quently, in a strict sense, limited to those individuals who do not easily suffer from motion sickness. That these circumstances would constitute a serious limitation regarding the generalisability of the findings appears unlikely, however. There is no apparent reason why the findings would in any significant way be different for those who are more inclined to suffer from motion sickness.

Another issue that could be discussed is the possibility to generalise the findings of the present simulator study to on-the-road conditions. One problem, which Svenson and Patten (2003) point out, is that attention priorities could be different in the two situations. However, it is reasonable to assume that the more realistic the simulation appears to the driver, the more similar the attention priorities will be. An advanced driving simulator such as the one used in the present study will be advantageous in this respect. Another problem mentioned by Svenson and Patten (2003) is that perceived speed may differ in the two situations. Even if this is true to some extent, again most probably depending on how realistic the driving simulation is, most research issues deal with differences between experimental conditions and not with specifying basic values, such as the choice of speed, lateral position etc. A simulator study by Törnros (1998) can be used as an example, where the driving speed in the simulator was higher than in real car driving. The effects of the different independent variables in the study were, however, almost identical in the simulator and in real driving.

It should be pointed out that the participants in the study were instructed to answer the phone when it rang (although not instructed to take the call immediately), to dial a phone number when instructed to do so via a signal, to read an SMS when it arrived or to watch the DVD movie while driving. In real life, the driver always has the possibility to wait and use the equipment once the traffic situation is suited to such extra activities. This way, the driver can choose to use the equipment in a safe or in a less safe manner. This difference between the experimental situation and the real life situation should however not be exaggerated, since the participants were instructed to drive in a normal manner.

The present study concentrated on the analysis of effects of mobile phone conversation on driving. Effects of dialling were analysed to a minor extent. Other aspects of mobile phone use while driving still remain to be analysed more in detail, such as starting or finishing a call, looking for a phone number to dial, mishaps like dropping the phone etc. A mobile phone with a screen showing black-and-white still images was used in the study. There are, however, newer and more advanced types of mobile phone on the market with the capacity to transmit moving images in colour. The risk of interference with the driving task may well increase further with these new phones. This issue would also require detailed study.

The SMS and DVD experiments were pilot studies. These should be followed up by larger studies, enabling a more comprehensive analysis of effects of relevance to traffic safety.

8 Conclusions

- Mobile phone conversation while driving caused increased mental workload.

- Drivers tried to compensate for the increased workload caused by phone conversation by slowing down and by increasing the headway to a lead vehicle in car following. The decreased variation in lateral position might also be interpreted as attempts to compensate. It could, however, just as well be an effect of the steering becoming less prioritised and in this way becoming more or less ‘locked’ during the phone conversation.

- The dialling part of a mobile phone call appeared to have more negative consequences from a safety point of view – even though drivers tried to compensate for the increased workload by slowing down, their variation in lateral position increased.

- Handsfree and handheld mobile phone use had similar effects on driving performance.

- Receiving SMS messages while driving had large negative effects on brake reaction time. The effects of a short SMS message are, however, expected to depend to a significant extent on the strategy for reading he message.

- Watching a DVD movie while driving caused increased mental workload. Drivers tried to compensate for this by increasing the headway to a lead vehicle in car following. There was, however, no tendency to compensate by speed reduction.

- The pilot studies of SMS and DVD should be followed up by larger studies.

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10 Appendices

10.1 Instructions

10.1.1 Instruction handsfree phone

Deltagarinstruktion

Din uppgift är att köra ca 8 mil i simulatorn. Körningen tar ungefär 1 timma, och du kommer att köra både på landsväg och i stadstrafik. Under försöket blir du uppringd på telefon ett antal gånger, och genomför då telefonsamtalen samtidigt som du kör. Innan försöket startar får du träna både på köruppgiften och på telefonuppgiften. Träningen tar ungefär 15 minuter. Efter körningen kommer du att få fylla i ett kort frågeformulär.

Telefonuppgiften

Telefonen du kommer att använda i försöket är så kallad handsfree, dvs. du behöver inte hålla den i handen när du pratar. När telefonen ringer ska du alltså **låta telefonen sitta kvar i hållaren,** och svara genom att **trycka på den gröna knappen**. Uppgiften du ska lösa i telefonen är en summeringsuppgift enligt följande schema:

Försöksledaren säger en siffra i telefonen. Sedan säger försöksledaren en siffra till. Du summerar talen och svarar med summan av de två. När du svarat säger försöksledaren ytterligare en siffra. Du svarar med summan av de två senaste siffrorna försöksledaren har sagt, och så vidare. Du kan se hur telefonuppgiften går till i exemplet nedan:

försöksledaren säger:		du svarar:
3		
9	→	12
1	→	10
1	→	2
9	→	10
6	→	15

Efter samtalet trycker du den röda knappen för att avsluta samtalet.

En knapp på fingret

Det sitter en lysdiodplatta vid vindrutan. När en lysdiod tänds ska du så fort som möjligt trycka pa en knapp som vi fäster på ditt vänstra pekfinger. När du trycker på knappen släcks dioden. Detta ar en uppgift som gäller under hela körningen.

Köruppgiften

Det är viktigt att du kör i simulatorn som du brukar köra under motsvarande förhållanden i verklig trafik. Du ska alltid köra rakt fram, om inget annat framgår av skyltningen.

Träning
Under träningspasset får du vänja dig vid att köra simulatorn, och vid att ta emot telefonsamtal under körning. Du kan under hela träningen ställa frågor till försöksledaren. Efter träningen sammanfattar försöksledaren din uppgift en gång till innan försöket startar.

Allmänt
Försöksledaren kan under hela körningen se och höra dig i simulatorn. Det är viktigt att du säger till så fort någonting inte känns bra. Du kan avbryta försöket när som helst. Du ska inte öppna dörren till simulatorn själv.

Sammanfattning

- Kör som du brukar köra under motsvarande förhållanden i verklig trafik.
- Låt telefonen sitta kvar i sin hållare under hela samtalet.
- Svara genom att trycka på den gröna knappen när telefonen ringer.
- Summera de två senaste talen försöksledaren sagt.
- Meddela försöksledaren om något inte känns bra.

10.1.2 Instruction handheld phone

Deltagarinstruktion
Din uppgift är att köra ca 8 mil i simulatorn. Körningen tar ungefär 1 timma, och du kommer att köra både på landsväg och i stadstrafik. Under försöket blir du uppringd på telefon ett antal gånger, och genomför då telefonsamtalen samtidigt som du kör. Innan försöket startar får du träna både på köruppgiften och på telefonuppgiften. Träningen tar ungefär 15 minuter. Efter körningen kommer du att få fylla i ett kort frågeformulär.

Telefonuppgiften
Telefonen du kommer att använda i försöket är så kallad handhållen, dvs. du håller den i handen när du pratar. När telefonen ringer ska du alltså **ta telefonen ur hållaren** och hålla den i handen under hela samtalet**.** Du svarar genom att **trycka på den gröna knappen**. Uppgiften du ska lösa i telefonen är en summeringsuppgift enligt följande schema:

Försöksledaren säger en siffra i telefonen. Sedan säger försöksledaren en siffra till. Du summerar talen och svarar med summan av de två. När du svarat säger försöksledaren ytterligare en siffra. Du svarar med summan av de två senaste siffrorna försöksledaren har sagt, och så vidare. Du kan se hur telefonuppgiften går till i exemplet nedan:

försöksledaren läser:		du svarar:
3		
9	→	12
1	→	10
1	→	2
9	→	10
6	→	15

När försöksledaren säger ”*tack, hej då*” trycker du den röda knappen för att avsluta samtalet. Efter avslutat samtal sätter du telefonen tillbaka i hållaren.

En knapp på fingret
Det sitter en lysdiodplatta vid vindrutan. När en lysdiod tänds ska du sa fort som möjligt trycka på en knapp som vi fäster på ditt vänstra pekfinger. När du trycker på knappen släcks dioden. Detta är en uppgift som gäller under hela körningen.

Köruppgiften
Det är viktigt att du kör i simulatorn som du brukar köra under motsvarande förhållanden i verklig trafik. Du ska alltid köra rakt fram, om inget annat framgår av skyltningen.

Träning
Under träningspasset får du vänja dig vid att köra simulatorn, och vid att ta emot telefonsamtal under körning. Du kan under hela träningen ställa frågor till försöksledaren. Efter träningen sammanfattar försöksledaren din uppgift en gång till innan försöket startar.

Allmänt
Försöksledaren kan under hela körningen se och höra dig i simulatorn. Det är viktigt att du säger till så fort någonting inte känns bra. Du kan avbryta försöket när som helst. Du ska inte öppna dörren till simulatorn själv.

Sammanfattning
- Kör som du brukar köra under motsvarande förhållanden i verklig trafik.
- Ta telefonen ur sin hållare och håll den i handen under hela samtalet.
- Svara genom att trycka på den gröna knappen när telefonen ringer.
- Summera de två senaste talen försöksledaren sagt.
- Meddela försöksledaren om något inte känns bra.

10.1.3 Instruction SMS

Deltagarinstruktion
Din uppgift är att köra ca 8 mil i simulatorn. Körningen tar ungefär 1 timma, och du kommer att köra både på landsväg och i stadstrafik. Under försöket får du sms-meddelanden ett antal gånger, och läser då meddelandena samtidigt som du kör. Innan försöket startar får du träna både på köruppgiften och på sms-uppgiften. Träningen tar ungefär 15 minuter. Efter körningen kommer du att få fylla i ett kort frågeformulär.

SMS-Uppgiften
Telefonen ligger på passageraresätet brevid dig. När telefonen piper under försöket, för att tala om att ett sms-meddelande har kommit fram, ska du ta telefonen i handen och sedan trycka på knappen under ordet ”*visa*”. Meddelandet visas då på displayen, och du läser det högt. Meddelandet kommer att vara en enkel fråga som du ska svara på genom att säga svaret högt (försöksledaren hör dig). Du ska alltså **inte** svara genom att skicka ett sms eller ringa ett samtal.
Ett sms-meddelande kan se ut ungefär så här: *”Vilken dag följer efter lördag?”*
Du läser meddelandet högt och svarar med: ”*söndag*”.

När du har läst meddelandet, och svarat på frågan, trycker du på knappen ”*tillbaka*” och lägger tillbaka telefonen på passagerаresätet.

En knapp på fingret
Det sitter en lysdiodplatta vid vindrutan. När en lysdiod tänds ska du så fort som möjligt trycka på en knapp som vi fäster på ditt vänstra pekfinger. När du trycker på knappen släcks dioden. Detta är en uppgift som gäller under hela körningen.

Köruppgiften
Det är viktigt att du kör i simulatorn som du brukar köra under motsvarande förhållanden i verklig trafik. Du ska alltid köra rakt fram om inget annat framgår av skyltningen.

Träning
Under träningspasset får du vänja dig vid att köra simulatorn, och vid att ta emot sms-meddelanden under körning. Du kan under hela träningen ställa frågor till försöksledaren. Efter träningen sammanfattar försöksledaren din uppgift en gång till innan försöket startar.

Allmänt
Försöksledaren kan under hela körningen se och höra dig i simulatorn. Det är viktigt att du säger till så fort någonting inte känns bra. Du kan avbryta försöket när som helst. Du ska inte öppna dörren till simulatorn själv.

