Is a hands-free phone safer than a handheld phone?

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Abstract

Although it is becoming more and more accepted that driving while talking on a cell phone can be hazardous, most jurisdictions are making handheld phone use illegal while allowing hands-free phone use. The scientific literature exploring the effects of these two types of cell phone use on driving and driving-related performance is reviewed here. Our review shows that talking on the phone, regardless of phone type, has negative impacts on performance especially in detecting and identifying events. Performance while using a hands-free phone was rarely found to be better than that using a hand held phone. Some studies found that drivers compensate for the deleterious effects of cell phone use when using a hand held phone but neglect to do so when using a hands-free phone. Current research does not support the decision to allow hands-free phone use while driving.

Résumé

Malgré que le fait de conduire en parlant au téléphone cellulaire soit de plus en plus reconnu comme étant hasardeux, plusieurs juridictions rendent illégale l'utilisation des téléphones portables mais permettent l'utilisation des téléphones main-libre tout en conduisant. Cet article présente une revue de la littérature scientifique explorant l'impact de ces deux types de téléphones cellulaires lors de la conduite automobile. Notre revue de littérature démontre que parler au téléphone, peu importe le type d'appareil utilisé, a un impact négatif sur la performance du conducteur, particulièrement en ce qui concerne la détection et l'identification d'événements. La performance du conducteur lors de l'utilisation d'un téléphone main-libre s'avère rarement supérieure à celle observée lors de l'utilisation d'un téléphone portable. Certaines études démontrent que les conducteurs compensent pour les effets nuisibles résultant de l'utilisation de téléphones cellulaires lorsqu'ils utilisent un téléphone portable mais négligent de faire de même lorsqu'ils utilisent un téléphone main-libre. La décision des juridictions de permettre l'utilisation des téléphones main-libre en conduisant n'est pas supportée par les études scientifiques.

INTRODUCTION

Today, there are more than 253 million cell phone subscribers in the US [1], and more than 19.3 million cell phone subscribers in Canada [2]. These figures are more than half of the total population in both countries suggesting that cell phones are becoming ubiquitous in our lives. It is not surprising, then, that there is an increase in the number of individuals who talk on their cell phones while driving. In fact, it is suggested that 85% of cell phone owners do use their phones while driving (Prevention Magazine cited in [3]). Although we use our hands and feet when we drive, driving is controlled by the mind. As William James noted, paying attention "...implies withdrawal from some things in order to deal effectively with others" [4, p. 403-404]. Hence, using our mind to carry on a conversation or perform any other attention-demanding activity (e.g., eating, problem solving) [5] will render it less available for processing the signals and performing the actions necessary to minimize accidents when driving.

If a cell phone conversation distracts the driver, then a cell phone conversation can be a possible safety hazard for driving. In fact, Goodman et al. [3] have noted a potential relationship between the increasing number of cell phones and an increasing frequency of cell-phone-related car accidents. Recently, Horrey and Wickens [6] conducted a meta-analysis and examined costs associated with cell phone use while driving. Based on standardized effect sizes along five dimensions in 23 studies they reported that using a cell phone while driving had substantial negative effects on driving-related performance in reaction time (RT), but not in lane maintenance.

In spite of the common understanding that a hands-free (HF) cell phone is a safer option than a handheld (HH) cell phone while talking and driving at the same time, the deleterious effects of cell phone use were similar for the HH and HF phones in Horrey and Wickens' report [6]. The purpose of their study was to provide a comprehensive picture of cell phone use in general, and consequently the difference between the two phone types, while mentioned, was neither emphasized nor covered in depth. The major purpose of the present review is to use the literature [7-17] to determine whether talking on a HF cell phone while driving is safe and whether there is difference in safety between talking on a HH phone and talking on a HF phone while driving. Across these studies of cell phone use, the degree to which the task performed is like driving varies greatly. We will use the term "fidelity" to refer to variation along this dimension. Reed and Green [18] suggested that driving-related performance suffered more from dialing a phone, in simulated driving than in field driving tasks. It is possible that not only the manual operation of dialing [18], but also the cognitive demands of conversing on a HH phone or a HF phone, may affect driving-related performance differently according to the fidelity of the driving situation being tested. Another purpose of this review is to examine this possibility.

We used the reference sections of papers (e.g., [6]) and online databases (e.g., PsycINFO, Web of Science Citation) to identify candidate papers for this review. The most important criterion for selection was that the relationship between driving-related performance and phone type (both HH and HF) was examined within a single study. We did not set any restrictions on the year of publication nor did we enforce any methodologically-based exclusions. In total we found ten studies (eight experimental and two epidemiological studies) that compared driving performance (experimental studies) and real accidents (epidemiological studies) while people were using HH and HF phones (Table 1).

