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Driving and telephoning: Relative accident risk when using hand-held and hands-free mobile phones

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ABSTRACT

Experimental research shows that using mobile phones while driving leads to impaired driving, and it has been suggested that this driving impairment to a large extent is a result of cognitive, rather than physical, distractions. This notion is partly supported by empirical data showing that use of handsfree phones is associated with impaired driving in much the same way as use of hand-held phones. In the present study, accident risk when using hand-held and handsfree phones was investigated in a sample of 4307 drivers who were involved in accidents in 2007. In addition, data from a similar survey from 1997 ($N = 5007$) were used in order to get more observations. Relative risk was estimated using "quasi-induced exposure" in multiple-vehicle accidents. Results from the two surveys combined showed a significant increase in accident risk for hand-held mobiles and for hand-held and handsfree phones together. A non-significant tendency towards increased risk for hands-free mobiles was also detected. However, analyses of data from 2007 separately did not result in statistically significant relative risk estimates for any of the mobile types. Hand-held users were more inclined to attribute the accident to mobile phone use than were handsfree users.

1. Introduction

Talking on a mobile phone while driving is commonly regarded as a factor contributing to traffic accidents, and several countries have laws restricting the use of mobile phones while driving. In Norway for instance, it has been forbidden to talk on hand-held phones since 2000 (Ministry of Transport and Communications, 2000). However, it is permitted to talk on handsfree phones while driving. The reasoning behind is that using a hand-held phone demands more of the driver, and interferes more with the driving, compared to using a handsfree phone. Thus, it is assumed that the "physical" or "structural" interference resulting from talking on hand-held phones is more dangerous than the "cognitive" or "capacity" interference resulting from handsfree phones. However, to date, there is no scientific unison that hand-held phones are riskier than handsfree phones (Sagberg, 2001; Consiglio et al., 2003; Törnros and Bolling, 2006). In the present study, accident risk is investigated for both hand-held and handsfree phones.

1.1. Mobile phone use and driving behaviour

Within traffic psychology and traffic safety research in general, mobile phone use while driving has typically been studied in highly controlled experiments (Hancock et al., 2003; Treffner and Barrett, 2004). The objective of such experimental studies is to investigate the effect of talking on a mobile phone while driving on driving *behaviour*, e.g., braking, response to traffic signals, variations in speed or lateral position, etc., and *subjective workload*, e.g., mental demand, effort and frustration (Matthews et al., 2003). When using highly controlled experimental designs, it is possible to isolate whatever effect one is interested in, for instance the effect of mobile phone use on braking and reaction to traffic signals, and determine a causal relationship. Importantly, most experiments have found an impact of talking on a mobile phone while driving on various driving behaviour and workload measures (Hancock et al., 2003; Rakauskas et al., 2004; Treffner and Barrett, 2004; Ma and Kaber, 2005; Törnros and Bolling, 2006).

Moreover, some experiments have also investigated effects of different types of mobile phones, i.e., hand-held, handsfree with speaker, handsfree with ear plug, etc. (Matthews et al., 2003; Törnros and Bolling, 2005). Törnros and Bolling (2005) found that handsfree and hand-held phones have more or less the same effect on mental workload – more specifically they detected an increase in mental workload when using either type of phones. However, they also found that speed decreased more when *conversing* on hand-held phones, and that speed decreased more when *dialling* with handsfree phones. These speed reductions are interpreted as behavioural adaptations, and the findings suggest that the two types of mobile phones both have detrimental effects on driving

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behaviour, and that people try to compensate for these detrimental effects by means of speed reduction. Consiglio et al. (2003) found no differences between hand-held and handsfree phones on reaction time for braking.

Experimental studies have been criticised for having limited ecological validity, as they often are conducted in simulators or use non-realistic conversations in trials. Moreover, demonstrating that using mobile phones while driving has an effect on driving behaviour and mental workload does not necessarily imply increased accident risk.

1.2. Mobile phone use and accident risk

Whereas the line of experimental research shows that talking on a mobile phone has effects upon driving behaviour and mental workload, studies of associations between mobile phone use and actual accident risk are less common.

Studies on mobile phone use and accident involvement differ with regard to the information provided, the design and methodologies used, and in turn to what degree they say something about the relative risk of being involved in an accident when using a mobile phone. First, there is so-called crash studies, in which data about crashes and contributing factors are based upon police reports and/or insurance company data. Such studies have for instance showed that distraction in general was a contributing factor in 6.6% of crashes, and that using or dialling a mobile phone accounted for 3.6% of these distraction related accidents (Gordon, 2009). However, such crash studies do not give information about relative risk as one does not have information about exposure, i.e., the amount of time spent using the mobile phone.