Sammanfattning

- Kör som du brukar köra under motsvarande förhållanden i verklig trafik.
- Dra inte ur sladden ur telefonen när du läser meddelandet.
- Tryck på knappen under ordet ”*visa*” för att se meddelandet.
- Läs meddelandet högt.
- Svara högt på frågan som ställs i meddelandet.
- Meddela försöksledaren om något inte känns bra.

10.1.4 Instruction DVD

Deltagarinstruktion
Din uppgift är att köra ca 8 mil i simulatorn. Körningen tar ungefär 1 timma, och du kommer att köra både på landsväg och i stadstrafik. Under ungefär halva körtiden ska du titta på en DVD-film samtidigt som du kör. Filmen visas på en skärm som finns placerad på mittkonsolen. Innan försöket startar får du träna på köruppgiften. Då kommer du även att få tillfälle att titta lite på filmen. Träningen tar ungefär 15 minuter. Efter körningen kommer du att få fylla i ett kort frågeformulär.

DVD-Uppgiften
På baksidan av den här instruktionen kan du läsa hur filmen, som du får se en del av, börjar. Under den del av filmen som du kommer att se syns oftast bara huvud-personens röda bil och lastbilen, men ibland ser man även andra fordon. När filmen visas i simulatorn är det din uppgift att nämna varje ”annat” fordon genom att högt säga vilken typ av fordon det är (t.ex. ”tåg”, ”bil”, etc.). Försöksledaren

kan höra vad du säger. Om samma fordon dyker upp flera gånger i samma scen räcker det om du nämner det bara en gång. Försöksledaren slår startar och stoppar filmen, du behöver alltså inte hantera filmen själv.

En knapp på fingret
Det sitter en lysdiodplatta vid vindrutan. När en lysdiod tänds ska du så fort som möjligt trycka på en knapp som vi fäster på ditt vänstra pekfinger. När du trycker på knappen släcks dioden. Detta är en uppgift som gäller under hela körningen.

Köruppgiften
Det är viktigt att du kör i simulatorn som du brukar köra under motsvarande förhållanden i verklig trafik. Du ska alltid köra rakt fram om inget annat framgår av skyltningen.

Träning
Under träningspasset får du vänja dig vid att köra simulatorn och får möjligheten att se lite av filmen. Du kan under hela träningen ställa frågor till försöksledaren. Efter träningen sammanfattar försöksledaren din uppgift en gång till innan försöket startar.

Allmänt
Försöksledaren kan under hela körningen se och höra dig i simulatorn. Det är viktigt att du säger till så fort någonting inte känns bra. Du kan avbryta försöket när som helst. Du ska inte öppna dörren till simulatorn själv.

Sammanfattning
- Kör som du brukar köra under motsvarande förhållanden i verklig trafik.
- Rapportera när ”andra fordon” syns på filmen genom att högt säga vilken typ av fordon det är.
- Meddela försöksledaren om något inte känns bra.

10.1.5 Instruction Handsfree dialling

Deltagarinstruktion
Din uppgift är att köra ca 15 km i simulatorn. Körningen tar ungefär tio minuter, och du kommer att köra på landsväg. Under försöket ska du ringa tre telefonsamtal samtidigt som du kör. Det finns inte någon träningsfas till den här uppgiften. Efter körningen kommer du att få fylla i ett kort frågeformulär.

Telefonuppgiften
Först får du prova att ringa till en telefon här i hallen på nummer **013-20 40 22**.

När du kör i simulatorn kommer ordet ”*RING!*” att dyka upp i vägmiljön framför dig. Då ska du börja slå numret som är fastklistrat på telefonen. Telefonen du kommer att använda i försöket är så kallad handsfree, dvs. du behöver inte hålla den i handen när du ringer. När du ringer samtalet ska du alltså **låta telefonen sitta kvar i hållaren.** När du slår första siffran försvinner ordet ”*RING!*”. Du slår hela numret och trycker sedan på den gröna knappen. Vänta tills samtalet besvaras med ”*hej, du kan lägga på nu*”. Lägg då på genom att trycka på den röda knappen. Gör likadant när ordet ”*RING!*” dyker upp andra och tredje gången.

En knapp på fingret
Det sitter en lysdiodplatta vid vindrutan. När en lysdiod tänds ska du så fort som möjligt trycka på en knapp som vi fäster pa ditt vänstra pekfinger. När du trycker på knappen släcks dioden. Detta är en uppgift som gäller under hela körningen.

Köruppgiften
Det är viktigt att du kör i simulatorn som du brukar köra under motsvarande förhållanden i verklig trafik.

Allmänt
Försöksledaren kan under hela körningen se och höra dig i simulatorn. Det är viktigt att du säger till så fort någonting inte känns bra. Du kan avbryta försöket när som helst. Du ska inte öppna dörren till simulatorn själv.

Sammanfattning
- Kör som du brukar köra under motsvarande förhållanden i verklig trafik.
- Låt telefonen sitta kvar i sin hållare medan du ringer.
- Slå numret och tryck sedan på den gröna knappen.
- Tryck på den röda knappen när försöksledaren har svarat.
- Meddela försöksledaren om något inte känns bra.

10.1.6 Instruction Handheld dialling

Deltagarinstruktion
Din uppgift är att köra ca 15 km i simulatorn. Körningen tar ungefär tio minuter, och du kommer att köra på landsväg. Under försöket ska du ringa tre telefonsamtal samtidigt som du kör. Det finns inte någon träningsfas till den här uppgiften. Efter körningen kommer du att få fylla i ett kort frågeformulär.

Telefonuppgiften
Först får du prova att ringa till en telefon här i hallen på nummer **013-20 40 22**.

När du kör i simulatorn kommer ordet ”*RING!*” att dyka upp i vägmiljön framför dig. Då ska du börja slå numret som är fastklistrat på telefonen. Telefonen du kommer att använda i försöket är så kallad handhållen, dvs. du håller den i handen när du ringer. När du ringer samtalet ska du alltså **ta telefonen ur hållaren.** När du tar telefonen i handen försvinner ordet ”*RING!*”. Du slår hela numret och trycker sedan på den gröna knappen. Vänta tills samtalet besvaras med ”*hej, du kan lägga på nu*”. Lägg då på genom att trycka på den röda knappen och sätt telefonen tillbaka i hållaren. Gör likadant när ordet ”*RING!*” dyker upp andra och tredje gången.

En knapp på fingret
Det sitter en lysdiodplatta vid vindrutan. När en lysdiod tänds ska du så fort som möjligt trycka på en knapp som vi fäster på ditt vänstra pekfinger. När du trycker på knappen släcks dioden. Detta är en uppgift som gäller under hela körningen.

Köruppgiften
Det är viktigt att du kör i simulatorn som du brukar köra under motsvarande förhållanden i verklig trafik.

Allmänt
Försöksledaren kan under hela körningen se och höra dig i simulatorn. Det är viktigt att du säger till så fort någonting inte känns bra. Du kan avbryta försöket när som helst. Du ska inte öppna dörren till simulatorn själv.

Sammanfattning

- Kör som du brukar köra under motsvarande förhållanden i verklig trafik.
- Ta telefonen ur sin hållare medan du ringer.
- Slå numret och tryck sedan på den gröna knappen.
- Tryck på den röda knappen och sätt telefonen tillbaka i hållaren när försöksledaren har svarat.
- Meddela försöksledaren om något inte känns bra.

10.2 Questionnaires

10.2.1 Questionnaire handsfree phone

RSME Rating Scale (Figure 5)

En av de **senaste händelserna** i trafiken var att en motorcykel körde ut från höger rätt framför dig. Försök att försätta dig tillbaka i denna situation. Just i denna situation, hur mycket mental ansträngning innebar uppgiften för dig?		Du har nu kört både i stadstrafik och på landsbygd medan du har använt en mobiltelefon. Försök att göra en bedömning hur du kände dig i genomsnitt under **hela körningen**. Under hela körningen, hur mycket mental ansträngning innebar uppgiften för dig?

Gör en bedömning genom att sätta kryss på lämplig plats på skalorna nedan. Du kan utnyttja hela skalan om du vill.

1. Vad är din inställning till att använda mobiltelefon under bilkörning?

<u>handhållen</u>

mycket negativ — mycket positiv

<u>handsfree</u>

mycket negativ — mycket positiv

2. Brukar du använda telefon när du kör bil?

- ☐ nej
- ☐ ja, med "handsfree" (telefonen sitter i hållaren)
- ☐ ja, med "hand held" (telefonen i handen)
- ☐ ja, med "headset/snäcka" (mikrofon och hörlurar)

Om ja, hur ofta använder du mobiltelefonen när du kör bil?

mycket sällan — mycket ofta

3. Hur ansträngande var det att prata i telefon och köra samtidigt?

inte alls ansträngande — mycket ansträngande

4. Om du fått välja, skulle du då ha tagit telefonen i handen istället för att låta den sitta kvar?

- ☐ ja
- ☐ nej
- ☐ spelar ingen roll

5. Vad koncentrerade du dig mest på under telefonsamtalen?

- ☐ telefonsamtalet
- ☐ bilkörningen
- ☐ ingen skillnad

6. Påverkades hastigheten av att du använde mobiltelefonen under körning?

- ☐ nej
- ☐ ja, jag ändrade hastigheten **medvetet** och körde

  ☐ långsammare ☐ snabbare

- ☐ ja, hastigheten ändrade sig **omedvetet** och blev

  ☐ lägre ☐ högre

7. Påverkades avståndet till framförvarande bilen av att du använde telefonen?

- ☐ nej
- ☐ ja, jag ändrade avståndet **medvetet**; jag

  ☐ minskade avståndet ☐ ökade avståndet

- ☐ avståndet ändrade sig **omedvetet** och

  ☐ minskades ☐ ökades

8. Påverkades sidoläget av att du använde telefonen?

- ☐ nej
- ☐ ja, jag ändrade sidoläget **medvetet** inom mitt körfält och körde

  ☐ längre till vänster ☐ längre till höger

- ☐ ja, sidoläget ändrade sig **omedvetet** inom mitt körfält och körde

  ☐ längre till vänster ☐ längre till höger

- ☐ ja, jag körde utanför mitt körfält och körde

  ☐ längre till vänster ☐ längre till höger

9. Påverkades ditt körbeteende på annat sätt av att du använde telefonen?

____

____

10. Tycker du att du körde sämre eller bättre än normalt när du pratade i mobiltelefon?

mycket sämre lika bra mycket bättre

11. Skulle du ha använt mobiltelefonen på samma sätt i verklig trafik?

- ☐ ja
- ☐ nej (varför inte: ____)

12. I vilken trafikmiljö tycker du det var enklast att använda telefonen?

- ☐ i tätort
- ☐ på landsbygd
- ☐ lika enkelt i tätort och på landsbygd

10.2.2 Questionnaire handheld phone

RSME Rating Scale (Figure 5)

En av de **senaste händelserna** i trafiken var att en motorcykel körde ut från höger rätt framför dig. Försök att försätta dig tillbaka i denna situation. Just i denna situation, hur mycket mental ansträngning innebar uppgiften för dig?		Du har nu kört både i stadstrafik och på landsbygd medan du har använt en mobiltelefon. Försök att göra en bedömning hur du kände dig i genomsnitt under **hela körningen**. Under hela körningen, hur mycket mental ansträngning innebar uppgiften för dig?

Gör en bedömning genom att sätta kryss på lämplig plats på skalorna nedan. Du kan utnyttja hela skalan om du vill.

