Crash Risk and Cell Phone Use: Important Questions on the Real Risk for Legal Decision Makers

by

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ABSTRACT

Problem Several countries have forbidden hand held cell phone use while driving. Others have not yet taken any action. Questions remain about the effects of phone use on the risk of a crash? What is the magnitude of the risk in real crashes so that decision can enact appropriate regulations? Our epidemiological research that compared 9352 male drivers being cell phone users with 13590 male non users, and 3339 female users with 9797 non users has shown a different collision risk than two other epidemiological studies that used a case-crossover method. There are important differences between the case-crossover design and the two cohorts design. The case-crossover attempts to estimate the relative risk when the driver is having a cell phone communication compared to when the same driver is not on the cell phone. The two cohorts design is comparing the overall crash rates of cell phone users versus non users, adjusted for other risk exposures. Note however that a dose-response relationship was found between crash rates and frequency of cell phone use.

Objective: To propose a Bayesian approach to estimate the crash risk of cell phone usage while driving, and to carry out a simulation study to verify if the case-crossover design can estimate accurately this risk.

Method: 1) A Bayesian approach to model the probability of having a road crash and the probability of using a cell phone during the time interval just before a road crash has happened. A novel approach to reconstruct the contingency table to estimate the crash risk is introduced. 2) Simulation studies were done to assess the appropriateness of the case-crossover design into this application. The simulation process consisted on the follow-up of virtual drivers with discrete time steps of 10 seconds. An inexact collision time was generated because the time in the police reports is an approximation and tends to be after the exact time. This can lead to misclassification of phone calls made after the crash into the hazard period. The data bank used for these studies comes from our epidemiological cohorts design. On each subject there was a follow-up of 4 years of driving records, and 24 months of cell phone use totalling 19 million calls.

Results: With the Bayesian analyses we found a RR of a crash when having a cell phone communication of 0.78 for those making less than one call a day and a RR of 2.27 for those with more than 7 calls a day. These results add precision and are similar to our previous results. Results of the simulations showed an overestimation of the real risk because of the inaccurate time of the crash in the police report. The choice of the length of the hazard period has also an important impact on the magnitude of the estimated risk.

Discussion: Case-crossover design was developed to assess the risk of a transient effect but is subjected to important fluctuation if the data lacks accuracy. Basic epidemiological studies that compare two large cohorts and analyze more in depth the cell phone users has the merit of assessing robust risk in a population.

Introduction

The immense popularity of the wireless phone and the continued worldwide growth of the wireless phone industry have created a new challenge for legislators. Wireless telephones can save lives by allowing quicker assistance, however, several safety concerns have been raised to their use while driving (Chapman and Sehofield, 1998). Several countries have forbidden cell phone use completely or hand held cell phone use while driving. Other jurisdictions have not yet taken any action. Questions remain about the effects of phone use on the risk of a crash. Regulators want to know the magnitude of the risk in real crashes before making regulations. Experimental studies conducted on driving simulators or with specially equipped vehicles have shown that the use of wireless phones while driving diminishes the performance of the driver, e.g. slower reaction time, mental over load and less lateral control of the vehicle (Lamble et al., 1999; Alm and Nilsson, 1995; McKnight and McKnight, 1993; Stein et al., 1987). However, it takes epidemiological studies and real crashes to assess the real risk in a population. Three epidemiological studies on assessing the crash risk and cell phone use have been published (Laberge-Nadeau, C. et al., 2003, McEvoy et al., 2005 and Redelmeier and Tibshirani 1997). The two last cited use a case-crossover design and the first one a two cohorts design; the two design yield important result differences.

The case-crossover attempts to estimate the relative risk for the driver having a cell phone communication compared to when the driver is not on the phone. The two cohorts design is comparing the overall crash rates of cell phone users versus non users, adjusted for other risk exposures. Laberge-Nadeau et al. (2003) compared cohorts of drivers: a random sample of 9 352 male cell phone users with a control sample of 13 590 male non users, and 3 339 female cell phone users with 9 797 female non users, over a period of four years for crashes and two years of phone use from the records of the cell phone company. They found odds ratios for a collision with PDO or injuries, adjusted for kilometres driven per year and other crash risk exposures, of 1.11 for men (95 percent confidence interval: 1.02, 1.22) and 1.21 for women (95 percent confidence interval: 1.03, 1.40). A secondary analysis compared the sole users of cell phone according to their frequency of cell phone use. The adjusted odds ratios for heavy users (males and females), compared to those who used their cell phone occasionally, varied between 2.2 and 2.7, the occasional users showing similar collision rates as the non users. There was a dose-response relationship for crash rates as a function of cell phone frequency use, for men and for women.