Second, there are epidemiological studies aiming at estimating accident risk associated with mobile phone use. Among the few studies on mobile phone use and accident risk, Laberge-Nadeau et al. (2003) found increased accident risk for both men (relative risk = 1.1) and women (relative risk = 1.2). However, in this study accident risk was linked to mobile phone use while driving *ever*, not in relation to mobile phone use before or during a specific accident. This limitation is also present in Wilson et al.'s (2003) study, in which they used an observational approach. They found a non-significant tendency towards increased accident risk for drivers who used a telephone at an observational point, compared to those who did not use a phone at the same observational point. The same limitation is present in a study by Violanti and Marshall (1996) who found that a group of accident involved drivers had more mobile phone conversations monthly and also longer conversations than a control group. However, it is not registered whether phone use was present during accidents. Moreover, differences between the accident and control groups may confound the results.

Accident related mobile phone use has, however, been studied elsewhere (McEvoy et al., 2007; Redelmeier and Tibshirani, 1997; Sagberg, 2001). In both Redelmeier and Tibshirani's (1997) and McEvoy et al.'s (2007) study, information about phone use prior to/during the accident was gathered from telephone companies. Moreover, in both studies cases were approached right after the accident when they sought medical treatment at hospital emergency departments. Redelmeier and Tibshirani (1997) found an increased relative risk of 4.3 associated with using a mobile phone, but no significant difference between hand-held and handsfree phones. McEvoy et al. (2007) also found an increased accident risk of about four associated with use of mobile phone up to 10 min before the crash. In this study, the increased risk associated with hand-held phones was 4.9, and 3.8 for handsfree phones, suggesting that there is no difference between the two types of phones. Even though these studies investigated phone use prior to an actual accident, one cannot entirely rule out that phone calls occurring right after the accidents are included in the analyses, although efforts were made in order to omit such phone calls. Sagberg (2001), using self-report of mobile phone use prior to/during a specific accident for each driver, found a significant relative risk of 2.2 for using any type of mobile phone. Looking at hand-held and handsfree phones separately, increased accident risk was found when using hand-held phones (relative risk = 3.6), however not for handsfree phones (relative risk = 1.8, ns). Thus, the results of research on mobile phone use and accident risk indicate that using hand-held phones are associated with increased accident risk, whereas the results regarding handsfree phones are more uncertain. It is, however, notable that none of the studies mentioned so far have found significant differences in risk between hand-held and handsfree phones.

Finally, in the last decade, naturalistic driving observation studies have gained field with regard to investigating driver distraction and accident risk. In the 100-car naturalistic study, relative risks for (a) dialling hand-held device and (b) talking/listening to a hand-held device were investigated (Klauer et al., 2006). Even though both types of behaviour contributed to several incidents, near-crashes, and crashes (only talking/listening), and had odds ratios above 1.0, only dialling a hand-held device turned out to be significantly associated with near-crash risk. However, estimates of population attributable risks showed that both dialling and talking/listening to a hand-held device contribute significantly to near-crashes and crashes. It is important to note, however, that the odds ratios were estimated in relation to both crashes and near-crashes. Even though these events were found to be equivalent in terms of critical features and therefore used together in analyses, it is important to have in mind that actual accidents differ from near-accidents, and efforts should be made in order to conduct a large scale naturalistic driving study for actual accidents to be used as the single dependent variable. Moreover, data recordings should be refined enough to be able to identify handsfree conversation in addition to hand-held conversations.

As mobile phone use in general has increased since the late 1990s (Statistics Norway, 2005) one could expect increases in accident involvement. However, decreases in accident risk could also be a potential effect of increased mobile phone use, as people get more skilled in handling the mobile phones.

