Understanding the distracted brain

Why driving while using hands-free cell phones is risky behavior

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Summary

In January 2004, at 4:00 p.m., in Grand Rapids, Michigan, a 20-year-old woman ran a red light while talking on a cell phone. The driver's vehicle slammed into another vehicle crossing with the green light directly in front of her. The vehicle she hit was not the first car through the intersection, it was the third or fourth. The police investigation determined the driver never touched her brakes and was traveling 48 mph when she hit the other vehicle. The crash cost the life of a 12-year-old boy. Witnesses told investigators that the driver was not looking down, not dialing the phone, or texting. She was observed looking straight out the windshield talking on her cell phone as she sped past four cars and a school bus stopped in the other south bound lane of traffic. Researchers have called this crash a classic case of inattention blindness caused by the cognitive distraction of a cell phone conversation.

Vision is the most important sense for safe driving. Yet, drivers using hands-free phones (and those using handheld phones) have a tendency to "look at" but not "see" objects. Estimates indicate that drivers using cell phones look but fail to see up to 50 percent of the information in their driving environment.[1] Distracted drivers experience what researchers call inattention blindness, similar to that of tunnel vision. Drivers are looking out the windshield, but they do not process everything in the roadway environment that they must know to effectively monitor their surroundings, seek and identify potential hazards, and respond to unexpected situations.[2]

Today there are more than 280 million wireless subscribers in the U.S. And although public sentiment appears to be turning against cell phone use while driving, many admit they regularly talk or text while driving. The National Highway Traffic Safety Administration estimates that 11 percent of all drivers at any given time are using cell phones, and the National Safety Council estimates more than one in four motor vehicle crashes involve cell phone use at the time of the crash.

Cell phone driving has become a serious public health threat. A few states have passed legislation making it illegal to use a handheld cell phone while driving. These laws give the false impression that using a hands-free phone is safe.

The driver responsible for the above crash was on the phone with her church where she volunteered with children the age of the young boy who lost his life as the result of her phone call. She pled guilty to negligent homicide and the lives of two families were terribly and permanently altered. Countless numbers of similar crashes continue everyday.

This paper will take an in-depth look at why hands-free cell phone use while driving is dangerous. It is intended that this information will provide background and context for lawmakers and employers considering legislation and policies.

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The Distracted Driving Problem

Motor vehicle crashes are the No. 1 cause of death in the United States for 3- to 34-year-olds. Crashes are among the top three causes of death throughout a person's lifetime.[3] They also are the No. 1 cause of work-related death.[4] Annually, more U.S. soldiers are killed in crashes in privately-owned vehicles than all other Army ground accidents combined.[5]

Each year since 1994, between 39,000 and 46,000 people have been killed in motor vehicle crashes.[6] That's more than 650,000 lives lost during the past 15 years. It includes people inside and outside of vehicles, as well as motorcyclists, bicyclists and pedestrians who were struck by vehicles. There are activities people tend to think are riskier than driving, such as flying in an airplane, but consider this: The lives lost on U.S. roadways each year are equivalent to the lives that would be lost from a 100-passenger jet crashing every day of the year.

In addition to the thousands of fatalities, many more people suffer serious life-changing injuries in motor vehicle crashes. More than 2.2 million injuries resulted from vehicle crashes in 2008.[7]

To reduce this toll, prevention must focus on the top factors associated with crashes. Driver distractions have joined alcohol and speeding as leading factors in fatal and serious injury crashes. The National Safety Council estimates 25 percent of all crashes in 2008 involved talking on cell phones – accounting for 1.4 million crashes and 645,000 injuries that year.[8]

Cell phone use has grown dramatically over the past 15 years. In 1995, cell phone subscriptions covered only 13 percent of the U.S. population; by 2008, that had grown to 87 percent.[9]

The National Highway Traffic Safety Administration estimates that at any point during the day, 11 percent of drivers are talking on cell phones.[10] More than half of respondents to a AAA Foundation for Traffic Safety survey reported talking on cell phones while driving during the previous 30 days.[11] Seventeen percent admitted they engaged in this behavior "often or very often." Because text messaging has grown dramatically – an almost 10,000-fold increase in 10 years – and because there is already near-public consensus that it's a serious driving safety risk, texting receives a great deal of attention. About 14 percent of people admitted to texting while driving in the past 30 days.[12] Although texting is clearly a serious distraction, NSC data shows drivers talking on cell phones are involved in more crashes. More people are talking on cell phones while driving more often, and for greater lengths of time, than they are texting. Thus, in 2008, an estimated 200,000 crashes involved texting or e-mailing, versus 1.4 million crashes involving talking on cell phones.[13]