Experimental studies examine the effect of the phone type on the driving-related performance. Importantly, the type of cell phone can be manipulated. There are different degrees of fidelity. At low levels of fidelity, there are non-driving studies that do not involve actual driving, but instead require participants to perform tasks, whose component operations (like tracking and RT tasks) are akin to driving operations (like keeping the car on the road; braking to avoid a collision) [9, 14]. Simulated driving studies have an intermediate degree of fidelity. In such studies, usually employing a driving simulator, participants drive on simulated roads [7, 8, 10, 15-17] while talking on a HH phone or a HF phone. Simulated driving studies, which are the most common among studies in general and also in this review, have advantages in terms of safety, cost, and experimental control [18]. Finally, a field driving study is the most realistic of all. In a field driving study, performance in an actual driving task is examined [12].

	Fidelity	Study	N	Phone task	Road complexity	Type of HF phone
Experimental	Non-driving	Consiglio et al [9]*	22	C	n/a	HFE
		Strayer & Johnston [14]*	48	C	n/a	?
	Simulated-driving	Haigney et al [10]	30	IP	Medium	HFE
		Strayer et al [15]*	40	C	Low/High	HFE
		Burns et al [8]*	20	IP	Mixed	HFE
		Törnros & Bolling [16,17]*	48	IP	Low/High	HFS
		Abdel-Aty [7]	20	C	Low/High	?
	Field-driving	Patten et al [12]*	40	IP	Low	HFS
Epidemiological		McEvoy et al [11]	456	n/a	?	?
		Redelmeier & Tibshirani [13]	699	n/a	?	?

Table 1 - Methods of the studies examining the effects of phone type (HH and HF) on driving-related performance.
***Attention was measured in a detection/identification task.**
C = conversation, IP = information processing, HFE = HF phone with an earpiece/headset, HFS = HF phone with a speaker

The general approach used in the experimental studies includes measuring driving-related variables while manipulating factors such as the phone type. Although driving-related variables differ greatly across the studies, these can be categorized into two general types: one is a measure of vehicle control (controlling an apparatus that represents a car, controlling a simulated car, or controlling a real car); the other is a measure of attention in detection or identification tasks, in which the participant's task is to detect or identify a target/event. The measures of vehicle control include lane maintenance (lane deviation, collision, off-road excursion (OFF)), vehicle speed, and so on. The measures of attention include RT and accuracy in detection or identification tasks. The focus here will be on these relevant variables from each study in which they were reported rather than upon all the (unique) variables reported in each study. Later, to allow a comparison across the experimental studies, the effects of cell phone use on vehicle speed (measure of vehicle control) and RT (measure of attention) will be presented graphically. Goodman et al. [3] report that 'driving too fast' and 'inattention' were the most commonly identified factors for cell phone related collisions. In this review, either driving too fast or too slow is considered as a poor vehicle control because participants in the studies here are typically asked to drive as they normally do or follow a pace car while following traffic rules.

Epidemiological studies are necessarily more realistic than the experimental studies. Epidemiological studies examine the relationship between cell phone conversation and motor vehicle accidents in the real world. For example, Redelmeier and Tibshirani [13] and McEvoy et al. [11] evaluated cell phone records of individuals involved in motor-vehicle accidents. The advantage of an epidemiological approach is that there are fewer experimental artifacts that can contaminate the data [19]. The main disadvantage is that such studies cannot establish causal relationships between the variables (e.g., cell phone use and occurrence of accidents).

1. Non-driving studies

Consiglio et al. [9] examined the effects of cell phone conversations and other potential auditory/verbal sources of interference (control versus listening to music on radio, conversing with a passenger, conversing with a HH phone, and conversing with a HF phone) as a within-subject factor[1] on RT in a braking response task. Twenty-two participants performed a braking response task, in which they were asked to release the accelerator and depress the brake pedal as quickly as possible following activation of a red break lamp located in front of them. In the three conversation conditions, participants answered straightforward scripted questions. When talking to the passenger in the passenger conversation condition, the participants were asked to look at the lamp rather than the passenger. Results indicated that RT was slower in the phone conditions, regardless of the phone type, than in the control condition. Importantly, there was no significant difference between the HH and the HF phone conditions. In addition, there was no difference in performance between the passenger and the phone conditions. The difference between the passenger and the phone conversations will be discussed later in this review.