1.3. Perceived risk of mobile phone use

It is an intuitively appealing notion that hand-held phones are riskier than handsfree phones, as it appears likely that holding something in your hands while driving is more dangerous than "only talking" while having both hands at the steering wheel. In line with this intuitive notion, regulation of hand-held phone use has been introduced in several countries, and people are generally positive towards such restrictions (Thulin and Gustafsson, 2004). People's perception of risk of different mobile phone types and accept of regulation of mobile phone use in traffic has been investigated by White et al. (2004). They found that hand-held phones were perceived as having significantly higher risk than handsfree phones. Moreover, respondents were more positive towards regulating use of hand-held than handsfree phones. This was especially true for respondents who reported to use handsfree phones themselves. The results of White et al. (2004) did not specify whether or not the respondents had been involved in a mobile phone related accident, and most likely none or only a few of them have been involved in such an accident. One interesting question is how risk is perceived among accident involved drivers who used either a hand-held or a handsfree phone before or during the accident. One could expect that drivers who have been involved in an accident when using a handsfree phone would evaluate this risk ("handsfree risk") in much the same way as accident involved drivers using a hand-held phone would evaluate "hand-held risk", providing both handsfree users and hand-held users were at-fault in the accident. In other words, it could be expected that both guilty handsfree users and guilty hand-held users would attribute the cause of the accident to their own mobile phone use.

1.4. The present study

The main aim of the present study was to investigate accident risk when using mobile phones while driving. More specifically, the following research questions were addressed: (a) Is using a mobile phone while driving associated with increased accident risk? and (b) Is there a difference in accident risk between using hand-held and handsfree phones? These research questions will be investigated and discussed by means of data from 1997 and 2007. Finally, drivers' perception of whether or not using a mobile phone while driving contributed to the accident in question was investigated. In particular, comparison was made between perceptions of drivers using hand-held and drivers using handsfree phones.

2. Methods

2.1. Procedure and data from 2007

Invitation letters to participate in the study were sent to 33,706 persons who had reported an accident to Gjensidige insurance company during 2007. The response rate was 18%, which means that only 6111 persons responded. Of these, data from 4307 drivers were usable for the present analyses of multiple-vehicle accidents.

Considering the low response rate, we investigated the data for responder bias. The analyses showed that the following driver groups were under-represented in our study sample (those who responded to the questionnaire) compared to the gross sample (all invited persons): (a) males (61% versus 64%), (b) young drivers (M = 48 years versus M = 47 years) and (c) at-fault drivers (54% versus 62%). Although these differences between the study sample and the gross sample were statistically significant, it is important to note that they are rather small.

The survey was web-based, and it was estimated that it would take approximately 20 min to complete the questionnaire. As web-based surveys tend to generate an under-representation of elderly respondents, the invitation letter stated clearly that anyone who did not have internet access or was not comfortable with internet could call a number in order to receive a paper questionnaire by mail. 456 persons used this option, and 50% of these were over 72 years old.

Each invitation letter referred to a specific accident that the recipient of the letter had been involved in during 2006, and participants were instructed to answer the survey thinking about that specific accident. The questionnaire covered the following themes that are relevant for the present study: (a) mobile phone use while driving, (b) culpability of accident, (c) accident type, (d) perception of risk of mobile phone use while driving and (e) driving exposure. More specifically, regarding use of mobile phone while driving, respondents were asked (i) Does it ever happen that you use a mobile phone while driving? (ii) Did the accident (that is asked about in the questionnaire) happen while you were using a mobile telephone? and (iii) What kind of mobile phone did you use when the accident happened (hand-held/handsfree)? Thus, information is provided on whether respondents used a mobile phone during (or right before) the accident, and for those who used a mobile phone during the accident, what kind of mobile phone. Information was not provided, however, on how respondents used the mobile phone, i.e., if he or she was talking, texting or dialling, etc.

2.2. Procedure and data from 1997[1]

A more or less similar procedure was used in 1997 and 2007, with the exception that the survey was not web-based in 1997. Invitation letters were sent to 29,600 persons, of which 9150 responded. Thus, the response rate was higher in 1997 (31%) than in 2007 (18%). For this particular study, we were only interested in multiple-vehicle crashes, and thus data from 5007 respondents were usable in the analyses of mobile phone related accident risk comparable to the data from 2007.

The questions regarding accident related mobile phone use in the questionnaire from 1997 were similar to the questions in the 2007 questionnaire.

2.3. Analyses

When lacking exposure data, a common method of analysing accident involvement is quasi-induced exposure (Stamatiadis and Deacon, 1997). In the present study we use this approach, as it is difficult to gain exposure data on mobile phone use.