Redelmeier and Tibshirani (1997) used a case-crossover design to assess the risk of a motor vehicle collision if a cell phone is used while driving. From the sample of 699 drivers cell phone uses who had a collision with property damage only, 157 were on the phone in the hazard interval of 9 minutes prior to the reported time of the collision. The estimated relative risk was therefore equal to 157/24 or 6.54 (95 percent confidence interval: 4.50, 9.99). Because it was not known if the cases were driving during the control period, the estimate was adjusted based on the results of a pilot survey. Thus the adjusted crash risk estimate was equal to 4.3 (95 percent confidence interval: 3.0, 6.5).

McEvoy et al. (2005) used also a case-crossover on 456 drivers (≥ 17 years) who owned or used mobile phones and had been involved in road crashes necessitating hospital attendance between April 2002 and July 2004. There results are similar to Redelmeier's: (odds ratio 4.1, 95% confidence interval 2.2 to 7.7, $P<0.001$). Increased risks were similar for men and for women.

For policy decision making, it is important to rely on precise and unbiased estimates of the real crash risk of cell phone use while driving. This paper proposes a Bayesian approach to estimate the crash risk of cell phone usage while driving and to verify if the case-crossover design can estimate accurately this risk.

Methods and Results

Two studies were carried out using the rich data bank of the two cohorts design:

1) A Bayesian approach was used to model the probability of having a road crash and the probability of using a cell phone during the time interval just before the occurrence of a road crash. A novel approach to reconstruct the contingency table to estimate the crash risk was introduced.

2) Simulation studies were carried out to assess the appropriateness of the case-crossover design for this application. The simulation process consisted on the follow-up of virtual drivers with discrete time steps of 10 seconds. An inexact collision time was generated because the time in the police reports is an approximation and tends to be after the exact time. This can lead to misclassification of phone calls made after the crash into the hazard period.

Data sources

According to our specifications, the "Société de l'assurance automobile du Québec" (SAAQ) mailed out an explanatory letter, a consent form, our questionnaire and a postage paid return envelope (addressed to the Laboratory on Transportation Safety) to 175 000 license holders of class 5 permits residing in (several) cities of the Province of Quebec. The consent form asked for permission to obtain the driver's record (collisions, infractions, demerit points and suspensions) of the respondent and, for a subscriber to a wireless phone service, to obtain the data on the use of the phone from the telephone companies (date, time, length and type of each telephone call, but not the telephone number of the connection unless it was an emergency call). A total of 36 079 questionnaires with consent form were returned to the Laboratory on Transportation Safety at the Université de Montréal.

The SAAQ insures all residents of Quebec for injuries sustained in collisions with a motor vehicle, it has the driver's record that contains among other variables the date, time and details about each police reported collision. The drivers' files records cover the period from January 1996 to August 2000, and the cell phone calls where obtained for the period 12 to 25 months (from August 1998 to August 2000) giving the date, time and duration of each call, if it was an emergency call or not. This file contains 19 million calls. From this databank, the two studies presented here utilized mostly the sole cell phone users' cohort. The method and results of each study will be summarized; details could be found in two papers (Angers J.F., et al. in Press, Bellavance F. et al. 2005).

1) The crash risk estimation of using a cellular phone while driving proposed by a Bayesian Approach.

This study attempts to insure that at the moment of the crash, the driver was having a cell phone communication; thus only the data of the 6 360 sole phone users were employed to assess the cell phone use at a specific time. From the data, a contingency table was built by crossing the event "to use the cell phone" and the event "to have a road crash". However, if the driver has not had an accident, we cannot tell whether or not he was using his cell phone or not while driving. Hence, we end up with an incomplete 2x2 contingency table. Consequently, we cannot compute the instantaneous risk directly, which is used to measure the association between the two variables "use of a mobile phone while driving" and "having a car accident". The authors modeled the probability of having a collision and the probability of having a cell phone communication at the moment of a road crash or in a short time interval prior to collision as shown in Figure 1 and 2. Using a Bayesian approach 1,000 contingency tables were simulated to obtain the means risks.