Strayer and Johnston [14, Experiment 1] examined the effects of phone conversation (single and dual tasks) as a within-subject factor and the effects of the phone type (control, HH, and HF) as a between-subject factor[2] on performance of a pursuit-tracking task. Forty-eight participants[3] performed the tracking task on a computer display. They were instructed to continue the task if the light on the screen was green but make a braking response when the light was red. In the control group, the participants performed the pursuit-tracking task while listening to a radio. In the phone groups, the participants discussed current topics (e.g., the then-ongoing Clinton presidential impeachment) on the phone while performing the pursuit-tracking task. RT and probability of missing the red lights were measured. Results indicated that RT was longer and probability to miss the red lights was higher in the phone groups than the control group. There was no significant difference between the two phone groups.

These non-driving studies show that talking on the phone while “driving” impairs performance in the measure of attention in detection and does so equally in the HH and the HF phone conditions (Table 2).

2. Simulated driving studies

By far the most common type of study uses some sort of simulated driving task, examining vehicle control and attention in measurements of physical quantity (i.e., meter, millisecond).

[1] A within-subject factor is a variable for which each level of that variable is tested with all the participants in the experiment.
[2] A between-subject factor is a variable for which each level of that variable is tested with a different group of the participants in the experiment.
[3] To make sure that the participants were attending to what they were listening to in the control condition, an additional control condition was run in which the participants listened to a selected passage from a book on a tape while they performed the tracking task. The participants were informed that questions on the tape would be asked later. Only the participants who scored more than 90 % correct on the questions were included in the analysis.

First, we are going to discuss studies whose major manipulation is the type of phone, then studies whose manipulations involve environmental complexity beside the phone type, and finally a study that examined the driving-related variables exclusively in terms of frequency of errors.

Haigney et al. [10] examined the effects of the phone type (HH and HF) during different periods of a call (pre-call, during call, and post-call) as within-subject factors on driving performance[4]. Thirty participants drove[5] a simulated road four times, populated with vehicles on either side of the highway. Each simulated driving included three call periods of 150 seconds. During a call period, participants verbally responded to a reasoning test. Number of collisions, number of off road excursions (OFFs), and vehicle speed were measured. The number of collisions and OFFs did not differ as a function of the period of a call. However, vehicle speed was slower during the call period than during the other periods. These patterns suggest a process of risk compensation [10] when talking on a phone (i.e., slowing down to avoid a collision or an off-road excursion). While the number of collisions and speed did not differ as a function of the phone type, there were significantly more OFFs with a HH phone than with a HF phone.

Strayer et al. [15] examined the effects of the phone type (control, HH, and HF) as a within-subject factor[6] on driving performance. Forty participants drove a simulated highway (38.6 km long). Their task was to follow a pace car that was intermittently braking. Naturalistic conversation[7] (15 minutes long) was used to simulate the demands of conversation over the phone. The total number of accidents, vehicle speed, following distance, and braking RT were measured. Results indicated that there were more accidents in the phone condition, irrespective of the phone type, than in the control condition. Moreover, braking RT was slower, and following distance was more variable in the phone condition, irrespective of the phone type, than in the control condition. There was no difference in vehicle speed between the control and the phone conditions[8]. Importantly, there was no significant difference between the two types of phone in any of these measures.

Burns et al. [8] examined the cell phone conversation (control, HH, and HF)[9], and traffic environment (motor way, 3-lane motor way, curved road, and 2-lane road) as within-subject factors on simulated-driving performance. Twenty participants were asked to 1) follow a pace car, driving between 80-113 km/h, on a motorway for 15 km, 2) drive as they normally did on a 3-lane motorway with a speed limit of 113 km/h for 4.7 km, 3) drive a section of a curved road maintaining a speed of 96.6 km/h for 3.6 km, and 4) respond to target warning signs by flashing their headlights while driving on a 2-lane road for 3.3 km. A sentence memory task and a verbal puzzle task included in casual conversation were used to simulate the demands of conversation over the phone. Lane deviation (deviation within a lane), vehicle speed, RT to the target signs, probability of missing the target signs, and false alarms to the target signs were measured. Lane deviation was unaffected by the phone conversation, regardless of the phone type. Vehicle speed was not different among the three phone conversation conditions on the motorway. However, vehicle speed was slower in the HH and HF conditions than in the control condition on the curves and on the two-lane roads. This tendency was significantly greater in the HH than in