Quasi-induced exposure leans upon the presumption that the prevalence of a risk factor, in our case mobile phone use, is the same among non-responsible drivers in multiple-vehicle accidents as in the driver population in general. Thus, if the percentage of mobile phone use among responsible drivers in multiple-vehicle crashes is higher than the percentage of mobile phone use among non-responsible drivers, it can be concluded that using mobile phones while driving increases accident risk. The relative risk equals the ratio of mobile phone use among responsible drivers to mobile phone use among non-responsible drivers (Sagberg, 2001).

In the following we have limited our analyses to multiple-vehicle accidents [$N(2007) = 4307$, $N(1997) = 5007$].

Statistical tests of relative risk ratios were first investigated by measuring each risk factor separately. Secondly, the risk factors were tested in logistic regressions in order to control for other relevant variables such as background factors and driving exposure.

Based on quasi-induced exposure, we estimated the relative risk for the various mobile phone types in 1997 and 2007 separately, as well as for the two datasets collapsed (Table 2). The following procedure was used in order to estimate relative risk (RR):

$$\mathrm{RR} = \frac{a/na}{b/nb}$$

a is the number of at-fault drivers with risk factor present; n_a, the number of at-fault drivers; b, the number of not-at-fault drivers with risk factor present; and n_b is the number of not-at-fault drivers.

Upper and lower limits of 95% confidence intervals (CI) were computed using the following formula:

$$\mathrm{Se(RR)} = \sqrt{\frac{1}{a} + \frac{1}{b} - \frac{1}{na} - \frac{1}{nb}}$$

$$95\%\mathrm{CI:}\ (\mathrm{RR} * e^{-1{,}96 * \mathrm{Se(RR)}}),\ \ (\mathrm{RR} * e^{1{,}96 * \mathrm{Se(RR)}}).$$

3. Results

3.1. Mobile phone use while driving (2007 study)

Sixty-two percent of respondents reported that they use mobile phones while driving – ever. In order to investigate what kind of drivers were more likely to use mobile phones while driving, a

[1] The 1997 figures reported in this article will deviate slightly from the reported figures in Sagberg (2001), as the present study is limited to multiple-vehicle accidents. In Sagberg (2001), single vehicle accidents were included.

logistic regression analysis was performed with "use of mobile phones while driving" (yes/no) as the dependent variable. The results showed that men were more likely than women to report such use (odds ratio = 1.56, $p < .001$), as were drivers with a university degree (odds ratio = 1.86, $p < .001$). Older drivers were less likely to report use of mobile phone while driving (odds ratio = 0.89, $p < 0.001$). Also, how many years the driver had held a driver's licence was a significant, albeit small predictor (odds ratio = 1.07, $p < .001$) as was high annual driving exposure (odds ratio = 1.02, $p < 0.001$). These results are fairly similar to what Brusque and Alauzet (2008) found.

3.2. Mobile phone use during the accident

Accident types among users and non-users of mobile phone during the accident are presented separately for 1997 and 2007 in Table 1. As there are only 24 and 29 respondents who reported using a mobile phone during the accident in 1997 and 2007 respectively, the numbers are most likely subject to random variance. However, there is a significant difference in the percentage of users and non-users of mobile phone during the accident when it comes to hitting another car in a rear-end collision; a significantly higher percentage of those who reported use of a mobile phone during the accident were involved in this type of accident compared to those who did not use a mobile phone during the accident. This was true both for data from 1997 (41.7% versus 21.0%, $p < .05$) and 2007 (37.9% versus 13.0%, $p < .01$).

In Table 2, further data regarding mobile phone use during the accident in question is presented for both 1997 and 2007. In addition, in order to achieve a larger sample, the two datasets are collapsed. In 1997, altogether 0.48% reported to have used a mobile phone during the accident, whereas the percentage in 2007 was 0.67. In 1997, 67% (16 out of 24) of the respondents who used a mobile phone used hand-held and 33% (8 out of 24) used handsfree. In 2007, these figures had changed to 41% (12 out of 29) (hand-held) and 55% (16 out of 29) (handsfree)[2].

The results show that there is a tendency towards increased accident risk for all types of mobile phones, and the relative risk estimates are consistently higher in 1997 than in 2007 (Table 2). However, the relative risk is only statistically significant under the following conditions: hand-held phones in 1997 and 2007 collapsed, hand-held and handsfree phones together in 1997, and hand-held and handsfree phones together in 1997 and 2007 collapsed. We tested whether the differences between relative risk estimates for hand-held and handsfree phones were significant by computing 95% confidence intervals for this difference. No such statistical differences were found in any of the three samples (1997, 2007, and 1997 and 2007 collapsed).