1. Vad är din inställning till att använda mobiltelefon under bilkörning?

handhållen

mycket negativ — mycket positiv

handsfree

mycket negativ — mycket positiv

2. Brukar du använda mobiltelefon när du kör bil?

- ☐ nej
- ☐ ja, med “handsfree” (telefonen sitter i hållaren)
- ☐ ja, med “hand held” (telefonen i handen)
- ☐ ja, med “headset/snäcka” (mikrofon och hörlurar)

Om ja, hur ofta använder du mobiltelefonen när du kör bil?

mycket sällan — mycket ofta

3. Hur ansträngande var det att prata i telefon och köra samtidigt?

inte alls ansträngande — mycket ansträngande

4. Om du fått välja, skulle du då låtit telefonen sitta kvar istället för att ta den i handen?

- ☐ ja
- ☐ nej
- ☐ spelar ingen roll

5. Vad koncentrerade du dig mest på under telefonsamtalen?

- ☐ telefonsamtalet
- ☐ bilkörningen
- ☐ ingen skillnad

6. Påverkades hastigheten av att du använde mobiltelefonen under körning?

- ☐ nej
- ☐ ja, jag ändrade hastigheten **medvetet** och körde

  ☐ långsammare ☐ snabbare

- ☐ ja, hastigheten ändrade sig **omedvetet** och blev

  ☐ lägre ☐ högre

7. Påverkades avståndet till framförvarande bilen av att du använde telefonen?

- ☐ nej
- ☐ ja, jag ändrade avståndet **medvetet**; jag

  ☐ minskade avståndet ☐ ökade avståndet

- ☐ avståndet ändrade sig **omedvetet** och

  ☐ minskades ☐ ökades

8. Påverkades sidoläget av att du använde telefonen?

- ☐ nej
- ☐ ja, jag ändrade sidoläget **medvetet** inom mitt körfält och körde

  ☐ längre till vänster ☐ längre till höger

- ☐ ja, sidoläget ändrade sig **omedvetet** inom mitt körfält och körde

  ☐ längre till vänster ☐ längre till höger

- ☐ ja, jag körde utanför mitt körfält och körde

  ☐ längre till vänster ☐ längre till höger

9. Påverkades ditt körbeteende på annat sätt av att du använde telefonen?

____

____

10. Tycker du att du körde sämre eller bättre än normalt när du pratade i mobiltelefon?

mycket sämre — lika bra — mycket bättre

|——————————|——————————|

11. Skulle du ha använt mobiltelefonen på samma sätt i verklig trafik?

☐ ja
☐ nej (varför inte: ______________________________

____)

12. I vilken trafikmiljö tycker du det var enklast att använda telefonen?

☐ i tätort
☐ på landsbygd
☐ lika enkelt i tätort och på landsbygd

10.2.3 Questionnaire SMS

RSME Rating Scale (Figure 5)

En av de **senaste händelserna** i trafiken var att en motorcykel körde ut från höger rätt framför dig. Försök att försätta dig tillbaka i denna situation. Just i denna situation, hur mycket mental ansträngning innebar uppgiften för dig?		Du har nu kört både i stadstrafik och på landsbygd medan du har använt en mobiltelefon. Försök att göra en bedömning hur du kände dig i genomsnitt under **hela körningen**. Under hela körningen, hur mycket mental ansträngning innebar uppgiften för dig?

Gör en bedömning genom att sätta kryss på lämplig plats på skalorna nedan. Du kan utnyttja hela skalan om du vill.

1. Vad är din inställning till att skicka och ta emot sms under bilkörning?

<u>skicka sms</u>

mycket negativ — mycket positiv

<u>ta emot sms</u>

mycket negativ — mycket positiv

2. Brukar du använda sms-funktionen när du kör bil?

- ☐ ja, jag läser inkommande sms
- ☐ ja, jag skickar sms
- ☐ nej

Om ja, hur ofta använder du sms-funktionen när du kör bil?

mycket sällan — mycket ofta

3. Skulle du under körning använda en tjänst som skickar ut trafikinformation på sms?

- ☐ ja
- ☐ nej

4. Hur ansträngande var det att läsa sms-meddelandet och köra samtidigt?

inte alls ansträngande — mycket ansträngande

5. Kände du dig "tvingad" att läsa meddelandena direkt?

nej, inte alls ja, mycket

6. När läste du meddelandena?

☐ direkt
☐ vid tidpunkt jag själv valde
☐ aldrig

7. Påverkades hastigheten av att du använde mobiltelefonen under körning?

☐ nej
☐ ja, jag ändrade hastigheten **medvetet** och körde

☐ långsammare ☐ snabbare

☐ ja, hastigheten ändrade sig **omedvetet** och blev

☐ lägre ☐ högre

8. Påverkades avståndet till framförvarande bilen av att du använde telefonen?

☐ nej
☐ ja, jag ändrade avståndet **medvetet**; jag

☐ minskade avståndet ☐ ökade avståndet

☐ avståndet ändrade sig **omedvetet** och

☐ minskades ☐ ökades

9. Påverkades sidoläget av att du använde telefonen?

- ☐ nej
- ☐ ja, jag ändrade sidoläget **medvetet** inom mitt körfält och körde
  - ☐ längre till vänster ☐ längre till höger
- ☐ ja, sidoläget ändrade sig **omedvetet** inom mitt körfält och körde
  - ☐ längre till vänster ☐ längre till höger
- ☐ ja, jag körde utanför mitt körfält och körde
  - ☐ längre till vänster ☐ längre till höger

10. Påverkades ditt körbeteende på annat sätt av att du använde telefonen?

____

____

11. Vad koncentrerade du dig mest på när ett meddelande kom?

- ☐ meddelandet
- ☐ bilkörningen

12. Tycker du att du körde sämre eller bättre än normalt när du tog emot sms-meddelandena?

mycket sämre — lika bra — mycket bättre

|——————————|——————————|

13. Skulle du hantera sms-meddelanden på samma sätt i verklig trafik?

- ☐ ja
- ☐ nej (varför inte: ______________________________

______________________________________)

14. I vilken trafikmiljö tycker du det var enklast att använda telefonen?

- ☐ i tätort
- ☐ på landsbygd
- ☐ lika enkelt i tätort och på landsbygd

10.2.4 Questionnaire DVD

RSME Rating Scale (Figure 5)

En av de **senaste händelserna** i trafiken var att en motorcykel körde ut från höger rätt framför dig. Försök att försätta dig tillbaka i denna situation. Just i denna situation, hur mycket mental ansträngning innebar uppgiften för dig?		Du har nu kört både i stadstrafik och på landsbygd, och under en del av körningen hade du tillfälle att titta på en film. Försök att göra en bedömning hur du kände dig i genomsnitt under **hela körningen**. Under hela körningen, hur mycket mental ansträngning innebar uppgiften för dig?

Gör en bedömning genom att sätta kryss på lämplig plats på skalorna nedan. Du kan utnyttja hela skalan om du vill.

1. Vad är din inställning till att titta på DVD under bilkörning?

   mycket negativ — mycket positiv

2. Hur ofta brukar du titta på DVD i bilen för underhållning (t. ex. titta på film) medan du kör?

   aldrig — alltid

3. Hur ansträngande var det att titta på filmen och köra samtidigt?

   inte alls ansträngande — mycket ansträngande

4. Har du sett filmen förut?

- ☐ ja
- ☐ nej

5. Hur intresserad var du av filmen?

inte alls ├────────────────────┤ mycket

6. Hur mycket tittade du på filmen?

inte alls ├────────────────────┤ mycket

7. Vad koncentrerade du dig mest på?

- ☐ att följa filmens handling
- ☐ enbart att leta efter “andra fordon”

8. Tror du att du missade “andra fordon”?

- ☐ ja, många
- ☐ ja, några
- ☐ nej, inga

9. Jämfört med nu i simulatorn, skulle du i verklig trafik ha tittat på den här filmen

- ☐ oftare
- ☐ ungefär lika mycket
- ☐ mer sällan

10. Medan filmen visades koncentrerade du dig mest på

- ☐ filmen
- ☐ bilkörningen
- ☐ ingen skillnad

11. Påverkades hastigheten av att du tittade på filmen under körning?

- ☐ nej
- ☐ ja, jag ändrade hastigheten **medvetet** och körde
  - ☐ långsammare ☐ snabbare
- ☐ ja, hastigheten ändrade sig **omedvetet** och blev
  - ☐ lägre ☐ högre

12. Påverkades avståndet till framförvarande bilen av att du tittade på filmen?

- ☐ nej
- ☐ ja, jag ändrade avståndet **medvetet**; jag
  - ☐ minskade avståndet ☐ ökade avståndet
- ☐ avståndet ändrade sig **omedvetet** och
  - ☐ minskades ☐ ökades

13. Påverkades sidoläget av att du tittade på filmen?

- ☐ nej
- ☐ ja, jag ändrade sidoläget **medvetet** inom mitt körfält och körde
  - ☐ längre till vänster ☐ längre till höger
- ☐ ja, sidoläget ändrade sig **omedvetet** inom mitt körfält och körde
  - ☐ längre till vänster ☐ längre till höger
- ☐ ja, jag körde utanför mitt körfält och körde
  - ☐ längre till vänster ☐ längre till höger

14. Påverkades ditt körbeteende på annat sätt av att du tittade på filmen?

____

____

15. Tycker du att du körde sämre eller bättre än normalt när du tittade på filmen?

mycket sämre | lika bra | mycket bättre

|———————|———————|

16. Tycker du att det var enklare att titta på filmen

- ☐ i tätort
- ☐ på landsbygd
- ☐ lika enkelt i tätort och på landsbygd

<u>Några frågor kring filmens innehåll</u>

1. Vad stod på lastbilens baksida?

___

2. Vad hette mannen?

___

3. Vad gjorde lastbilen med skolbussen?

___

4. Vilka djur hade kvinnan med bensinstationen?

___

5. Vad hände vid järnvägskorsningen?

___

6. Varför hjälpte paret i bilen inte mannen?

10.2.5 Questionnaire Dialling

1. Brukar du **ringa** telefonsamtal medan du kör?

- ☐ nej
- ☐ ja, oftast använder jag mig av
  - ☐ kortnummer
  - ☐ röststyrning
  - ☐ slår hela numret

Om ja, hur ofta ringer du samtal när du kör bil?

mycket sällan — mycket ofta

2. Hur ansträngande var det att slå numret och köra samtidigt?

inte alls ansträngande — mycket ansträngande

3. Hur ofta tittade du på telefonen när du slog numret?

inte alls — för varje siffra

4. Slog du fel och behövde korrigera?

aldrig — ofta

5. Hur ofta tittade du på vägen medan du slog numret?

inte alls — efter varje siffra

6. Vad koncentrerade du dig mest på under uppringningen?

☐ telefonen
☐ bilkörningen
☐ ingen skillnad

7. Påverkades hastigheten av att du använde mobiltelefonen under körning?

☐ nej
☐ ja, jag ändrade hastigheten **medvetet** och körde

☐ långsammare ☐ snabbare

☐ ja, hastigheten ändrade sig **omedvetet** och blev

☐ lägre ☐ högre

8. Påverkades sidoläget av att du använde telefonen?

☐ nej
☐ ja, jag ändrade sidoläget **medvetet** inom mitt körfält och körde

☐ längre till vänster ☐ längre till höger

☐ ja, sidoläget ändrade sig **omedvetet** inom mitt körfält och körde

☐ längre till vänster ☐ längre till höger

☐ ja, jag körde utanför mitt körfält och körde

☐ längre till vänster ☐ längre till höger

9. Påverkades ditt körbeteende på annat sätt av att du använde telefonen?

____

____

10. Tycker du att du körde sämre eller bättre än normalt när du ringde samtalet?

mycket sämre — lika bra — mycket bättre

11. Skulle du ha använt mobiltelefonen på samma sätt i verklig trafik?

- ☐ ja
- ☐ nej (varför inte: ________________________________

____)

RSME Rating Scale (Figure 5)

Du har nu kört på landsbygd medan du har ringt samtal med en mobiltelefon. Försök att göra en bedömning hur du kände dig i genomsnitt under **hela körningen**.