[4] The effect of cell phone type (HH and HF) on the phone conversation was examined too. There were no effects of this variable.
[5] Driving instruction (e.g., follow a pace car, etc) was not reported in this study.
[6] This factor included an additional condition in which the participants consumed alcohol. This will be discussed later.
[7] Topics were identified on the first day as being of interest to the participant.
[8] However, the authors reported that the difference was significant at an alpha level of 0.1.
[9] This factor included an additional condition in which the participants consumed alcohol. This will be discussed later.

the HF conditions. Drivers might have slowed down when talking on a HH phone because they were aware of mental and physical load imposed on them. Thus, this is a kind of a compensatory behavior [see also 12, 16]. In addition, for the curved road, speed was more variable in the HH than in the HF conditions. Moreover, in the detection task (which was performed only on the curves), RT was slower, probability of missing target signs, and probability of false alarms were greater in both phone conditions than in the control condition. RT was slower with the HH than with the HF phones, but this trend was not significant. There was no significant difference between the HH and the HF phones in false alarms[10].

Törnros and Bolling [16[11], 17] examined the effects of the phone use (phone and control) and environmental complexity as within-subject factors and the phone type (HH and HF) as a between-subject factor. There were two types of environment, rural and urban. Further, the rural environment had two levels, differing in speed limit. The urban environment had three levels, differing in complexity. There were 48 participants in the study and their task was to drive simulated highways (total of 70 km long) that led through the urban and rural environments, as they normally would do. Participants also performed a peripheral detection task (PDT**)** while they were driving. In the phone conditions, participants verbally responded to a paced serial addition task. Vehicle speed and lane deviation in the driving task, and RT and accuracy in the PDT task were measured. Results indicated that vehicle speed was slower in the phone conditions than the control condition, but this pattern was due mainly to slower speed in the HH than in the control conditions. This suggests that conversing with the HH phone may cause a larger compensatory effect than with the HF phone; in other words, drivers may underestimate risks associated with conversing with the HF phone [see also 8, 12]. When environmental complexity was taken into consideration, speed reduction was observed only in the rural environment with higher speed limit and the most complex urban environment [17]. In addition, in these environments, speed reduction was observed even with the HF phones. These patterns show the compensatory effect when the driving environment is relatively challenging. Unexpectedly, lane deviation was greater in the control than in the phone conditions. Perhaps this difference was a direct consequence of the compensatory slowing of the vehicle in the phone condition. This pattern, however, is inconsistent with Strayer et al. [15], who showed impairments in lane maintenance in the phone condition. There was no significant difference between the HH and HF phone conditions for this variable. In the PDT, RT was longer and accuracy was worse in the phone conditions, irrespective of the phone type, than in the control condition.

Abdel-Aty [7] examined the effects of the phone type (HH and HF) and the period of a call (pre-call, during call, and post-call) as within-subject factors as well as the effects of traffic density (low and high) as a between-subject factor on the number of driving-related errors during a simulated driving task. This study is different from other simulated studies because this is only one study in this review that focused on frequency of errors. There were twenty participants in this experiment. They sat in front of the driving apparatus and were asked to drive to explore a simulated city, which included vehicles and pedestrians, while following all traffic rules. During the phone calls, some personal information (e.g., name, ages, etc.) was requested to simulate the demands of conversation over the phone. The number of errors the participants made such as lane deviation, leaving the road, crossing the median, crashing, disobeying the speed limit, failing to stop, and other errors were measured. Results indicated that the total numbers of error

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[10] This false alarm finding is based on a personal communication with one of the authors.
[11] The participants performed two experiments, one measuring effects of conversation and the other measuring effects of dialing. We report only the results from the former experiment for our review purpose.

across the error categories were greater in the during the call than before the call and there was no difference between the HH and HF conditions. However, there was an exception. The participants tended to violate the speed limit more frequently when using the HH phones (60%) than the HF phones (40%). This is the only study in this review that shows faster speed when talking on a HH phone than when talking on a HF phone (for the opposite pattern, see [8, 12, 16]. Surprisingly, the number of errors was greater for the low traffic than high traffic conditions in the post-call condition. These patterns suggest that the negative effect of using a cell phone may be carried over for a while after conversation is terminated and that this pattern is prominent for the environment with low density [7]. It is possible that lack of alertness in the low density condition encouraged the participants to 'think' about the conversation they had just completed.

The simulated driving studies generally show that talking on the phone while driving impaired the measure of vehicle control especially in speed control and the measure of attention (Table 2). Participants slowed down and reacted slowly when talking on the phone. Although slowing down could be considered as an example of a poor vehicle control, it is important to consider that it might also be an appropriate adaptation to the dual task demands. However, there seems to be little effect of phone conversation on lane maintenance. The results are not clear regarding the effects of phone type on speed control. Lastly, there seem to be little effects of phone type on measure of lane maintenance and attention.