In order to control for potential confounding factors, a logistic regression was performed on the data from 1997 and 2007 collapsed (Table 3). Sex, age, education, years with drivers' licence, and exposure measured as annual kilometres were entered as independent variables in addition to mobile phone use. The results from the estimates of relative risk in Table 2 were supported; using hands-free mobile phones was not a significant predictor when controlling for confounding factors, whereas using hand-held phones was significant (Table 3). A similar analysis was performed with a dichotomous mobile phone use variable (i.e., handsfree and hand-held users versus non-users) as predictor. The results showed that using a mobile phone (whether this was a handsfree or a hand-held) was a significant predictor and indicated a higher risk (OR = 1.92, $p < 0.05$) than not using a mobile phone.

[2] The numbers from 2007 do not add to 100%, as we lack information about one type of mobile phone, i.e., whether it was a hand-held or handsfree (see Table 2).

Table 1
Type of accidents among respondents who used a mobile phone during the accident in question and those who did not use a mobile phone during the accident. Samples from 1997 and 2007.

	1997 (n = 5007, missing 96)		2007 (n = 2745, missing 1562)	
	Mobile phone used in accident			
Type of accident	Yes	No	Yes	No
Head on collision	16.7	14.8	4.0	14.2
Being hit during roadside stop	0	3.7	0.0	1.8
Collision with crossing road user	4.2*	23.2	12.0	21.6
Overtaking	0	3.0	0.0	2.9
Rear-end collision – hitting	41.7*	21.0	44.0**	19.9
Rear-end collision – being hit	25	29.2	36.0	34.4
Lane change	12.5	5.0	4.0	5.2
Total	100	100	100.0	100.0
N	24	4887	25	2720

Note: This analysis was only performed for comparable data. In the 2007 survey, additional accident type categories could be chosen by the respondents. These are omitted in the present table in order to make the data sets comparable, hence the high number of missing values in 2007.
* $p < .05$.
** $p < .01$.

Table 2
At-fault and not-at-fault drivers using a mobile phone during the crash. Relative risk and 95% confidence intervals. Driver samples from 1997 and 2007 separately and collapsed. N = 9314.

		Sample		
		1997	2007	Together
Sample size	At fault	2085	1785	3870
	Not at fault	2922	2522	5444
	All drivers	5007	4307	9314
Used telephone during crash				
Hand-held				
At fault	Frequency	10	7	17
	%	0.48	0.39	0.44
Not at fault	Frequency	6	5	11
	%	0.21	0.20	0.20
All drivers	Frequency	16	12	28
	%	0.32	0.28	0.30
Relative risk	RR	2.34	1.98	2.17*
	95% CI	0.85–6.44	0.63–6.24	1.02–4.65
Handsfree				
At fault	Frequency	5	8	13
	%	0.24	0.45	0.34
Not at fault	Frequency	3	8	11
	%	0.10	0.31	0.20
All drivers	Frequency	8	16	24
	%	0.16	0.37	0.26
Relative risk	RR	2.34	1.41	1.66
	95% CI	0.56–9.78	0.53–3.77	0.74–3.71
All phones				
At fault	Frequency	15	15	30
	%	0.72	0.84	0.78
Not at fault	Frequency	9	14[a]	23[a]
	%	0.31	0.56	0.42
All drivers	Frequency	24	29[a]	53[a]
	%	0.48	0.67	0.57
Relative risk	RR	2.34*	1.51	1.83*
	95% CI	1.02–5.35	0.73–3.14	1.06–3.16

[a] The figure for all phones differs from the sum of" handsfree" and" handheld" because information about phone type was missing for one not-at-fault driver.
* Statistically significant with $p < .05$.

3.3. Perception of risk: judgement of crash causation

Risk perception of mobile phone use was measured indirectly by asking the respondents who had used a mobile phone before/

Table 3
Logistic regression with dependent variable "at-fault/not-at-fault" showing odds ratios associated with the independent variables controlled for the other independent variables. Significant predictors in bold. $N = 6631$(data from 1997 and 2007).

	Exp (B)
Sex (1 = woman, 2 = man)	1.07
Age	1.02***
Education	1.09
Years with drivers licence	0.98***
Annual km	1.00
Hands-free mobile use	1.66
Hand-held mobile use	2.18*

Note: The N here is smaller than in Table 2, as some cases got excluded because of missing information on relevant variables.
* $p < 0.05$.
*** $p < 0.001$.