During 2009, cell phone distractions while driving hit our nation's political and media agendas. Webster's Dictionary named "distracted driving" its Word of the Year.[14] In 2009:

- More than 200 state bills were introduced to ban cell phone use – texting and talking – while driving.[15] Laws passed were front-page news.
- The U.S. Department of Transportation convened a Distracted Driving Summit, which the Secretary of Transportation called the most important meeting in the Department of Transportation's history.
- President Barack Obama issued an Executive Order banning federal employees from texting while driving.[16]
- A National Safety Council membership survey showed employers of all sizes, sectors and industries are implementing employee policies banning talking and texting while driving.[17]
- Public opinion polls show a majority of the public support these efforts.[18]

Distractions now join alcohol and speeding as leading factors in fatal and serious injury crashes.

But there's a troubling common thread to these prevention efforts:

- Nearly all legislation focuses on banning only handheld phones or only texting while driving.
- All state laws and many employer policies allow hands-free cell phone use.
- Public opinion polls show people recognize the risks of talking on handheld phones and texting more than they recognize the risks of hands-free phones.[19]
- Many drivers mistakenly believe talking on a hands-free cell phone is safer than handheld.[20]

A hands-free device most often is a headset that communicates via wire or wireless with a phone, or a factory-installed or aftermarket feature built into vehicles that often includes voice recognition. Many hands-free devices allow voice-activated dialing and operation.

Hands-free devices often are seen as a solution to the risks of driver distraction because they help eliminate two obvious risks – visual, looking away from the road and manual, removing your hands off of the steering wheel. However, a third type of distraction can occur when using cell phones while driving – cognitive, taking your mind off the road.

Hands-free devices do not eliminate cognitive distraction.

The amount of exposure to each risk is key. Crashes are a function of the severity of each risk and how often the risk occurs. Most people can recognize when they are visually or mechanically distracted and seek to disengage from these activities as quickly as possible. However, people typically do not realize when they are cognitively distracted, such as taking part in a phone conversation; therefore, the risk lasts much, much longer. This likely explains why researchers have not been able to find a safety benefit to hands-free phone conversations.

The National Safety Council has compiled more than 30 research studies and reports by scientists around the world that used a variety of research methods, to compare driver performance with handheld and hands-free phones. All of these studies show hands-free phones offer no safety benefit when driving (Appendix A). Conversation occurs on both handheld and hands-free phones. The cognitive distraction from paying attention to conversation – from listening and responding to a disembodied voice – contributes to numerous driving impairments. Specific driving risks are discussed in detail later in this paper. First, let us look at why hands-free and handheld cell phone conversations can impair your driving ability.

Hands-free devices offer no safety benefit when driving.

Hands-free devices do not eliminate cognitive distraction.

Multitasking: A Brain Drain

This section provides the foundation to understand the full impact of driving while engaging in cell phone conversations on both handheld and hands-free phones. It explains how cognitively complex it is to talk on the phone and drive a vehicle at the same time, and why this drains the brain's resources.

Multitasking is valued in today's culture, and our drive for increased productivity makes it tempting to use cell phones while behind the wheel. People often think they are effectively accomplishing two tasks at the same time. And yes, they may complete a phone conversation while they drive and arrive at their destination without incident, thus accomplishing two tasks during the same time frame. However, there are two truths to this common belief.

1. People actually did not "multitask."
2. People did not accomplish both tasks with optimal focus and effectiveness.

Multitasking is a myth. Human brains do not perform two tasks at the same time. Instead, the brain handles tasks sequentially, switching between one task and another. Brains can juggle tasks very rapidly, which leads us to erroneously believe we are doing two tasks at the same time. In reality, the brain is switching attention between tasks – performing only one task at a time.

In addition to "attention switching," the brain engages in a constant process to deal with the information it receives:

1. **Select** the information the brain will attend to
2. **Process** the information
3. **Encode,** a stage that creates memory
4. **Store** the information.

Depending on the type of information, different neural pathways and different areas of the brain are engaged. Therefore, the brain must communicate across its pathways.

Furthermore, the brain must go through two more cognitive functions before it can act on saved information. It must:

5. **Retrieve** stored information
6. **Execute** or act on the information.[21]

When the brain is overloaded, all of these steps are affected. But people may not realize this challenge within their brains (see sidebar).

Figure 1. Inattention blindness and encoding.
Source: National Safety Council

Why do drivers miss important driving cues?

Everything people see, hear, feel taste or think – all sensory information – must be committed to short-term memory before it can be acted on. Short-term memory can hold basic information for a few seconds. However, to get even very basic information into short-term memory, the brain goes through three stages to prioritize and process information. The first stage is called "encoding."