Under hela körningen, hur mycket mental ansträngning innebar uppgiften för dig? Gör en bedömning genom att sätta ett kryss på lämplig plats på skalan nedan. Du kan utnyttja hela skalan om du vill.

10.3 SMS messages

Note: the text messages are shown on 3 lines exactly as they were shown on the mobile phone screen.

Vilken dag följer efter onsdag?
Vilken månad följer efter mars?
Vilken dag kommer före tisdag?
Vilken månad kommer före november?
Vilken månad följer efter december?
Vilken dag kommer före fredag?
Vilken dag följer efter måndag?
Vilken månad kommer före maj?

10.4 DVD movie description

Description to the participant before the drive

En affärsman måste åka till ett möte ganska långt ifrån hemorten någonstans i sydvästra USA. Han tar sin röda bil och ger sig iväg. Vägen är lång och enformig och går mest genom öde ökenområde. Vid ett tillfälle hinner mannen ikapp en gammal lastbil som han kör om. Lastbilen ökar då farten och kör om mannen i den röda bilen. Efter att mannen återigen kör om lastbilen blir stämningen alltmer hotfullt.

General description

Duel (1971) 90 min.

David Mann is trying to drive his car across California. When he tries to pass a gas tanker, the driver somehow takes offence. At first the unseen driver just annoys David by continually passing him and slowing down. Then he starts playing mind games with David, tempting him to pass the tanker, only to prevent him when he tries. The story is seen from David's point of view, with commentary as he thinks to himself [1].

10.5 Handsfree and handheld phone

10.5.1 Questionnaire – perceived mental effort

10.5.1.1 Perceived mental effort (phone call during last motorbike situation)

Table 6 *Effects of phone use on perceived mental effort at last motorbike situation.*

	Handsfree: Call – no call (df=22)	Handheld: Call – no call (df=22)
t	.733	.006
Sign. (2-tailed)	.472	.995

10.5.2 Questionnaire – opinion of handsfree and handheld phone

10.5.3 Differences in opinion between participants using handsfree and handheld phone

Table 7 *Opinion on phone modes.*

	Handsfree: Opinion on handsfree compared to handheld (df=21)	Handheld: Opinion on handsfree compared to handheld (df=22)	Opinion on handsfree: Handsfree compared to handheld (df=45)	Opinion on handheld: Handsfree compared to handheld (df=44)
t	6.007	6.702	.288	.019
Sign. (2-tailed)	.000	.000	.775	.985

[1] From the Internet movie database: http://us.imdb.com/Title?0067023

10.5.4 Driving speed

10.5.4.1 Average speed

90 km/h rural: Car following

Table 8 *Effect of phone use on average speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=20)
t	3.174	2.106
Sign. (2-tailed)	.004	.048

Table 9 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – handheld (df=43)	Difference between hands-free and handheld phone when using phone (df=45)
t	.101	2.142
Sign. (2-tailed)	.920	.038

90 km/h rural: No event

Table 10 *Effect of phone use on average speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=23)
t	1.606	3.436
Sign. (2-tailed)	.122	.002

Table 11 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=46)	Difference between hands-free and handheld phone when using phone (df=46)
t	1.231	1.108
Sign. (2-tailed)	.225	.274

70 km/h rural: No event

Table 12 *Effect of phone use on average speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=23)
t	1.936	1.853
Sign. (2-tailed)	.065	.077

***Table 13** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=46)	Difference between hands-free and handheld phone when using phone (df=46)
t	2.657	1.510
Sign. (2-tailed)	.011	.138

50 km/h urban complex: No event

***Table 14** Effect of phone use on average speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	3.146	4.314
Sign. (2-tailed)	.005	.000

***Table 15** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=46)
t	.938	.589
Sign. (2-tailed)	.353	.559

50 km/h urban medium: No event

***Table 16** Effect of phone use on average speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	.508	2.527
Sign. (2-tailed)	.617	.019

***Table 17** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=45)
t	1.641	1.190
Sign. (2-tailed)	.108	.240

50 km/h urban simple: No event

Table 18 *Effect of phone use on average speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	.205	1.698
Sign. (2-tailed)	.839	.104

Table 19 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=46)
t	.805	.752
Sign. (2-tailed)	.425	.456

10.5.4.2 Speed variance

90 km/h rural: Car following

Table 20 *Effect of phone use on speed variance – paired t-tests.*

	Handsfree (df=23)	Handheld (df=20)
t	1.804	2.123
Sign. (2-tailed)	.084	.046

Table 21 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=43)	Difference between hands-free and handheld phone when using phone (df=45)
t	.384	1.046
Sign. (2-tailed)	.703	.301

90 km/h rural: No event

Table 22 *Effect of phone use on speed variance – paired t-tests.*

	Handsfree (df=23)	Handheld (df=23)
t	.279	.357
Sign. (2-tailed)	.783	.725

Table 23 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=46)	Difference between hands-free and handheld phone when using phone (df=46)
t	.075	1.306
Sign. (2-tailed)	.940	.198

70 km/h rural: No event

Table 24 *Effect of phone use on speed variance – paired t-tests.*

	Handsfree (df=23)	Handheld (df=23)
t	1.895	.652
Sign. (2-tailed)	.071	.521

Table 25 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=46)	Difference between hands-free and handheld phone when using phone (df=46)
t	.782	.451
Sign. (2-tailed)	.438	.654

50 km/h urban complex: No event

Table 26 *Effect of phone use on speed variance – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	2.410	.579
Sign. (2-tailed)	.024	.569

Table 27 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=46)
t	1.985	1.138
Sign. (2-tailed)	.053	.261

50 km/h urban medium: No event

***Table 28** Effect of phone use on speed variance – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	2.019	2.079
Sign. (2-tailed)	.055	.049

***Table 29** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=45)
t	.052	.925
Sign. (2-tailed)	.959	.360

50 km/h urban simple: No event

***Table 30** Effect of phone use on speed variance – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	.289	.593
Sign. (2-tailed)	.775	.560

***Table 31** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Difference between phone and no phone: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=46)
t	.655	.199
Sign. (2-tailed)	.510	.843

10.5.4.3 Maximum speed

90 km/h rural: Car following

***Table 32** Effect of phone use on maximum speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=20)
t	1.874	1.317
Sign. (2-tailed)	.074	.203

Table 33 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – handheld (df=43)	Difference between handsfree and handheld phone when using phone (df=45)
t	.024	.260
Sign. (2-tailed)	.981	.796

90 km/h rural: No event

Table 34 *Effect of phone use on maximum speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=23)
t	1.110	2.558
Sign. (2-tailed)	.278	.018

Table 35 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone (df=46)
t	.952	1.049
Sign. (2-tailed)	.346	.300

70 km/h rural: No event

Table 36 *Effect of phone use on maximum speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=23)
t	1.249	.570
Sign. (2-tailed)	.224	.574

Table 37 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone (df=46)
t	1.228	.748
Sign. (2-tailed)	.226	.458

50 km/h urban complex: No event

Table 38 *Effect of phone use on maximum speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	.121	2.520
Sign. (2-tailed)	.905	.019

Table 39 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=46)
t	1.771	2.094
Sign. (2-tailed)	.083	.042

50 km/h urban medium: No event

Table 40 *Effect of phone use on maximum speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	.520	1.242
Sign. (2-tailed)	.608	.227

Table 41 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=45)
t	.534	.006
Sign. (2-tailed)	.596	.995

50 km/h urban simple: No event

Table 42 *Effect of phone use on maximum speed – paired t-tests.*

	Handsfree (df=23)	Handheld (df=22)
t	.631	.305
Sign. (2-tailed)	.534	.764

Table 43 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use: comparison handsfree – hand-held (df=45)	Difference between hands-free and handheld phone when using phone (df=46)
t	.690	.896
Sign. (2-tailed)	.494	.375

10.5.5 Brake reaction time performance at events

70 km/h rural: Motorbike

Table 44 *Effect of phone use on brake reaction time – paired t-tests.*

	Handsfree (df=22)	Handheld (df=22)
t	.623	.801
Sign. (2-tailed)	.540	.432

Table 45 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at motorbike situation: compa-rison handsfree – handheld (df=44)	Difference between hands-free and handheld phone when using phone (df=44)
t	.163	-.107
Sign. (2-tailed)	.871	.915

50 km/h urban complex: Bicycle

Table 46 *Effect of phone use on brake reaction time – paired t-tests.*

	Handsfree (df=18)	Handheld (df=20)
t	.509	.633
Sign. (2-tailed)	.617	.534

Table 47 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bicycle situation: compa-rison handsfree – handheld (df=38)	Difference between hands-free and handheld phone when using phone (df=38)
t	.017	.464
Sign. (2-tailed)	.987	.645

50 km/h urban medium: Traffic light

Table 48 *Effect of phone use on brake reaction time – paired t-tests.*

	Handsfree (df=17)	Handheld (df=17)
t	1.235	1.365
Sign. (2-tailed)	.234	.190

Table 49 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at traffic light situation: comparison handsfree – handheld (df=34)	Difference between hands-free and handheld phone when using phone (df=34)
t	1.794	.955
Sign. (2-tailed)	.082	.346

50 km/h urban simple: Bus

Table 50 *Effect of phone use on brake reaction time – paired t-tests (bus).*

	Handsfree (df=15)	Handheld (df=12)
t	.192	2.617
Sign. (2-tailed)	.850	.023

Table 51 *Comparisons between handsfree and handheld phone – t-tests for independent samples (bus).*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=27)	Difference between hands-free and handheld phone when using phone (df=27)
t	1.846	.822
Sign. (2-tailed)	.076	.419

10.5.6 Lateral position variance

90 km/h rural: Car following and no event

Table 52 *Effect of phone use on lateral position variance – paired t-tests.*

	Car following: Handsfree (df=23)	Car following: Handheld (df=20)	No event: Handsfree (df=23)	No event: Handheld (df=23)
t	1.625	1.002	2.082	2.112
Sign. (2-tailed)	.118	.328	.049	.046

Table 53 Comparisons between handsfree and handheld phone – t-tests for independent samples.

	Effect of phone use at car following situation: comparison handsfree – handheld (df=43)	Effect of phone use at no event situation: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone – car following situation (df=44)	Difference between handsfree and handheld phone when using phone – no event situation (df=46)
t	.530	.220	.711	.669
Sign. (2-tailed)	.599	.827	.481	.507

70 km/h rural: Motorbike and no event

Table 54 Effect of phone use on lateral position variance – paired t-tests.

	Motorbike: Handsfree (df=23)	Motorbike: Handheld (df=22)	No event; Handsfree (df=23)	No event: Handheld (df=23)
t	.892	1.385	.948	.553
Sign. (2-tailed)	.381	.180	.353	.585

Table 55 Comparisons between handsfree and handheld phone – t-tests for independent samples.