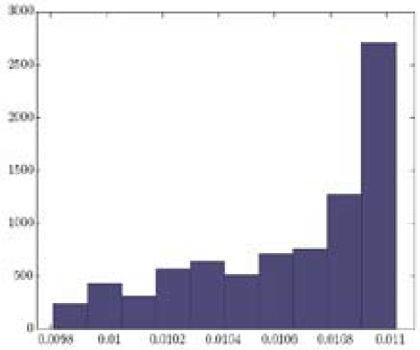


Figure 1 : Call probabilities.

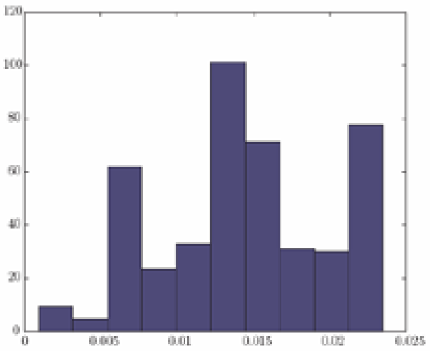


Figure 2 : Accident probabilities.

Results of the Bayesian approach study

This data set, has 442 drivers involved in 473 road crashes. Consequently, some drivers were involved in more than one collision. Hence, in the analysis, we considered 473 × 15 = 7095 driver-minutes who had a crash. Amongst those 140 were using a cell phone and 6955 did not use the phone in the 15 minutes before crash (Table 1).

Since in some cases there were more than one cell phone call made in the 15 minutes period before the time of the road crash noted on the police report three different ways to built the 2 by 2 table were selected only the last call made in the 15 minutes frame was kept. Details about the completion of the 2x2 contingency table are found in Angers F. (in press).

Table 1 : Incomplete 2 × 2 contingency table.

	To have a road crash		
To use the cell phone	**Yes**	**No**	**Total**
Yes	140		
No	6955		
Total	7095	88870	95865

Considering all cell phone users, results show that someone who is using a cell phone while driving has approximately 74% (1.735) more chance to get involved in a road crash (Table 2) the instantaneous risk changes with respect to the intensity of the cell phone usage. Therefore, the cell phone use was divided in five groups containing each approximately 20% of the observations. The groups are [0-1), [1-2), [2-3.5), [3.5-7) and [7, ∞) average cell phone calls per day (see Table 2). These subsets will help us figure out if there is a dose-response relationship between the frequency of calls made per day and the risk of being involved in a road crash. The results follow mostly a monotonic curve rising along with the average number of cell phone calls per day.

Table 2: α-credible sets for the instantaneous risk

Average usage (calls per day)	RR	Confidence interval (last call case)
<1	0.781	[0.702,0.86]
[1-2)	1.356	[1.219,1.50]
[2-3.5)	1.487	[1.339,1.65]
[3.5-7)	1.895	[1.715,2.09]
≥7	2.270	[2.034,2.52]
All users	1.735	[1.632,1.84]

With this new method, it was found that using a cell phone increases the overall risk of having a road crash by 74%. Moreover, the instantaneous risk increases up to 2.27 with a greater use of the cell phone. These results are similar but more precise (while driving) than the ones given by the two cohort design. However, there is a much lower crash risk than into the case-crossover designs.

2) Simulation studies to assess the appropriateness of the case-crossover design for this application.

In this design, a major source of bias comes from the misclassification of phone cells due to reporting errors of the exact time of the collisions. The case-crossover study design was first proposed to assess the effect of transient exposures on the risk of onset of acute events by comparing a subject to itself using matched control time periods. This novel case-crossover design has received a lot of attention and it is increasingly used in epidemiological studies. A re-analysis of the data of the sole cell phone users was performed using the case-crossover method. The previous day was chosen for the control day and the hazard and control period was T-10 to T-1 minute where T was the time of collision reported by the police. All emergency calls were removed from this analysis because they were likely made after the collision. From the cell phone users' cohort, 389 had a total of 407 collisions reported by the police (292 PDO and 115 with injury) during the two year period for which cell phone usage was available from their telephone companies. The method and results are summarized, details can be found in Bellavance F. et al. (2005).