Encoding is the step in which the brain selects what to pay attention to. Encoding is negatively affected by distractions and divided attention. During this first stage, the brain will "screen out" information as a way to deal with distraction overload (Figure 1).

All human brains have limited capacity for attention. When there is too much information, the brain must decide what information is selected for encoding. Some decision processes are conscious and within a person's "control," while other decisions are unconscious so we're not aware of them. Therefore, people do not have control over what information the brain processes and what information it filters out.

For example, a person who is talking on a cell phone while driving has a brain that's dealing with divided attention. The brain is overloaded by all the information coming in. To handle this overload, the driver's brain will not encode and store all of the information.[22, 23]

Some information is prioritized for attention and possible action, while some is filtered out. The driver may not be consciously aware of which critical roadway information is being filtered out.

Performance is impaired when filtered information is not encoded into working short-term memory.[24]
The brain doesn't process critical information and alert the driver to potentially hazardous situations. This is why people miss critical warnings of navigation and safety hazards when engaged in cell phone conversations while driving.

The brain not only juggles tasks, it also juggles focus and attention. When people attempt to perform two cognitively complex tasks such as driving and talking on a phone, the brain shifts its focus (people develop "inattention blindness") (page 9). Important information falls out of view and is not processed by the brain. For example, drivers may not see a red light. Because this is a process people are not aware of, it's virtually impossible for people to realize they are mentally taking on too much.

When we look at a view before us – whether we are in an office, restaurant or hospital, at the beach, or driving in a vehicle – we believe we are aware of everything in our surroundings. However, this is not the case. Very little information actually receives full analysis by our brains. Research shows we are blind to many changes that happen in scenery around us, unless we pay close and conscious attention to specific details, giving them full analysis to get transferred into our working memory.[25]

Brain researchers have identified "reaction-time switching costs,"[26] which is a measurable time when the brain is switching its attention and focus from one task to another. Research studying the impact of talking on cell phones while driving has identified slowed reaction time to potential hazards are tangible, measurable and risky (page 10). Longer reaction time is an outcome of the brain switching focus. This impacts driving performance.

The cost of switching could be a few tenths of a second per switch. When the brain switches repeatedly between tasks, these costs add up.[27]

Even small amounts of time spent switching can lead to significant risks from delayed reaction and braking time. For example, if a vehicle is traveling 40 mph, it goes 120 feet before stopping. This equals eight car lengths (an average car length is 15 feet). A fraction-of-a-second delay would make the car travel several additional car lengths. When a driver needs to react immediately, there is no margin for error.

Brains may face a "bottleneck" in which different regions of the brain must pull from a shared and limited resource for seemingly unrelated tasks, constraining the mental resources available for the tasks.[28, 29] Research has identified that even when different cognitive tasks draw on two different regions of the brain, we still can have performance problems when trying to do dual tasks at the same time. This may help explain why talking on cell phones could affect what a driver sees: two usually unrelated activities become interrelated when a person is behind the wheel. These tasks compete for our brain's information processing resources. There are limits to our mental workload.[30]

The workload of information processing can bring risks when unexpected driving hazards arise.[31] Under most driving conditions, drivers are performing well-practiced, automatic driving tasks. For example, without thinking about it much, drivers slow down when they see yellow or red lights, and activate turn signals when intending to make a turn or lane change. These are automatic tasks for experienced drivers. Staying within a lane, noting the speed limit and navigation signs, and checking rear- and side-view mirrors also are automatic tasks for most experienced drivers. People can do these driving tasks safely with an average cognitive workload. During the vast majority of road trips, nothing bad happens, as it should be. But that also can lead people to feel a false sense of security or competency when driving. Drivers may believe they can safely multitask; however, a driver always must be prepared to respond to the unexpected.

A driver's response to sudden hazards, such as another driver's behavior, weather conditions, work zones, animals or objects in the roadway, often is the critical factor between a crash and a near-crash. When the brain is experiencing an increased workload, information processing slows and a driver is much less likely to respond to unexpected hazards in time to avoid a crash.

The industrial ergonomics field has been able to identify physical workload limits and, in the same way, the workload limits of our brains now are being identified. The challenge to the general public is the bottlenecks and limits of the brain are more difficult to feel and literally see than physical limits.

Multitasking Impairs Performance

We can safely walk while chewing gum in a city crowded with motor vehicles and other hazards. That is because one of those tasks – chewing gum – is not a cognitively demanding task.

When chewing gum and talking, people still are able to visually scan the environment for potential hazards:

- Light poles along the sidewalk
- Boxes suddenly pushed out a doorway at ground level before the delivery man emerges
- Moving vehicles hidden by parked vehicles
- Small dog on a leash
- Uneven sidewalk

People do not perform as well when trying to perform two attention-demanding tasks at the same time.[32] Research shows even pedestrians don't effectively monitor their environment for safety while talking on cell phones.[33-35] The challenge is managing two tasks demanding our cognitive attention.