	Effect of phone use at motorbike situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone – motor-bike situation (df=45)	Difference between handsfree and handheld phone when using phone – no event situa-tion (df=46)
t	.440	.973	.712	.054
Sign. (2-tailed)	.662	.336	.480	.957

50 km/h urban simple: Bus and no event

Table 56 Effect of phone use on lateral position variance – paired t-tests.

	Bus: Handsfree (df=23)	Bus: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld (df=22)
t	1.147	.471	1.068	.187
Sign. (2-tailed)	.263	.642	.297	.853

__Table 57__ Comparisons between handsfree and handheld phone – t-tests for independent samples.

	Effect of phone use at bus situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=45)	Difference between hands-free and hand-held phone when using phone – bus situation (df=45)	Difference between hands-free and handheld phone when using phone – no event situation (df=45)
t	.563	.886	.264	1.024
Sign. (2-tailed)	.576	.380	.793	.311

10.5.7 Lateral acceleration

10.5.7.1 Lateral acceleration variance

90 km/h rural: Car following and no event

__Table 58__ Effect of phone use on lateral acceleration variance – paired t-tests.

	Car following: Handsfree: (df=23)	Car following: Handheld (df=20)	No event: Handsfree (df=23)	No event: Handheld (df=23)
t	2.984	1,226	1.363	2.865
Sign. (2-tailed)	.007	.234	.186	.009

__Table 59__ Comparisons between handsfree and handheld phone – t-tests for independent samples.

	Effect of phone use at car following situation: comparison handsfree – handheld (df=43)	Effect of phone use at no event situation: comparison handsfree – handheld (df=46)	Difference between hands-free and handheld phone when using phone – car following situation (df=44)	Difference between handsfree and handheld phone when using phone – no event situation (df=46)
t	.277	.756	1.200	.583
Sign. (2-tailed)	.783	.453	.237	.563

70 km/h rural: Motorbike and no event

__Table 60__ Effect of phone use on lateral acceleration variance – paired t-tests.

	Motorbike: Handsfree (df=23)	Motorbike: Handheld (df=22)	No event: Handsfree (df=23)	No event l: Handheld (df=23)
t	3.383	3.736	2.121	1.293
Sign. (2-tailed)	.003	.001	.045	.209

Table 61 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at motorbike situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event 1 situation: comparison handsfree – handheld (df=46)	Difference between hands-free and hand-held phone when using phone – motor-bike situation (df=45)	Difference between hands-free and handheld phone when using phone – no event situation (df=46)
t	.120	2.448	.129	.888
Sign. (2-tailed)	.905	.018	.898	.379

50 km/h urban simple: Bus and no event

Table 62 *Effect of phone use on lateral acceleration variance – paired t-tests.*

	Bus: Handsfree (df=23)	Bus: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld (df=23)
t	.869	1.271	.431	.381
Sign. (2-tailed)	.394	.217	.670	.707

Table 63 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=45)	Difference between hands-free and hand-held phone when using phone – bus situation (df=45)	Difference between hands-free and handheld phone when using phone – no event situation (df=45)
t	.136	.094	.240	.038
Sign. (2-tailed)	.892	.926	.811	.970

10.5.7.2 Maximum lateral acceleration

90 km/h rural: Car following and no event

Table 64 *Effect of phone use on maximum lateral acceleration – paired t-tests.*

	Car following: Handsfree (df=23)	Car following: Handheld (df=20)	No event: Handsfree (df=23)	No event: Handheld (df=23)
t	2.536	1.678	1.299	.215
Sign. (2-tailed)	.018	.109	.207	.832

Table 65 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – handheld (df=44)	Effect of phone use at no event situation: comparison handsfree – handheld (df=46)	Difference between hands-free and handheld phone when using phone – car following situation (df=45)	Difference between hands-free and hand-held phone when using phone – no event situation (df=46)
t	1.047	.892	1.024	.662
Sign. (2-tailed)	.301	.377	.311	.511

70 km/h rural: Motorbike and no event

Table 66 *Effect of phone use on maximum lateral acceleration – paired t-tests.*

	Motorbike: Handsfree (df=23)	Motorbike: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld (df=23)
t	2.841	2.061	1.931	.375
Sign. (2-tailed)	.009	.051	.066	.711

Table 67 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at motorbike situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=46)	Difference between hands-free and handheld phone when using phone – motor-bike situation (df=45)	Difference between hands-free and hand-held phone when using phone – no event situation (df=46)
t	.216	1.252	.506	.484
Sign. (2-tailed)	.830	.217	.615	.631

50 km/h urban simple: Bus and no event

Table 68 *Effect of phone use on maximum lateral acceleration – paired t-tests.*

	Bus: Handsfree (df=23)	Bus: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld: (df=23)
t	.208	2.449	1.109	1.212
Sign. (2-tailed)	.837	.023	.279	.238

Table 69 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – hand-held (df=45)	Difference between hands-free and hand-held phone when using phone – bus situation (df=45)	Difference between hands-free and hand-held phone when using phone – no event situation (df=45)
t	1.517	.115	.963	.246
Sign. (2-tailed)	.136	.909	.341	.807

10.5.8 Longitudinal acceleration

10.5.8.1 Longitudinal acceleration variance

70 km/h rural: Motorbike

Table 70 *Effect of phone use on longitudinal acceleration variance – paired t-tests.*

	Motorbike: Handsfree (df=23)	Motorbike: Handheld (df=20)
t	2.466	1.875
Sign. (2-tailed)	.022	.074

Table 71 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at motorbike situation: compa-rison handsfree – handheld (df=45)	Difference between hands-free and handheld phone when using phone – motorbike situation (df=45)
t	.160	.431
Sign. (2-tailed)	.873	.669

50 km/h urban complex: Bicycle

Table 72 *Effect of phone use on longitudinal acceleration variance – paired t-tests.*

	Bicycle: Handsfree (df=23)	Bicycle: Handheld (df=23)
t	2.783	2.256
Sign. (2-tailed)	.011	.034

***Table 73** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bicycle situation: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone – bicycle situation (df=46)
t	.021	1.811
Sign. (2-tailed)	.983	.077

50 km/h urban medium: Traffic light

***Table 74** Effect of phone use on longitudinal acceleration variance – paired t-tests.*

	Traffic light: Handsfree (df=23)	Traffic light: Handheld (df=22)
t	.251	.215
Sign. (2-tailed)	.804	.832

***Table 75** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at traffic light situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – traffic light situation (df=45)
t	.326	1.441
Sign. (2-tailed)	.746	.157

50 km/h urban simple: Bus

***Table 76** Effect of phone use on longitudinal acceleration variance – paired t-tests.*

	Bus: Handsfree (df=23)	Bus: Handheld (df=22)
t	.621	.587
Sign. (2-tailed)	.540	.563

***Table 77** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – bus situation (df=45)
t	.834	.212
Sign. (2-tailed)	.409	.833

10.5.8.2 Maximum longitudinal deceleration

70 km/h rural: Motorbike

***Table 78** Effect of phone use on maximum longitudinal deceleration – paired t-tests.*

	Motorbike: Handsfree (df=23)		Motorbike: Handheld (df=22)	
	Phone	No phone	Phone	No phone
mean	6.87	7.40	6.34	6.90
sd	1.94	2.04	2.43	2.39
t	1.168		1.109	
Sign. (2-tailed)	.255		.279	

***Table 79** Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at motorbike situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – motorbike situation (df=45)
t	.057	.837
Sign. (2-tailed)	.955	.407

50 km/h urban complex: Bicycle

Table 80 *Effect of phone use on maximum longitudinal deceleration – paired t-tests.*

	Bicycle: Handsfree (df=23)		Bicycle: Handheld (df=23)	
	Phone	No phone	Phone	No phone
mean	5.87	6.53	6.62	6.60
sd	2.11	2.39	2.03	2.11
t	1.142		.042	
Sign. (2-tailed)	.265		.967	

Table 81 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bicycle situation: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone – bicycle situation (df=46)
t	.897	1.263
Sign. (2-tailed)	.374	.213

50 km/h urban medium: Traffic light

Table 82 *Effect of phone use on maximum longitudinal acceleration – paired t-tests.*

	Traffic light: Handsfree (df=23)		Traffic light: Handheld (df=22)	
	Phone	No phone	Phone	No phone
mean	5.84	5.63	6.04	6.32
sd	2.74	2.87	2.44	3.12
t	.385		.569	
Sign. (2-tailed)	.704		.575	

Table 83 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at traffic light situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – traffic light situation (df=45)
t	.662	.263
Sign. (2-tailed)	.512	.794

50 km/h urban simple: Bus

Table 84 *Effect of phone use on maximum longitudinal deceleration – paired t-tests.*

	Bus: Handsfree (df=23)		Bus: Handheld (df=22)	
	Phone	No phone	Phone	No phone
mean	5.31	5.89	5.08	4.56
sd	2.37	2.27	2.53	1.97
t	1.174		1.022	
Sign. (2-tailed)	.252		.318	

Table 85 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – bus situation (df=45)
t	1.551	-.324
Sign. (2-tailed)	.128	.747

10.5.9 Distance headway

10.5.9.1 Mean distance headway

90 km/h rural: Car following

Table 86 *Effect of phone use on mean distance headway – paired t-tests.*

	Car following: Handsfree (df=21)	Car following: Handheld (df=18)
t	2.390	3.593
Sign. (2-tailed)	.026	.002

Table 87 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – handheld (df=39)	Difference between handsfree and handheld phone when using phone – car following situation (df=43)
t	.177	.196
Sign. (2-tailed)	.861	.846

10.5.9.2 Distance headway variance

90 km/h rural: Car following

Table 88 *Effect of phone use on distance headway variance – paired t-tests.*

	Car following: Handsfree (df=21)		Car following: Handheld (df=18)	
	Phone	No phone	Phone	No phone
mean	1341.5	714.6	1824.2	1135.5
sd	2196	412.6	2058.1	1046.6
t	1.489		2.063	
Sign. (2-tailed)	.151		.054	

Table 89 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – hand-held (df=39)	Difference between hands-free and handheld phone when using phone – car following situation (df=43)
t	.036	.718
Sign. (2-tailed)	.971	.476

10.5.9.3 Minimum distance headway

90 km/h rural: Car following

Table 90 *Effect of phone use on minimum distance headway – paired t-tests.*

	Car following: Handsfree (df=21)	Car following: Handheld (df=18)
t	3.192	2.609
Sign. (2-tailed)	.004	.018

Table 91 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – hand-held (df=39)	Difference between hands-free and handheld phone when using phone – car following situation (df=43)
t	.937	1.493
Sign. (2-tailed)	.354	.143

50 km/h urban simple: Bus

Table 92 *Effect of phone use on minimum distance headway – paired t-tests.*

	Bus: Handsfree (df=20)	Bus: Handheld (df=18)
t	.779	.603
Sign. (2-tailed)	.445	.554

Table 93 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=38)	Difference between handsfree and handheld phone when using phone – bus situation (df=39)
t	.015	.104
Sign. (2-tailed)	.988	.918

10.5.9.4 Minimum time headway

90 km/h rural: Car following

Table 94 *Effect of phone use on minimum time headway – paired t-tests.*

	Car following: Handsfree (df=21)	Car following: Handheld (df=18)
t	2.268	2.432
Sign. (2-tailed)	.034	.026