From Bellavance study et al., the key element emerges: 1) times of the collisions written in the police reports are not exact and often a multiple of five minutes; 2) times of the collisions written in the police reports are more likely to be after the exact time of the collision; 3) for cell phone users, the probability of making a cell phone call in the minutes following the time of a collision is increased; 4) phone calls right after a collision are not necessarily made to emergency services.

To minimize the misclassification of phone calls made after the collision as a contribution to the event, Redelmeier and Tibshirani (1997) and McEvoy et al. (2005) took precautions. However, there is no guaranty that no phone calls were misclassified. A simulation model was done to estimate, with the case-crossover method, the relative risk (RR) of having a collision when having cell phone communication while driving. The model takes into account the features described above. Randomness of the time of the collision registered in the police reports is introduced and the probability of making phone calls right after the collision is increased. The impact of these characteristics on the estimates of the (RR) is evaluated.

Simulation model

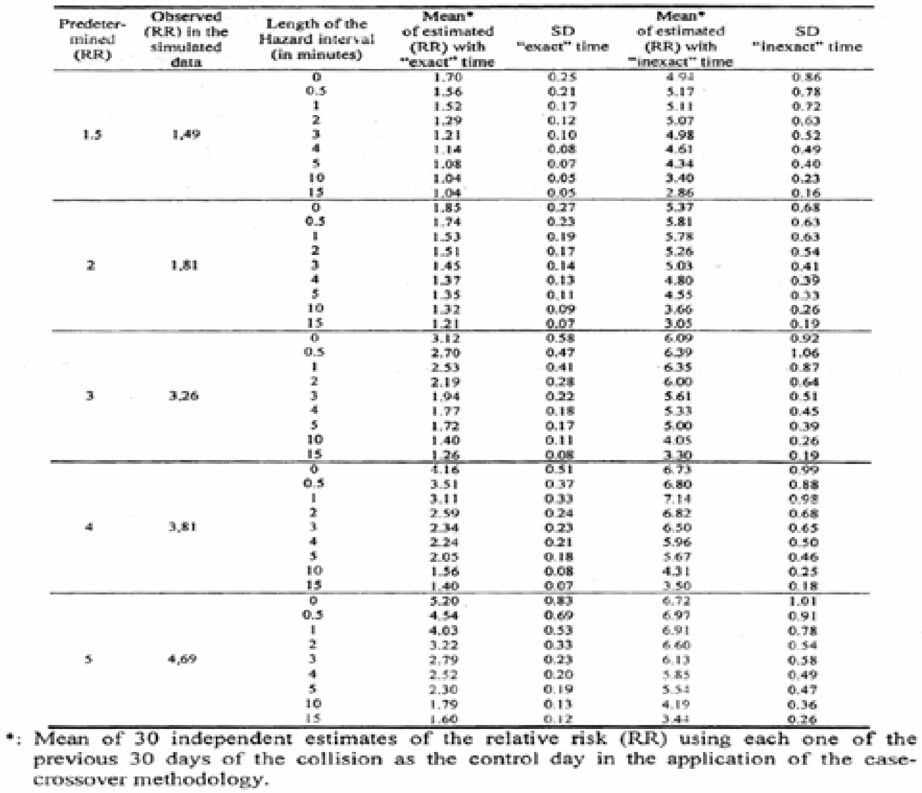
The simulation model is time-discrete, the time step chosen being 10 seconds. For each 10 seconds interval in a given day, the empirical probability of receiving or placing a cell phone call is calculated. N is the number of cell phone users-day on which the empirical distribution of phone calls was obtained ($N = 4\ 340\ 100$), and 180 is the number of 10 seconds intervals in a 30 minutes interval. The simulation process consisted in the follow up of virtual drivers during 18 months with time steps of 10 seconds. To avoid the problem of intermittent driving in the application of the case-crossover methodology, the simulation model was simplified by having each individual continuously driving during 18 months.

For each of the five simulation runs, the case-crossover methodology was applied to estimate the (RR) using the "exact" and "inexact" times of all generated collisions. The relative risk was computed for each one of the following nine different lengths of the hazard interval: 0, 0.5, 1, 2, 3, 4, 5, 10 and 15 minutes. Hence, if T is the time of the collision and X the length of the period at risk, the hazard interval considered is [T-X, T]. The same interval was used for the control day. An independent estimate of the (RR) was obtained using each one of the preceding 30 days as the control day. The mean and standard deviation (SD) of these 30 relative risks were computed to increase the precision of the (RR) estimates.