3. Field driving study

There is only one experimental study comparing HH and HF phone use while participants were actually driving in the real world. Patten et al. [12] examined the effects of the phone type (HH and HF) and conversation complexity (control, simple, and complex) as within-subject factors on driving and PDT performance. There were 40 participants whose task was to drive, as they normally would while following traffic rules. They drove a section of a highway (starting at a point A, drove to a point B, and returned to the point A) with relatively low levels of road complexity and interactions with other vehicles. The speed limit was 110 km/h on this highway. The participants drove 74 km and it took about one hour to drive though the section. Participants were tested with the different type of phone and complexity of conversation on the way to a point B and on the way back to a point A from a point B. They also performed a PDT, in which they responded by depressing a small switch attached to the left index finger to a light stimulus appearing in their periphery, while they were driving. To simulate the demands of conversation over the phone for the simple and the complex conditions, a digit shadowing task and a memory-addition task were used, respectively. Vehicle speed in the driving task and RT and accuracy in the PDT were measured. Vehicle speed was slower in the phone conditions than in the control condition due mainly to slower speed with the HH phone. Speed in the HF condition was not significantly different from the control condition. The authors suggested that a HH phone might remind the participants of their "*self*-imposed impediment," resulting in a compensatory speed reduction [see also 8, 16]. In the detection task, RT was longer and accuracy was worse in the phone conditions than in the control condition, and there was no significant difference between the two phone types in this measure. Moreover, RT was longest in the complex conversation condition, followed by the simple and the control conversation conditions. This pattern was the same with the HH and the HF phones, suggesting that the conversation complexity rather than the phone type was a more important factor affecting driver distraction.

		Control vs. HF			HH vs. HF		
		Vehicle control		Attention	Vehicle control		Attention
		Speed	LM	RT	Speed	LM	RT
Non-driving	Consiglio et al. [9]			√			ns
	Strayer & Johnston [14]			√			ns
Simulated-driving	Haigney et al. [10][a]	√	?		ns	√[b]	
	Strayer et al. [15]	ns[c]	√	√	ns	ns	ns
	Burns et al. [8][d]	√	ns	√	√	ns	ns[e]
	Törnros & Bolling [16,17]	ns	√[f]	√	√	ns	ns
	Abdel-Aty [7][g]	?	?		√[h]	ns	
Field-driving	Patten et al. [12]	ns		√	√		ns
Number of studies showing a cost		2/5	1/3	6/6	4/6	1/5	0/6

Table 2 - Results of the experimental studies examining the effects of phone type [Control vs. HF (is the HF safe?), and HF vs. HH (is the HF safer than HH?)] on driving-related performance

LM = lane maintenance (lane deviation, collision, off-road excursion); √ = significant difference (vehicle speed: slower speed for the HF than for the control conditions or slower speed for the HH than for the HF conditions; LM: poor LM for the HF than for the control conditions or poor LM for the HH than for the HF conditions; RT: slower RT for the HF than for the control conditions or slower RT for the HH than for the HF conditions. When direction of the significance is different, it will be noted.); ns = no significant difference; ? = data not available; (blank space) = not measured; (underline) = implied results

a. **The control condition in this study was calculated by taking a mean of the pre-call and the post-call conditions.**
b. **There is a significant difference in off-road excursions. But, there is no difference in the number of collisions.**
c. **The difference is significant at an alpha level of 0.1.**
d. **The results are from the curved road condition (one of the four traffic environments). Only in this condition were both vehicle speed and RT to warning signals measured.**
e. **There is a non-significant trend for the HH condition to be slower than the HF condition.**
f. **LM is better in the (HF) phone than in the control conditions.**
g. **In this study, average numbers of driver errors were compared. The numbers of individual driver errors were rarely compared.**
h. **Disobeying the speed limit occurred more frequently in the HH phone than in the HF conditions.**

This field driving study shows that talking on the phone while driving impairs attention regardless of the phone type (Table 2). As in most of the other studies reviewed here, participants slowed down when using a HH phone, a behavior which might be an appropriate adaptation to the dual task demands.