Table 95 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – handheld (df=39)	Difference between handsfree and handheld phone when using phone – car following situation (df=43)
t	.937	1.493
Sign. (2-tailed)	.354	.143

50 km/h urban simple: Bus

Table 96 *Effect of phone use on minimum time headway – paired t-tests.*

	Bus: Handsfree (df=20)	Bus: Handheld (df=18)
t	.779	.416
Sign. (2-tailed)	.445	.682

Table 97 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=38)	Difference between handsfree and handheld phone when using phone – bus situation (df=39)
t	.015	.104
Sign. (2-tailed)	.988	.918

10.5.10 Minimum time to collision

90 km/h rural: Car following

Table 98 *Effect of phone use on minimum time to collision – paired t-tests.*

	Car following: Handsfree (df=21)		Car following: Handheld (df=18)	
	Phone	No phone	Phone	No phone
mean	3.88	3.99	3.70	3.56
sd	.533	.895	.767	.834
t	.566		.872	
Sign. (2-tailed)	.577		.395	

Table 99 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – handheld (df=39)	Difference between handsfree and handheld phone when using phone – car following situation (df=43)
t	.965	.196
Sign. (2-tailed)	.341	.846

50 km/h urban simple: Bus

Table 100 *Effect of phone use on minimum time to collision – paired t-tests.*

	Bus: Handsfree (df=20)		Bus: Handheld (df=18)	
	Phone	No phone	Phone	No phone
mean	1.15	1.14	1.15	1.18
sd	.225	.256	.256	.324
t	.215		.448	
Sign. (2-tailed)	.832		.659	

Table 101 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=38)	Difference between handsfree and handheld phone when using phone – bus situation (df=39)
t	.496	.054
Sign. (2-tailed)	.623	.957

10.5.11 Number of participants stopping at events

Handsfree

Table 102 *Number of participants stopping at events.*

Situation	Stops	Does not stop	Total
Bicycle – Phone call	23	1	24
Bicycle – No Phone call	20	4	24
Traffic light – Phone call	20	4	24
Traffic light – No Phone call	20	4	24
Bus – Phone call	21	3	24
Bus – No Phone call	22	2	24

Wilcoxon Signed Ranks Test: Effect of phone use at bicycle situation: z=1.732; n.s., effect of phone use at traffic light situation: z=.000; n.s., effect of phone use at bus situation: z=1.000; n.s.

Handheld

Table 103 *Number of participants stopping at events.*

Situation	Stops	Does not stop	Total
Bicycle – Phone call	19	5	24
Bicycle – No Phone call	19	5	24
Traffic light – Phone call	21	3	24
Traffic light – No Phone call	19	4	23
Bus – Phone call	20	3	23
Bus – No Phone call	21	3	24

Wilcoxon Signed Ranks Test: Effect of phone use at bicycle situation: z=.000; n.s., effect of phone use at traffic light situation: z=1.000; n.s., effect of phone use at bus situation: z=.000; n.s.

10.5.12 PDT performance

10.5.12.1 Reaction time

90 km/h rural: Car following and no event

Table 104 *Effect of phone use on PDT reaction time – paired t-tests.*

	Car following: Handsfree (df=23)	Car following: Handheld (df=19)	No event: Handsfree: (df=23)	No event: Handheld (df=22)
t	2.617	4.229	7.451	4.156
Sign. (2-tailed)	.015	.000	.000	.000

Table 105 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at car following situation: comparison handsfree – handheld (df=42)	Effect of phone use at no event situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – car following situation (df=45)	Difference between handsfree and handheld phone when using phone – no event situation (df=45)
t	.740	1.362	.708	.754
Sign. (2-tailed)	.463	.180	.482	.455

70 km/h rural: Motorbike and no event

Table 106 *Effect of phone use on PDT reaction time – paired t-tests.*

	Motorbike: Handsfree (df=23)	Motorbike: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld (df=23)
t	5.540	5.648	5.360	3.649
Sign. (2-tailed)	.000	.000	.000	.001

Table 107 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at motorbike situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=46)	Difference between handsfree and handheld phone when using phone – motorbike situation (df=45)	Difference between handsfree and handheld phone when using phone – no event situation (df=46)
t	1.555	.262	1.078	.265
Sign. (2-tailed)	.127	.794	.287	.792

50 km/h urban complex: Bicycle and no event

Table 108 *Effect of phone use on PDT reaction time – paired t-tests.*

	Bicycle: Handsfree (df=23)	Bicycle: Handheld (df=23)	No event: Handsfree (df=23)	No event: Handheld (df=22)
t	2.943	4.748	2.896	5.271
Sign. (2-tailed)	.007	.000	.008	.000

Table 109 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bicycle situation: comparison handsfree – handheld (df=46)	Effect of phone use at no event situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – bicycle situation (df=46)	Difference between handsfree and handheld phone when using phone – no event situation (df=46)
t	-1.377	1.537	.250	.783
Sign. (2-tailed)	.175	.131	.803	.438

50 km/h urban medium: Traffic light and no event

Table 110 *Effect of phone use on PDT reaction time – paired t-tests.*

	Traffic light: Handsfree: (df=23)	Traffic light: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld (df=21)
t	2.393	3.397	5.232	4.065
Sign. (2-tailed)	.025	.003	.000	.001

Table 111 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at traffic light situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=44)	Difference between hands-free and hand-held phone when using phone – traffic light situation (df=46)	Difference between handsfree and hand-held phone when using phone – no event situa-tion (df=44)
t	1.762	.145	1.512	.242
Sign. (2-tailed)	.085	.885	.137	.810

50 km/h urban simple: Bus and no event

Table 112 *Effect of phone use on PDT reaction time – paired t-tests.*

	Bus: Handsfree (df=23)	Bus: Handheld (df=22)	No event: Handsfree (df=23)	No event: Handheld (df=22)
t	4.732	5.288	4.079	3.469
Sign. (2-tailed)	.000	.000	.000	.002

Table 113 *Comparisons between handsfree and handheld phone – t-tests for independent samples.*

	Effect of phone use at bus situation: comparison handsfree – handheld (df=45)	Effect of phone use at no event situation: comparison handsfree – handheld (df=45)	Difference between handsfree and handheld phone when using phone – bus situation (df=45)	Difference between handsfree and handheld phone when using phone – no event situation (df=46)
t	1.568	.267	1.083	.084
Sign. (2-tailed)	.124	.791	.285	.934

10.5.12.2 Missed signals

90 km/h rural: Car following and no event

Table 114 *PDT missed signals – effect of phone use.*

	Handsfree: Car following (n=24)	Handheld: Car following (n=20)	Handsfree: No event (n=24)	Handheld: No event (n=24)
z	2.295	2.727	3.078	3.408
Sign. (2-tailed)	.022	.006	.002	.001

Table 115 *PDT missed signals – comparisons between handsfree and handheld phone.*

	Effect of phone use at car following situation: comparison handsfree – handheld	Effect of phone use at no event situation: comparison handsfree – handheld	Difference between handsfree and handheld when phone was used at car following situation (handsfree n=24, handheld n=23)	Difference between handsfree and handheld when phone was used at no event situation (handsfree n=24, handheld n=24)
z	.572	.128	.097	.075
Sign. (2-tailed)	.567	.663	.923	.940

70 km/h rural: Motorbike and no event

Table 116 *PDT missed signals – effect of phone use.*

	Handsfree: motorbike (n=24)	Handheld: motorbike (n=23)	Handsfree: no event (n=24)	Handheld: no event (n=24)
z	3.407	3.599	3.446	2.953
Sign. (2-tailed)	.001	.000	.001	.003

Table 117 *PDT missed signals – comparisons between handsfree and handheld phone.*

	Effect of phone use at motorbike situation: comparison handsfree – handheld	Effect of phone use at no event situation: comparison handsfree – handheld	Difference between hands-free and hand-held when phone was used at motor-bike situation (handsfree n=24, handheld n=23)	Difference between hands-free and hand-held when phone was used at the no event situation (handsfree n=24, handheld n=24)
z	1.086	.436	.982	.618
Sign. (2-tailed)	.277	.663	.326	.536

50 km/h urban complex: Bicycle and no event

Table 118 *PDT missed signals – effect of phone use.*

	Handsfree: bicycle (n=24)	Handheld: bicycle (n=24)	Handsfree: no event (n=24)	Handheld: no event (n=23)
z	2.450	2.890	2.254	3.660
Sign. (2-tailed)	.014	.004	.024	.000

Table 119 *PDT missed signals – comparisons between handsfree and handheld phone.*

	Effect of phone use at bicycle situa-tion: compa-rison hands-free – hand-held	Effect of phone use at no event situation: comparison handsfree – handheld	Difference between hands-free and hand-held when phone was used at bicycle situation (handsfree n=24, handheld n=24)	Difference between hands-free and hand-held when phone was used at no event situation (handsfree n=24, handheld n=24)
z	.526	1.861	.021	.950
Sign. (2-tailed)	.599	.063	.984	.342

50 km/h urban medium: Traffic light and no event

Table 120 *PDT missed signals – effect of phone use.*

	Handsfree: traffic light (n=24)	Handheld: traffic light (n=23)	Handsfree: no event (n=24)	Handheld: no event (n=23)
z	2.768	2.792	3.435	3.332
Sign. (2-tailed)	.006	.005	.001	.001

Table 121 *PDT missed signals – comparisons between handsfree and handheld phone.*

	Effect of phone use at traffic light situation: comparison handsfree – handheld	Effect of phone use at no event situation: comparison handsfree – handheld	Difference between hands-free and hand-held when phone was used at traffic light situation (handsfree n=24, handheld n=24)	Difference between hands-free and hand-held when phone was used at no event situation (handsfree n=24, handheld n=23)
z	.713	.075	.227	.043
Sign. (2-tailed)	.476	.940	.820	.965

50 km/h urban simple: Bus and no event

Table 122 *PDT missed signals – effect of phone use.*

	Handsfree: bus (n=24)	Handheld: bus (n=24)	Handsfree: no event (n=24)	Handheld: no event (n=24)
z	3.332	3.633	2.158	3.093
Sign. (2-tailed)	.001	.000	.031	.002

Table 123 *PDT missed signals – comparisons between handsfree and handheld phone.*

	Effect of phone use at bus situation: comparison handsfree – handheld	Effect of phone use at no event situation: comparison handsfree – handheld	Difference between hands-free and hand-held when phone was used at bus situation (handsfree n=24, handheld n=23)	Difference between hands-free and hand-held when phone was used at no event situation (handsfree n=24, handheld n=24)
z	1.387	.043	1.451	.742
Sign. (2-tailed)	.165	.965	.147	.458

10.5.13 Secondary task performance

***Table 124** Comparisons between handsfree (n=24) and handheld phone (n=22) – Mann Whitney U test.*

	Number of additions		Number of errors:		Percentage correct answers	
	handsfree	handheld	handsfree	handheld	handsfree	handheld
median	22.2	24.7	3.1	2.6	82.4	87.3
Quartile deviation	2.80	3.58	1.05	.90	6.47	5.27
z	.957		.924		.616	
Sign. (2-tailed)	.339		.356		.538	