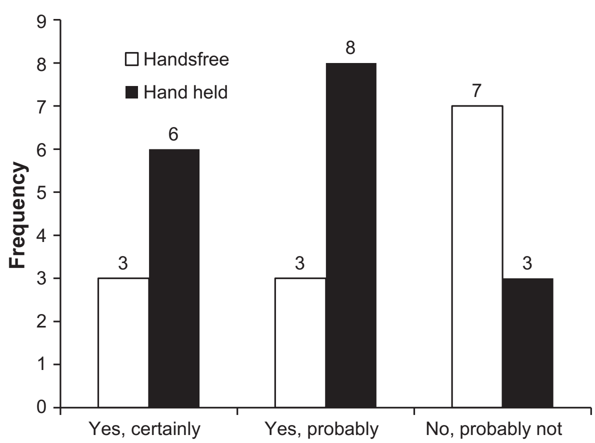

Fig. 1. At-fault drivers' responses to the question: "Do you believe the crash could have been avoided if you hadn't used the telephone?" Data from 1997 and 2007 collapsed. $N = 30$.

during the accident if they believed the crash could have been avoided if they had not used the mobile phone. Thus, the question is a measure of the drivers' perception of a potential causal relationship between their own mobile phone use and the crash the respondent in question was involved in. Only drivers "at-fault" are included in the analysis, as mobile use probably was not contributing to the crashes among "not-at-fault" drivers. Data from 1997 and 2007 are collapsed. Six persons using hand-held phones were sure that the crash would have been avoided, and eight persons were fairly sure. In comparison, only three handsfree users were sure and three were fairly sure that the crash could have been avoided, whereas seven handsfree users believed that the crash probably could not have been avoided if they had not used a mobile (Fig. 1). Only three hand-held users thought that the crash could not have been avoided if they had not used a mobile phone.

4. Discussion

The main objectives of the present study was to investigate (a) accident risk associated with mobile phone use, (b) accident risk when using different types of mobile phones and (c) perception of risk among accident involved drivers who had been using either handsfree or hand-held phones. The overall results showed no significant increase of accident risk associated with either hand-held or handsfree phone use in 2007. However, combining the data from 1997 and 2007, significant relative risk estimates were found for hand-held phones, but not for handsfree phones. As for perception of risk, hand-held users were more inclined to believe that the accident could have been avoided if they had not been using the mobile phone, than handsfree users.

4.1. Mobile phone use while driving

In 2007, 0.67% of the respondents had used a mobile phone just before or during the accident in question. This was a higher percentage than was found by Sagberg (2001) in his survey from 1997, in which 0.48% of respondents had used a mobile phone during the accident. In comparison, in a study on pure exposure to various distracters, Stutts et al. (2005) found that of the total time the vehicles were moving, participants used 1.3% of the time talking on a mobile phone. However, for the Norwegian data, the observed increase in mobile phone use while driving may reflect the general increase in mobile phone use in Norway since 1997; 58% of inhabitants in Norway owned a mobile phone in 1999, whereas 90% owned a mobile phone in 2004 (Statistics Norway, 2005). Furthermore, the percentage of handsfree users among those who had used a mobile phone during the accident has increased from 33% (8 out of 24 drivers) in 1997 to 55% (16 out of 29 drivers) in 2007. This relative increase in handsfree use can be explained by the introduction of a law in March 2000 in Norway, restricting use of hand-held phones while driving. Thus, the increase in mobile phone use while driving and the increase in handsfree use relative to hand-held use are expected based on actual societal developments.

4.2. Accident risk and mobile phone use

Relative risk for mobile phone use while driving was estimated using quasi-induced exposure (Stamatiadis and Deacon, 1997). Results from the 2007 study showed a tendency towards increased risk when using mobile phones, but none of the relative risk estimates were statistically significant, neither was the difference in relative risk between hand-held and handsfree phones. The results from 1997 show a tendency towards increased accident risk for all mobile types, and surprisingly, the relative risk estimates for handsfree, hand-held and the two types collapsed, are equal (RR = 2.34). Of these, only the relative risk estimate for mobile phones generally (i.e., handsfree and hand-held collapsed) turned out to be significant. Having in mind that most of the results were non-significant, inspection of the estimates indicates that the risk for mobile phones in general, as well as for both hand-held and handsfree, is lower in 2007 than in 1997. If this decrease in accident risk reflects a true tendency, one explanation might be that people are more skilled in using mobile phones – in general and while driving. Thus, a learning effect may explain such a potential decrease in accident risk over the years. Learning effects of mobile phone use was studied by Shinar et al. (2005) in a simulator study. They found a learning (practice) effect of mobile phone talking on driving behaviour and a reduction in subjective workload.