4. Epidemiological studies

Redelmeier and Tibshirani [13] and McEvoy et al. [11] evaluated the cell phone records of individuals involved in motor-vehicle accidents resulting in damage to property and resulting in hospitalization, respectively. Both studies show that cell phone use was associated with a fourfold increase in the likelihood of getting into an accident, linking cell phone use and traffic accidents in the real world. One common finding from these studies is that there was no safety advantage to the HF as compared with the HH phones. Thus, the HH and HF phones seem to be equally dangerous in the real world settings. As mentioned earlier, accidents in the real world could be as a result of poor vehicle control (poor driving skill) and/or as a result of attention being distracted from the task of driving.

SUMMARY OF THE STUDIES

A summary of the results from the experimental studies discussed above is presented in Table 2. The results for the measures of vehicle control (speed and lane maintenance) and attention (RT) are presented separately for control vs. HF phone groups, and HH vs. HF phone groups. The number of studies in which group differences had been found, showing costs for the HF phone group relative to control (is the HF phone safe?) and for HH phone group relative to the HF phone group (is the HF phone safer than HH phone), was counted and reported on the last row of Table 2.

Based on the examination of each study above and Table 2, it can be concluded that conversation with HF phones impairs detection RT more than the control. All the studies that examine the difference show this pattern. Importantly, none of the studies show the difference between the HF and the HH phones on the same measure, suggesting no safety advantage of the HF over the HH phones (see also Figure 1A). However, one study [8] showed a tendency of the HH phone drivers to react to the warning signs slower than the HF phone drivers. In this study, the participants flashed the headlight when detecting the events. It is possible that the manual tasks of handling a steering wheel and holding a cell phone might have interfered with another manual task of flashing headlight. There are three other studies in which the participants' RT was measured from their manual responses and none of which found an HF phone advantage [12, 14, 16, 17]. These responses included pressing a micro switch attached to the finger [12, 16, 17] or pressing a button located in the thumb position on top of the joystick [14]. Perhaps flashing the headlight is not an easy response for a detection task and this might cause a slower reaction.

As for vehicle control, the patterns are not as clear as that for detection RT. Only two out of five experimental studies show that conversation with HF phones affected speed control (i.e., causing slower driving). However, when comparing the difference between the HF and the HH phones, slowing down seems to be greater for the HH than for the HF phones. The data in Figure 1B (which is, admittedly from a subset of the studies, those that reported the HH and HF data separately) illustrates a consistent trend: greater slowing down with the HH phones than with the HF phones.

One out of three studies shows that conversation with HF phones impairs lane maintenance, and one study out of five shows a difference between the HF and the HH phones on the same measure. These patterns suggest little safety advantage of the HF over the HH phones. This pattern is, at first, surprising because drivers using a HH phone should be at a disadvantage in stable lane maintenance with only one hand controlling the steering wheel. It seems likely, however, that participants are more aware of workload imposed by the HH phone use than by the HF phone use. Indeed, it is probably this awareness that leads to the compensatory behavior of slowing down (see above). The slower speed in the HH phone condition allows drivers to maintain lane position at the same level as in the HF phone condition where a higher speed (less, or no, compensation) is maintained [8, 16, 17, but see 7]. Although slowing down may be considered poor vehicle control and considered dangerous when there are vehicles immediately behind, on balance it seems to be an adaptive strategy to improve safety in the context of a cell-phone conversation.