***Table 125** Percentage correct answers.*

Situation	**Phone mode**	**Number of participants**	**Median (%)**	**Mann Whitney U test**	**Significance (2-tailed)**
90 km/h rural: Car following	Handsfree	24	87.0	z=.692	.489
"	Handheld	23	90.0		
90 km/h rural: No event	Handsfree	24	86.8	z=1.554	.120
"	Handheld	24	92.9		
70 km/h rural: Motorbike	Handsfree	24	85.4	z=.032	.975
"	Handheld	23	88.9		
70 km/h rural: No event	Handsfree	24	86.2	z=1.036	.300
"	Handheld	24	91.9		
50 km/h urban complex: Bicycle	Handsfree	24	76,9	z=1.259	.208
"	Handheld	24	79.1		
50 km/h urban complex: No event	Handsfree	24	84,5	z=.847	.397
"	Handheld	24	90.0		
50 km/h urban medium: Traffic light	Handsfree	24	80.6	z=.248	.804
"	Handheld	24	82.1		
50 km/h urban medium: No event	Handsfree	24	87.0	z=1.485	.137
"	Handheld	24	90.7		
50 km/h urban simple: Bus	Handsfree	24	85.0	z=.268	.788
"	Handheld	24	83.8		
50 km/h urban simple: No event	Handsfree	24	84.0	z=.454	.650
"	Handheld	24	87.8		

10.5.14 Result summary

Table 126 *Results handsfree mobile phone study. Difference between phone condition and control condition. Statistically significant results (bold), and non-significant results (in parenthesis).*

	A	B	C	D	E	F	G	H	I	J
	90 km/h	**70 km/h**	**50 km/h bicycle complex**	**50 km/h traffic light medium**	**50 km/h bus simple**	**50 km/h no event simple**	**50 km/h no event medium**	**50 km/h no event complex**	**70 km/h mc**	**90 km/h car follow**
Mean speed (km/h)	(-2,8)	(+1,9)				(-.2)	(-.4)	**-1.9**		**-2.4**
Speed var. (km/h)	(-1.5)	(26.1)				(+2.1)	(+6.0)	-16.7		(-20.3)
Max speed (km/h)	(-2.1)	(+1.7)				(+1.0)	(-.7)	(-.1)		(-2.8)
Brake reaction time (ms)			(-165)	(-85)	(-27)				(-62)	
Lat.pos. variance (cm)	**-2.5**	(-1.1)			(-3.3)	(+.7)			(-.7)	(-4.8)
Lat.acc. variance (cm/s^2)	(-9.8)	**-12.2**			(+.3)	(-.1)			**-13.9**	**-7.8**
Max.lat. acc. (cm/s^2)	(-12.9)	(-17.9)			(-1.3)	(-4.0)			**-21.2**	**-14.8**
Acc. variance (cm/s^2)			**-21.2**	(-1.3)	(-5.1)				**-26.1**	
Min acc. (braking) (cm/s^2)			(-66)	(+21)	(-58)				(-53)	
Mean dist headway (m)										**+24.6**
Dist. headway variance (m)										(+627.9)
Min.dist. headway (m)					(+2.0)					**+22.3**
Min.time headway (s)					(+.07)					**+.25**
Min. TTC (s)					(+.01)					(-.11)
ss stopping at event (n)			(+3)	(0)	(-1)					
PDT reaction time (ms)	**+233**	**+185**	**+118**	**+76**	**+129**	**+119**	**+182**	**+105**	**+138**	**+128**
PDTmiss (%)	**+10.0**	**+15.4**	**+16.1**	**+8.5**	**+7.1**	**+6.6**	**+12.4**	**+8.4**	**+10.5**	**+9.6**

Table 127 *Results handheld mobile phone study. Difference between phone condition and control condition. Statistically significant results (bold), and non-significant results (in parenthesis).*

	A	B	C	D	E	F	G	H	I	J
	90 km/h	**70 km/h**	**50 km/h bicycle complex**	**50 km/h traffic light medium**	**50 km/h bus simple**	**50 km/h no event simple**	**50 km/h no event medium**	**50 km/h no event complex**	**70 km/h mc**	**90 km/h car follow**
Mean speed (km/h)	**-5.8**	(-2.2)				(-1.1)	**-2.4**	**-2.7**		**-2.5**
Speed var. (km/h)	(-1.0)	(-10.0)				(-7.4)	**+5.8**	(+4.8)		**-14.9**
Max speed (km/h)	**-4.8**	(-1.0)				(-.3)	(-1.5)	**-2.8**		(-2.9)
Brake reaction time (ms)			(-157)	(+65)	**+320**				(-85)	
Lat.pos. variance (cm)	**-2.9**	(+1.1)			(-1.1)	(-.1)			(-1.3)	(-2.6)
Lat.acc. variance (cm/s^2)	**-16.7**	(+6.5)			(+.5)	(-.1)			**-14.7**	(-6.3)
Max.lat. acc. (cm/s^2)	(-12.9)	(-1.7)			**+10.1**	(-4.7)			(-18.6)	(-15.7)
Acc. variance (cm/s^2)			**-21.5**	(+1.4)	(+3.2)				(-23.5)	
Min acc. (braking) (cm/s^2)			(+2)	(-28)	(+52)				(-56)	
Mean dist headway (m)										**+27.3**
Dist. headway variance (m)										(+688.7)
Min.dist. headway (m)					(+2.0)					**+13.9**
Min.time headway (s)					(-.04)					**+.35**
Min. TTC (s)					(-.03)					(+.14)
ss stopping at event (n)			(0)	(+2)	(-1)					
PDT reaction time (ms)	**+164**	**+169**	**+196**	**+187**	**+203**	**+108**	**+174**	**+184**	**+207**	**+177**
PDTmiss (%)	**+7.7**	**+9.5**	**+13.9**	**+9.1**	**+16.9**	**+7.1**	**+12.5**	**+11.7**	**+16.7**	**+6.5**

10.6 SMS

10.6.1 Brake reaction time performance at events

70 km/h rural: Motorbike

Table 128 *Effect of SMS on brake reaction time – paired t-test.*

	SMS - no SMS (df=8)
t	3.185
Sign. (2-tailed)	.013

50 km/h urban complex: Bicycle

Table 129 *Effect of SMS on brake reaction time – paired t-test.*

	SMS - no SMS (df=8)
t	1.356
Sign. (2-tailed)	.212

50 km/h urban medium: Traffic light

Table 130 *Effect of SMS on brake reaction time – paired t-test.*

	SMS - no SMS (df=4)
t	1.970
Sign. (2-tailed)	.120

50 km/h urban simple: Bus

Table 131 *Effect of SMS on brake reaction time – paired t-test.*

	SMS - no SMS (df=4)
t	1.839
Sign. (2-tailed)	.140

10.6.2 Maximum longitudinal deceleration

70 km/h rural: Motorbike

Table 132 *Effect of SMS on maximum longitudinal deceleration – paired t-test.*

	SMS (n=9)	No SMS (n=9)
mean	6.28	6.42
sd	2.86	2.26
t	.193	
Sign. (2-tailed)	.852	

50 km/h urban complex: Bicycle

Table 133 *Effect of SMS on maximum longitudinal deceleration – paired t-test.*

	SMS (n=8)	No SMS (n=8)
mean	4.23	5.96
sd	3.21	2.61
t	1.706	
Sign. (2-tailed)	.132	

50 km/h urban medium: Traffic light

Table 134 *Effect of SMS on maximum longitudinal acceleration – paired t-test.*

	SMS (n=8)	No SMS (n=8)
mean	2.12	3.79
sd	2.34	2.21
t	2.025	
Sign. (2-tailed)	.083	

50 km/h urban simple: Bus

Table 135 *Effects of SMS on maximum longitudinal deceleration – paired t-test.*

	SMS (n=9)	No SMS (n=9)
mean	4.30	3.78
sd	1.37	2.46
t	.602	
Sign. (2-tailed)	.564	

10.6.3 Number of participants stopping at events

Table 136 *Number of participants stopping at events.*

Situation	Stops	Does not stop	Total
Bicycle – SMS	8	2	10
Bicycle – No SMS	6	4	10
Traffic light – SMS	5	5	10
Traffic light – No SMS	7	3	10
Bus – SMS	9	1	10
Bus – No SMS	8	2	10

Wilcoxon Signed Ranks Test: Effect of SMS at bicycle situation: z=1.414; n.s., effect of SMS at traffic light situation: z=1.414; n.s., effect of SMS at bus situation: z=1.000; n.s.

10.6.4 Result summary

Table 137 *Results SMS study. Difference between SMS condition and control condition. Statistically significant results (bold), and non-significant results (in parenthesis).*

	A	B	C	D	E	F	G	H	I	J
	90 km/h no event	**70 km/h rural no**	**50 km/h bicycle**	**50 km/h traffic**	**50 km/h bus**	**50 km/h no event**	**50 km/h no event**	**50 km/h no event**	**70 km/h comple x**	**90 km/h car**
Brake reaction time (ms)			**(+257)**						**+679**	
Min acc. (braking) (cm/s^2)			**(-173)**	**(-167)**	**(+52)**				**(-14)**	
ss stopping at event (n)			**(+2)**	**(-2)**	**(+1)**					

10.7 DVD

10.7.1 Driving speed

10.7.1.1 Average speed

Total route

Table 138 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	58.4	57.6
sd	8.02	8.70
t	.493	
Sign. (2-tailed)	.637	

90 km/h rural: Car following

Table 139 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	67.5	68.2
sd	1.49	1.27
t	1.434	
Sign. (2-tailed)	.202	

90 km/h rural: No event

Table 140 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=8)	No DVD (n=8)
mean	80.3	85.1
sd	8.53	11.58
t	2.120	
Sign. (2-tailed)	.637	

70 km/h rural: No event

Table 141 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=8)	No DVD (n=8)
mean	69.4	69.0
sd	12.36	8.99
t	.194	
Sign. (2-tailed)	.852	

50 km/h urban complex: No event

Table 142 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=3)	No DVD (n=3)
mean	43.2	45.4
sd	7.71	6.81
t	1.009	
Sign. (2-tailed)	.419	

50 km/h urban medium: No event

Table 143 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	53.3	54.2
sd	9.34	10.19
t	.938	
Sign. (2-tailed)	.384	

50 km/h urban simple: No event

Table 144 *Effect of DVD use on average speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	54.2	52.4
sd	17.06	10.96
t	.727	
Sign. (2-tailed)	.495	

10.7.1.2 Speed variance

Total route

Table 145 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=7)
t	3.784
Sign. (2-tailed)	.007

90 km/h rural: Car following

Table 146 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=6)
t	1.336
Sign. (2-tailed)	.230

90 km/h rural: No event

Table 147 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=7)
t	.197
Sign. (2-tailed)	.849

70 km/h rural: No event

Table 148 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=7)
t	1.113
Sign. (2-tailed)	.295

50 km/h urban complex: No event

Table 149 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=2)
t	.255
Sign. (2-tailed)	.823

50 km/h urban medium: No event

Table 150 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=6)
t	2.138
Sign. (2-tailed)	.076

50 km/h urban simple: No event

Table 151 *Effect of DVD use on speed variance – paired t-tests.*

	DVD – no DVD (df=6)
t	.539
Sign. (2-tailed)	.609

10.7.1.3 Maximum speed

Total route

Table 152 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=8)	No DVD (n=8)
mean	99.3	102.3
sd	10.53	10.77
t	1.540	
Sign. (2-tailed)	.168	