Results of the simulation studies

The simulation results are presented in Table 3. The first column gives the predetermined relative risks that were used in the simulations. The observed relative risks in the simulated data are reported in the second column. They are relatively close to their predetermined relative risks. The mean of the 30 estimated relative risks obtained by applying the case-crossover methodology with the “exact” time of the collisions (one estimate for each one of the previous 30 days as the control day), are presented in the fourth column for each of the nine different chosen lengths of the hazard interval. The standard deviation of the 30 estimated relative risks is given in the fifth column. Similarly, the mean and SD of the relative risks estimated using the “inexact” time are reported in the last two columns.

Table 3: Results of the five simulation runs, each with 5 000 “virtual” drivers involved in at least one road crash.



Predeter-mined (RR)	Observed (RR) in the simulated data	Length of the Hazard interval (in minutes)	Mean* of estimated (RR) with "exact" time	SD "exact" time	Mean* of estimated (RR) with "inexact" time	SD "inexact" time
1.5	1,49	0	1.70	0.25	4.94	0.86
		0.5	1.56	0.21	5.17	0.78
		1	1.52	0.17	5.11	0.72
		2	1.29	0.12	5.07	0.63
		3	1.21	0.10	4.98	0.52
		4	1.14	0.08	4.61	0.49
		5	1.08	0.07	4.34	0.40
		10	1.04	0.05	3.40	0.23
		15	1.04	0.05	2.86	0.16
2	1,81	0	1.85	0.27	5.37	0.68
		0.5	1.74	0.23	5.81	0.63
		1	1.53	0.19	5.78	0.63
		2	1.51	0.17	5.26	0.54
		3	1.45	0.14	5.03	0.41
		4	1.37	0.13	4.80	0.39
		5	1.35	0.11	4.55	0.33
		10	1.32	0.09	3.66	0.26
		15	1.21	0.07	3.05	0.19
3	3,26	0	3.12	0.58	6.09	0.92
		0.5	2.70	0.47	6.39	1.06
		1	2.53	0.41	6.35	0.87
		2	2.19	0.28	6.00	0.64
		3	1.94	0.22	5.61	0.51
		4	1.77	0.18	5.33	0.45
		5	1.72	0.17	5.00	0.39
		10	1.40	0.11	4.05	0.26
		15	1.26	0.08	3.30	0.19
4	3,81	0	4.16	0.51	6.73	0.99
		0.5	3.51	0.37	6.80	0.88
		1	3.11	0.33	7.14	0.98
		2	2.59	0.24	6.82	0.68
		3	2.34	0.23	6.50	0.65
		4	2.24	0.21	5.96	0.50
		5	2.05	0.18	5.67	0.46
		10	1.56	0.08	4.31	0.25
		15	1.40	0.07	3.50	0.18
5	4,69	0	5.20	0.83	6.72	1.01
		0.5	4.54	0.69	6.97	0.91
		1	4.03	0.53	6.91	0.78
		2	3.22	0.33	6.60	0.54
		3	2.79	0.23	6.13	0.58
		4	2.52	0.20	5.85	0.49
		5	2.30	0.19	5.54	0.47
		10	1.79	0.13	4.19	0.36
		15	1.60	0.12	3.44	0.26

*: Mean of 30 independent estimates of the relative risk (RR) using each one of the previous 30 days of the collision as the control day in the application of the case-crossover methodology.

The estimated relative risks using the “exact” time are similar to the predetermined (RR) for small lengths of the hazard interval. They decrease and get closer to 1 as the length of the hazard interval increases. The results are however very different when the relative risk is estimated using the “inexact” time of the collisions. For the predetermined (RR)s of 1.5 and 2, the means of the estimated relative risks, and the lower bounds of the 95 percent confidence interval, are above the true relative risks for all nine hazard intervals considered. The means of the estimated (RR)s vary between 2.86 and 5.17 for the true (RR) of 1.5 and between 3.05 and 5.81 for the true (RR) of 2. The lower bounds of the 95 percent confidence interval are above the predetermined (RR)s of 3, 4 and 5 for the hazard intervals smaller or equal to 10, 5 and 3 minutes respectively. In general, the mean of the estimated (RR)s increases slightly with the length of the hazard interval between 0 and 0.5 minute and then decreases continuously with the length of the interval greater than 1 minute. For hazard intervals in the range of 0 to 2 minutes, the overestimating bias is greater for smaller values of the predetermined (RR), and diminishes with the increasing value of the true (RR).