The applicability of this explanation to the Norwegian results is speculation, as most of the relative risk estimates turned out to be non-significant. One explanation of the non-significant results is the low number of observations of mobile phone use in both studies. In order to somewhat alleviate this problem, we collapsed the samples from 1997 and 2007 and estimated the relative risk for the different types of mobile phones in this "grand sample". The results from these analyses showed a significant relative risk for mobile phone use in general (hand-held and handsfree collapsed) and for hand-held phones, however not for handsfree phones. Moreover, the relative risk was highest for hand-held phones. It can only be speculated about these results supporting the notion that the combined physical and cognitive distraction is more dangerous than the cognitive distraction alone, as the differences in relative risk between mobile types were not significant. Thus, the present results more or less replicated Redelmeier and Tibshirani (1997) and Sagberg (2001). One important point regarding the hand-held and handsfree distinction is that we cannot rule out that handsfree users were using the phone to write text messages and not talking, as we do not have information about how the respondents used the phone. Information about how the mobile phones were used, and estimation of relative risk for talking, text messaging, and dialling, should be included in subsequent research, preferably large scale naturalistic driving studies.

A limitation that may affect the results is that respondents may be unwilling to report mobile phone use in relation to a specific accident, especially when the invitation letter to participate was sent from an insurance company. However, one would expect that misinformation about such mobile phone use would be higher among drivers at-fault in the accident, than innocent drivers. If there is an under-representation of at-fault drivers who were using a mobile phone during the accident, it would mean that our relative risk estimates are conservative, i.e., the relative risk is underestimated.

4.3. Judgment of crash causation

Perception of risk of mobile phone use among at-fault accident involved drivers, who had been using a mobile phone, was measured indirectly by asking them to evaluate whether the accident could have been avoided if they had not been using the mobile phone. As all of these drivers had been using a mobile phone before/during the accident and were the guilty part in the accident, one could expect them all to attribute the accident to the use of mobile phone. Contrary to expectation, there was an indication of a difference in how hand-held users and handsfree users evaluated the contribution of the mobile phone to the accident. The hand-held users were more inclined to attribute the accident to the mobile phone use than handsfree users, and most hand-held users were "sure" or "fairly sure" that the accident would have been avoided if they had not been using the phone. In contrast, most handsfree users were fairly sure that the accident happened independently of their mobile phone use. This may indicate that hand-held phones are perceived as more dangerous than handsfree phones, also among handsfree users who have been in a mobile related accident. That people in general perceive hand-held phones as riskier than handsfree phones is not unexpected and has been demonstrated elsewhere (Thulin and Gustafsson, 2004; White et al., 2004). However, that handsfree users who have been involved in a mobile phone related accident and was deemed guilty of the accident, does not acknowledge the risk of such use, is surprising. One explanation is that it is prohibited to use hand-held phones, but not handsfree phones, while driving in Norway. Consequently, drivers using handsfree phones may reason that as it is allowed to talk in handsfree while driving this is not dangerous, and thus they attribute the accident to other factors.

4.4. Conclusions

In conclusion, the present research seems to support previous epidemiological studies with different methodologies, in showing that telephoning while driving is associated with increased risk (although the relative risk was not significant for the 2007 data separately), and that there are no significant differences in risk between handsfree and hand-held telephones.

There is a need of more large-scale studies in order to make more definite conclusions regarding risk difference between handsfree and hand-held mobile phones, and also differences between the different phases of using the telephone.

A particular challenge is to get reliable data on actual use of mobile phones during crashes, and how the mobile phone was used.

Compared to the previous studies that were reviewed in Section 1.2, the present study has both strengths and shortcomings. The main limitations are the low response rate and the possibility of self-report bias, whereas an important strength is the collection of information about actually using the mobile phone at the time of the crash.

The high degree of uncertainty in studies of mobile phone use and accident risk is in part due to difficulties of getting observations of mobile phone use associated with accidents, and better methods and procedures for data-gathering are called for. One way to improve data could for instance be to collect information about mobile phone use during or before accidents in routine accident investigations, by collecting data from mobile phone operator companies.

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