90 km/h rural: Car following

Table 153 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	82.1	81.8
sd	8.26	14.23
t	.589	
Sign. (2-tailed)	.577	

90 km/h rural: No event

Table 154 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=8)	No DVD (n=8)
mean	88.3	93.7
sd	10.25	13.11
t	1.779	
Sign. (2-tailed)	.119	

70 km/h rural: No event

Table 155 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=8)	No DVD (n=8)
mean	79.5	80.1
sd	12.61	10.24
t	.275	
Sign. (2-tailed)	.791	

50 km/h urban complex: No event

Table 156 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=3)	No DVD (n=3)
mean	53.3	57.7
sd	5.98	5.12
t	1.716	
Sign. (2-tailed)	.228	

50 km/h urban medium: No event

Table 157 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	67.2	68.0
sd	13.64	13.24
t	.580	
Sign. (2-tailed)	.583	

50 km/h urban simple: No event

Table 158 *Effect of DVD use on maximum speed – paired t-tests.*

	DVD (n=7)	No DVD (n=7)
mean	66.5	64.8
sd	13.95	12.60
t	1.404	
Sign. (2-tailed)	.210	

10.7.2 Brake reaction time performance at events

70 km/h rural: Motorbike

Table 159 *Effect of DVD use on brake reaction time – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	2.048	2.301
sd	.630	.258
t	1.157	
Sign. (2-tailed)	.291	

50 km/h urban complex: Bicycle

Table 160 *Effect of DVD use on brake reaction time – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	2.798	2.270
sd	.374	.724
t	1.545	
Sign. (2-tailed)	.173	

50 km/h urban medium: Traffic light

Table 161 *Effect of DVD use on brake reaction time – paired t-test.*

	DVD (n=4)	No DVD (n=4)
mean	1.114	1.503
sd	.312	1.162
t	.612	
Sign. (2-tailed)	.584	

50 km/h urban simple: Bus

Table 162 *Effect of DVD use on brake reaction time – paired t-test.*

	DVD (n=3)	No DVD (n=3)
mean	1.000	1.132
sd	.117	.717
t	.282	
Sign. (2-tailed)	.804	

10.7.3 Maximum longitudinal deceleration

70 km/h rural: Motorbike

Table 163 *Effect of DVD use on maximum longitudinal deceleration – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	5.16	5.53
sd	2.24	3.04
t	.366	
Sign. (2-tailed)	.727	

50 km/h urban complex: Bicycle

Table 164 *Effect of DVD use on maximum longitudinal deceleration – paired t-test.*

	DVD (n=8)	No DVD (n=8)
mean	5.12	5.17
sd	1.37	2.04
t	.055	
Sign. (2-tailed)	.958	

50 km/h urban medium: Traffic light

Table 165 *Effect of DVD use on maximum longitudinal deceleration – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	5.35	3.62
sd	3.15	2.75
t	1.993	
Sign. (2-tailed)	.093	

50 km/h urban simple: Bus

Table 166 *Effect of DVD use on maximum longitudinal deceleration – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	4.03	4.84
sd	1.16	.795
t	2.357	
Sign. (2-tailed)	.057	

10.7.4 Distance headway

10.7.4.1 Mean distance headway

90 km/h rural: Car following

Table 167 *Effect of DVD use on mean distance headway – paired t-test.*

	DVD – no DVD (df=6)
T	2.872
Sign. (2-tailed)	.028

10.7.4.2 Distance headway variance

90 km/h rural: Car following

Table 168 *Effect of DVD use on distance headway variance – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	822.1	721.7
sd	228.0	241.0
t	.835	
Sign. (2-tailed)	.436	

10.7.4.3 Minimum distance headway

90 km/h rural: Car following

Table 169 *Effect of DVD use on minimum distance headway – paired t-test.*

	DVD – no DVD (df=6)
t	3.278
Sign. (2-tailed)	.017

50 km/h urban simple: Bus

Table 170 *Effect of DVD use on minimum distance headway – paired t-test.*

	DVD – no DVD (df=6)
t	.645
Sign. (2-tailed)	.543

10.7.5 Minimum time headway

90 km/h rural: Car following

Table 171 *Effect of DVD use on minimum time headway – paired t-test.*

	DVD – no DVD (df=6)
t	3.996
Sign. (2-tailed)	.007

50 km/h urban simple: Bus

Table 172 *Effect of DVD use on minimum time headway – paired t-test.*

	DVD – no DVD (df=6)
t	.846
Sign. (2-tailed)	.430

10.7.6 Minimum time to collision

90 km/h rural: Car following

Table 173 *Effect of DVD use on minimum time to collision – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	3.806	3.469
sd	.462	.850
t	1.202	
Sign. (2-tailed)	.275	

50 km/h urban simple: Bus

Table 174 *Effect of DVD use on minimum time to collision – paired t-test.*

	DVD (n=7)	No DVD (n=7)
mean	1.193	1.039
sd	.552	.482
t	.542	
Sign. (2-tailed)	.608	

10.7.7 Number of participants stopping at events

Table 175 *Number of participants stopping at events.*

Situation	Stops	Does not stop	Total
Bicycle – DVD	5	3	8
Bicycle – No DVD	5	3	8
Traffic light – DVD	4	4	8
Traffic light – No DVD	3	4	7
Bus – DVD	6	2	8
Bus – No DVD	7	0	7

Wilcoxon Signed Ranks Test: Effect of DVD use at bicycle situation: z=.000; n.s., effect of DVD use at traffic light situation: z=1.000; n.s., effect of DVD use at bus situation: z=1.000; n.s.

10.7.8 PDT performance

10.7.8.1 Reaction time

Total route

Table 176 *Effect of DVD use on PDT reaction time – paired t-tests.*

	DVD – no DVD (df=7)
t	2.184
Sign. (2-tailed)	.065

90 km/h rural: Car following and no event

Table 177 *Effect of DVD use on PDT reaction time – paired t-tests.*

	Car following: DVD – no DVD (df=5)	No event: DVD – no DVD (df=6)
t	2.243	4.129
Sign. (2-tailed)	.075	.006

70 km/h rural: Motorbike and no event

Table 178 *Effect of DVD use on PDT reaction time – paired t-tests.*

	Motorbike: DVD – no DVD (df=6)	No event: DVD – no DVD (df=6)
t	1.644	3.719
Sign. (2-tailed)	.151	.010

50 km/h urban complex: Bicycle and no event

Table 179 *Effect of DVD use on PDT reaction time – paired t-tests.*

	Bicycle: DVD – no DVD (df=6)	No event: DVD – no DVD (df=5)
t	1.583	5.623
Sign. (2-tailed)	.164	.030

50 km/h urban medium: Traffic light and no event

Table 180 *Effect of DVD use on PDT reaction time – paired t-tests.*

	Traffic light: DVD – no DVD (df=5)	No event: DVD – no DVD (df=5)
t	1.778	5.264
Sign. (2-tailed)	.135	.003

50 km/h urban simple: Bus and no event

Table 181 *Effect of DVD use on PDT reaction time – paired t-tests.*

	Bus: DVD – no DVD (df=5)	No event: DVD – no DVD (df=5)
t	2.883	5.264
Sign. (2-tailed)	.034	.003

10.7.8.2 Missed signals

Total route

Table 182 *PDT missed signals – effect of DVD use.*

	DVD (n=8)	No DVD (n=8)
median	11.5	10.5
Quartile deviation	6.125	5.375
z	.840	
Sign. (2-tailed)	.401	

90 km/h rural: Car following and no event

Table 183 *PDT missed signals – effect of DVD use.*

	Car following		No event	
	DVD (n=7)	No DVD (n=7)	DVD (n=8)	No DVD (n=8)
median	0	0	0	0
Quartile deviation	0	3.33	0	0
z	1.000		0.000	
Sign. (2-tailed)	.317		1.000	

70 km/h rural: Motorbike and no event

Table 184 *PDT missed signals – effect of DVD use.*

	Motorbike		No event	
	DVD (n=7)	No DVD (n=7)	DVD (n=8)	No DVD (n=8)
median	0	0	0	0
Quartile deviation	2.89	4.16	4.69	4.45
z	.447		0.000	
Sign. (2-tailed)	.655		1.000	

50 km/h urban complex: Bicycle and no event

Table 185 *PDT missed signals – effect of DVD use.*

	Bicycle		No event	
	DVD (n=8)	No DVD (n=8)	DVD (n=3)	No DVD (n=3)
median	10.60	0	0	0
Quartile deviation	11.71	27.10	5.47	0
z	1.185		1.000	
Sign. (2-tailed)	.236		.317	

50 km/h urban medium: Traffic light and no event

Table 186 *PDT missed signals – effect of DVD use.*

	Traffic light		No event	
	DVD (n=7)	No DVD (n=7)	DVD (n=7)	No DVD (n=7)
median	6.70	11.10	4.55	0
Quartile deviation	7.82	10.0	2.74	0
z	.507		1.511	
Sign. (2-tailed)	.612		.131	

50 km/h urban simple: Bus and no event

Table 187 *PDT missed signals – effect of DVD use.*

	Bus		No event	
	DVD (n=7)	No DVD (n=7)	DVD (n=7)	No DVD (n=7)
median	0	0	0	0
Quartile deviation	9.28	7.14	3.18	5.00
z	1.095		.535	
Sign. (2-tailed)	.273		.593	

10.7.9 Result summary

***Table 188** Results DVD study. Difference between DVD condition and control condition. Statistically significant results (bold), and non-significant results (in parenthesis).*

	A	B	C	D	E	F	G	H	I	J
	90 km/h no event	**70 km/h rural no event**	**50 km/h bicycle complex**	**50 km/h traffic light medium**	**50 km/h bus simple**	**50 km/h no event simple**	**50 km/h no event medium**	**50 km/h no event complex**	**70 km/h mc**	**90 km/h car follow**
Mean speed (km/h)	(-4.8)	(+.4)				(+1.8)	(-.9)	(2.2)		(-.7)
Speed var. (km/h)	(-.9)	(+14.4)				(-15.7)	(+7.0)	(+4.0)		(-25.9)
Max speed (km/h)	(-5.4)	(-.6)				(+.7)	(-.8)	(-4.4)		(+.3)
Brake reaction time (ms)			(+528)	(-389)	(-132)				(-253)	
Min acc. (braking) (cm/s^2)			(-5)	(+173)	(-81)				(-37)	
Mean dist headway (m)										**+15.4**
Dist headway variance (m)										(+100.4)
Min dist headway (m)					(-5.2)					**+16.1)**
Min time headway (s)					(+.24)					**+.26**
Min TTC (s)					(+.154)					(+.337)
ss stopping at event (n)			(0)	(+1)	(-1)					
PDT reaction time (ms)	**+135**	**+88**	(+118)	(+106)	**+148**	**+122**	**+163**	**+56**	(+346)	(+67)
PDT miss (%)	(0)	(0)	(+10.6)	(-4.4)	(+2.1)	(-1.8)	(+4.6)	(0)	(0)	(0)

10.8 Dialling

10.8.1 Result summary

Table 189 *Results dialling study. Difference between phone condition and control condition. Statistically significant results (bold), and non-significant results (in parenthesis).*

	Handsfree	Handheld
mean speed (km/h)	**- 3.8**	**- 2.0**
lat. pos. variance (cm)	**+ 4.1**	(+ 6.0)
PDT reaction time (ms)	**+ 299**	**+ 234**
PDT miss (%)	**+ 28.2**	**+ 19.6**