Discussion

Two critical issues were investigated in the application of the case-crossover methodology to estimate the risk of road crashes when having a cell phone conversation while driving. They are the inaccurate time of the collisions often recorded after the exact time, and the very short duration of cell phone calls. Combined with the increased probability of using the cell phone right after the crash and because there is little guaranty emergency services will be alerted, unless it is a severe or fatal road crash (Haigney D.E. and Westerman S.J. 2001), the likelihood of misclassifying a case as exposed to a cell phone conversation in the hazard interval is therefore very high. The simulations demonstrate in this instance, that the case-crossover approach overestimates the true relative risk. The misclassification bias is quite important for the smaller predetermined relative risks. Indeed, the estimated relative risks with the inexact time in the simulations, for hazard intervals of two minutes or less, vary between 4.98 and 5.17 for the true (RR) of 1.5, and between 5.26 and 5.81 for the true (RR) of 2. The overestimation is still present even for the largest hazard interval considered in this study.

In the simulation study, results show that the case-crossover design can produce accurate estimates of the relative risk in ideal conditions. In our setting this means that the time of the collision is known exactly, the length of the hazard interval is appropriately chosen, and the drivers are on the road during the control interval. In those circumstances, this design is very attractive as it is cost effective. But, as it was reported by Greenland (1996 and 1999) and as seen in our simulations results, the case-crossover design is very sensitive to misclassification bias and to the choice of the length of the hazard interval. It should therefore be used with caution.

Policy decision makers are confronted with different results of epidemiological studies on the risk of cell phone use while driving. Redelmeier and Tibshirani estimated the adjusted crash risk at 4.3 for PDO (Property Damage Only) and McEnvoy found an odds ratio of 4.1 for injury crashes. The simulation study (Bellavance et al. 2005) has raised serious doubts about an over estimation of the real risk found by the latter two studies. On the other hand Laberge-Nadeau et al. with a robust method, two cohort design, have shown much lower crash risk. The RR for injury collisions and for all collisions is 38% higher for men and women cell users, but when Km driven and driving habits are incorporated in the model the men registered 1.11 (1.02, 1.22) and women 1.21 (1.03, 1.40). There is a volunteer bias for men not found for women. The most significant result is a dose-response relationship between the frequency of phone use and crash risk. The adjusted RR for heavy users are at least two compared to those making minimal use of cell phones, the latter shown similar collision rates as do the non-users cohort. Moreover the Bayesian approach estimates the influence of the use of cell phone while driving on the risk of a road crash that required a novel approach. The overall instantaneous risk was 1.735. There was also a dose-response relationship between the frequency of the cell phone use and crash risk. Interestingly light user (less than 1 call/day) registered a RR of 0.781. Whereas heavy ones (≥ 7 calls/day) incurred a RR of 2.27.

The use of the case-crossover design results with the simulations showed that when random errors are introduced between the exact time of the collisions and the time recorded in the police reports, the relative risk (RR) estimates were up to three times larger than the true (RR). The bias due to exposure misclassification was larger for smaller values of the true (RR). The results also showed the importance of the choice of the length of the hazard interval. However, some authors have raised several methodological problems with this design such as time trends in exposure, selection bias and confounding (Suissa S., 1995), recall bias (Greenland, S. 1999), proper choice of the length of the hazard or “at risk” period (Maclure, M., Mittleman MA 2000), or length bias of gap time (Varadan R., Erangakis 2004). Greenland (1996, 1999) also pointed out that case-crossover and other similar matched-pair designs can be more sensitive to misclassification bias than traditional unpaired epidemiological studies.

This is particularly critical for policy decision making because in general, small relative risks will suggest milder interventions such as education campaigns, compared to more aggressive actions, such as prohibitive laws, when the true relative risks are higher. A study that grossly overestimates a small relative risk will mislead decision makers and can therefore have serious negative impacts. Therefore it is important to rely on precise and unbiased estimate of the real crash risk of cell phone use while driving.

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