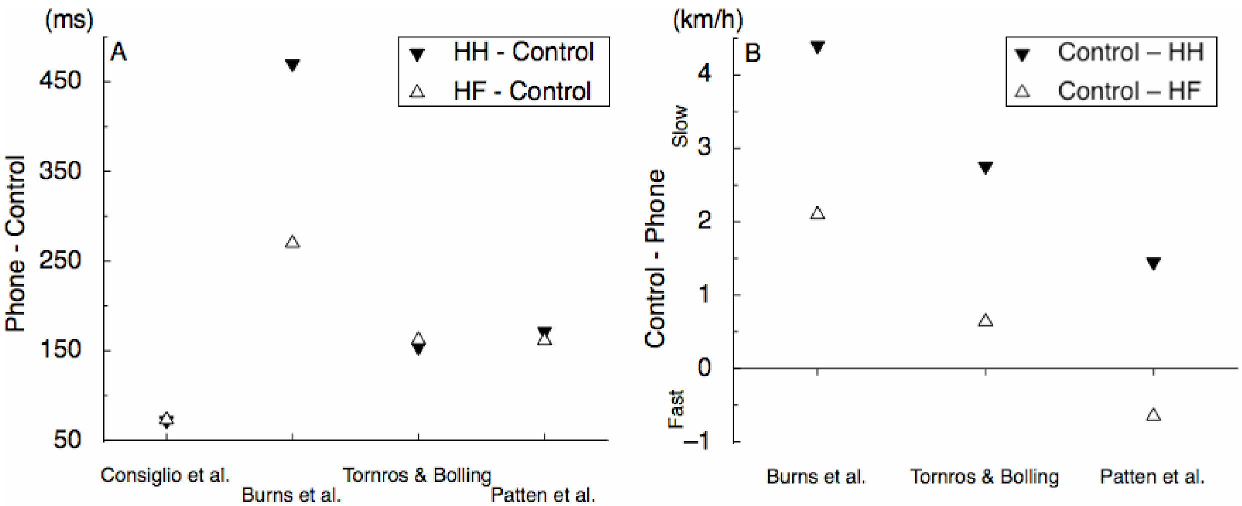

Figure 1. (A) Difference between the control and HF phone (HF minus control), and the control and HH phone (HH minus control) conditions in detection RT in ms, and (B) difference between the control and the HF phone (control minus HF), and the control and the HH phone (control minus HH) conditions in speed control in km/h for the studies whose data are available. The results of Burns et al. [8] in A and B are from the curved road condition (one of the four traffic environments in their study). Only in this condition were both vehicle speed and RT to warning signals measured.

One purpose of this review paper has been to evaluate the effects of phone conversation and phone type on driving performance across different levels of driving fidelity. Table 2 shows that there are clear patterns in the measure of attention across the different fidelities within the experimental studies; phone conversation regardless of the phone type impairs detection/identification RT. On the other hand, there is not a clear pattern in the measure of vehicle control. These patterns are consistent with the conclusions of Horrey and Wickens [6], who show costs of using phones while driving regardless of the phone type with clear costs for RT tasks but little costs for tracking tasks (i.e., lane maintenance). Even though the HH phone condition in this review is restricted to HH phone use for conversation and not for dialing, a similarity between Horrey and Wickens's meta-analysis and the patterns found in this review is revealed. Talking on the phone impairs attention and there is little difference between the HH and HF phones. Moreover, meta-awareness of the possibly deleterious effects of HH phone use seems to result in a compensatory speed decrease thereby maintaining performance in keeping the car in the lane. These patterns can be interpreted as consistent with the results from the epidemiological studies that there is a greater likelihood of getting into an accident when talking on the phone regardless of the phone type. We assume that accidents could happen because of poor vehicle control and distracted attention. Given the experimental studies described here, it seems likely that accidents reported in the epidemiological studies occurred due to distracted attention rather than poor vehicle control [see also 20].

OTHER FACTORS TO BE CONSIDERED

We reviewed the studies above focusing on the manipulation of the phone type (especially for the experimental studies) and its effects on driving performance according to the different fidelities. There are some other potentially important factors in relation to the phone type manipulation.

1. Type of conversation

In the broader literature, the type of conversation has been shown to affect driving-related performance [e.g., 21-23; but see 24], with performance in information processing tasks generally being more impaired than in the naturalistic conversation tasks. However, in the studies reviewed here, there was considerable variation in the type and complexity of conversation (see Table 1) which makes firm conclusions difficult to draw. For example, in some studies in this review [e.g., 12], information processing tasks were used and their complexity was manipulated to simulate the demands of conversation over the phone. In other studies [e.g., 15], more naturalistic conversation was used.

As mentioned above, the difference between the phone conversation and the passenger conversation was not found by Consiglio et al. [9]. They manipulated potentially interfering factors on driving performance (control, radio listening, conversation with passenger, conversation using HH phone, and conversation using HF phone). In the three conversation conditions, the participants answered straightforward scripted questions. They reported that performance of the detection task was not necessarily better in the passenger than in the phone conditions. In this study, the naturalness of the passenger condition was minimized; participants answered scripted questions while focusing on the red lamp in front of them. This unnatural conversation might be cognitively demanding and as such might offset the advantage of conversation with a passenger. In fact, when active interaction was involved between the passenger and the driver, there was an advantage for the passenger conversation over the phone conversation [25, 26]. When active interaction is involved, the driver and the passenger can develop the same situational awareness [25] making it less likely that the passenger will initiate a conversation that might distract the driver's attention.

2. Environment complexity

Environmental complexity was found to affect driving performance [e.g., 20, 27]; driving in a complex environment is more easily impaired than in a simple environment. Environmental complexity in the reviewed studies varies within and across the studies (see Table 1). In Burns et al. [8], the drivers slowed down when driving and talking on the phone at the same time only when the environment was challenging (i.e., the curves and 2-lane roads as opposed to 3-lane motorways). In such an environment, this tendency was greater with the HH phone than with the HF phone. In Törnros and Bolling [17], the drivers slowed down when excessive workload was imposed in an attentionally demanding environment, regardless of the phone type. Physical demands such as handling the steering wheel and braking, and attentional demands to surroundings may be greater in the complex environment than in the simple environment. Awareness of such physical and attentional demands could add more subjective workload. Holding a phone may become an additional physical load and thus an additional subjective workload in more complex environment [e.g., 28]. In addition, talking on a phone may become an additional attentional load in such an environment. Drivers may slow down to reduce the total subjective workload from talking on the phone while driving in such a complex environment.

3. HF phone with an earpiece/headset vs. HF phone with a speaker

Matthews, Legg, and Charlton [29] examined the effect of phone type (HH, HF with an external speaker, and HF with an earpiece) on drivers' subjective workload and intelligibility of words in a field study. They show that the subjects' intelligibility of words was poorer for the HF with an external speaker than for the HH or the HF phones with an earpiece. In addition, the subject's frustration (one of the components of workload) was greater for the HF phone with an external speaker than for the HH phone or the HF phone with an earpiece. Thus, the participants felt frustrated when they could not hear well. Participants performed a field-driving task in Matthews et al. [29]. Various interfering sounds while driving must be greater with the HF phone with an external speaker than the other phones. They did not measure the effects of the phone type on driving performance. However, it is possible that different conversational workloads affect driving performance, just like potentially increased workload due to complex environment could affect driving performance. Whether the HF phone with an earpiece/headset or with a speaker was used varied across studies (Table 1). In future studies, the effects of those phone type (HH phone, HF phone with an external speaker, and HF phone with an earpiece) on driving performance needs to be examined.

4. Relative risk associated with talking on the phone while driving

A clear pattern found in this review is that driving-related performance, especially detection/identification of events, is poorer when driving while talking on the phone (irrespective of the phone type) than when driving without conversing. It can be argued that worse than normal driving does not necessarily mean dangerous [8]. However, Burns et al. [8] and Strayer et al. [15] compared drunk and cell phone drivers and found that talking on the phone while driving is as dangerous as or more dangerous than driving drunk. For example, both Burns et al. [8] and Strayer et al. [15] show that the participants in the phone condition, regardless of the phone type, were slow to respond to signals. Regarding speed control, Strayer et al. [15] show that there was no difference in vehicle speed between the phone and the alcohol conditions and that there was no difference between the phone and the control conditions (but see footnote 8). However, Burns et al. [8] show that the participants in both the phone and the alcohol conditions failed to follow the instruction to drive closer to 96.6 km/h. Note that the participants tended to drive slower in the phone conditions while they tended to drive faster in the alcohol condition. The violation of the speed instruction (i.e., difference between the instructed speed and actual speed) was the greatest when the participants used HH phones. Driving drunk is illegal in many countries. Perhaps similar restrictions regarding use of the phone while driving should be considered.

5. Limitation and suggestion for future studies

There is a common misconception that talking on a HF phone is safer than talking on a HH phone, and may even be as safe as in a control or baseline condition. In our province of Nova Scotia, for example, a ban on cell phone use while driving came into effect on April 1, 2008, but this rule does not apply to HF phones. Thus, it is important for scientists to be able to convincingly inform policy-makers of the dangers of HF phone use while driving. A review of the pertinent literature, like this one, sought to uncover what was the "true" danger (relative to control) of using a HF phone and whether this danger differed from that of using a HH phone. Whereas we could report the outcome of the statistical comparisons made in all of the studies (Table 2), we had difficulty analyzing the studies quantitatively (Figure 1) because often data were not reported when there was no significant difference between the two phone types. We recommend researchers studying driving and cell phone use consistently report the data for this variable if they manipulate it.

CONCLUSION

The epidemiological and the experimental studies show similar patterns that talking on the phone while driving impairs driving performance for both HH and HF phones. Talking on a phone, regardless of the phone type, has negative impacts on detecting and identifying events. In the real world, such detection failures might mean failing to notice pedestrians crossing streets or missing traffic signals, resulting in critical accidents. Moreover, driving while talking on the phone may be more dangerous than or as dangerous as driving drunk. Thus, rather than the phone type, the important factor for driving safety is whether or not the driver is talking on the phone at all. Use of HF phones is as dangerous as use of HH phones while driving; possibly even more dangerous because of the underestimation of its danger.

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NOTES

The manuscript has not been previously published nor is it presently being considered for publication elsewhere.