Certainly most would agree that driving a vehicle involves a more complex set of tasks than walking.

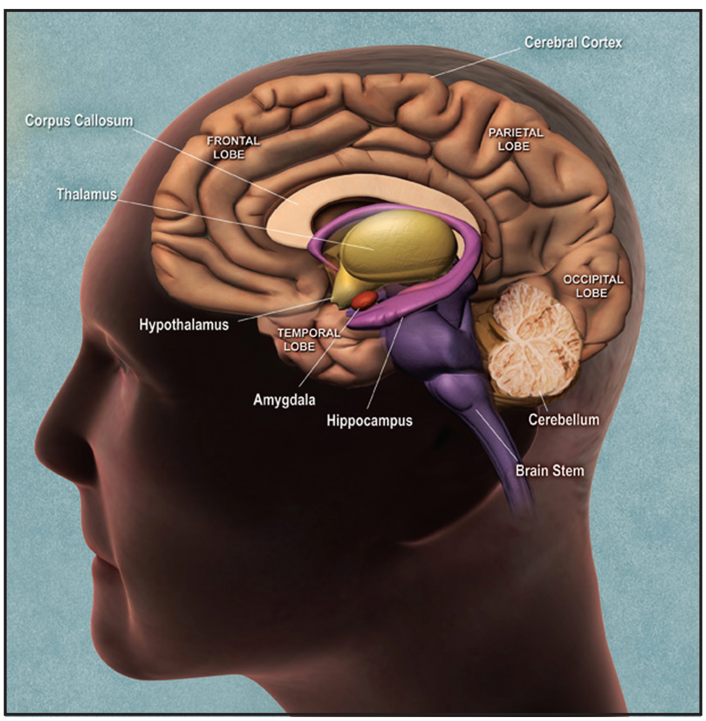


Figure 2. The four lobes of the brain.
Source: National Institutes of Health

What are primary and secondary tasks? What happens when people switch attention between them?

When people perform two tasks at the same time, one is a primary task and the other a secondary task. One task gets full focus (primary) and the other moves to a back burner (secondary). People can move back and forth between primary and secondary tasks.

Secondary, or back-burner status, doesn't mean people are ignoring the task. When a person stands before a stovetop full of pots, all pots and burners can be monitored at the same time. But one pot is getting primary attention, such as a front pot being stirred. While stirring the right front pot, the person sees the covered left back burner pot begin to boil and bubble over. Quickly, the person must remove the hot lid, remembering to grab a potholder first. The person also must keep his or her hand away from steam as the lid is lifted. It is difficult to continue evenly stirring the right front pot while switching attention and attending to the back burner pot. A person may or may not be aware that the stirring pattern has changed in the front pot, which was supposed to be the primary task getting full attention. Or a person may have even put the spoon down, knowing he or she can't do two potentially harmful tasks at one time and stay safe.

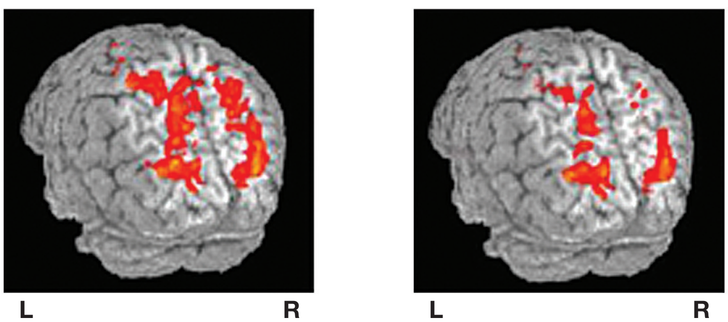
Certainly, driving a vehicle is a more cognitively complex activity than cooking. The human brain does the same switching between primary and secondary tasks when a person is driving a vehicle (primary task) while talking on a handheld or hands-free cell phone (secondary task).

Should driving a vehicle ever be a "back burner" task?

The brain is behind all tasks needed for driving: visual, auditory, manual and cognitive. Recent developments in functional magnetic resonance imaging (fMRI) now allow researchers to see the brain's reactions to specific challenges and tasks.

A Carnegie Mellon University study produced fMRI pictures of the brain while study participants drove on a simulator and listened to spoken sentences they were asked to judge as true or false.[36] The pictures below show that listening to sentences on cell phones decreased activity by 37 percent in the brain's parietal lobe (Figure 2), an area associated with driving. In other words, listening and language comprehension drew cognitive resources away from driving. This area of the brain is important for navigation and the type of spatial processing associated with driving. Because this study involved listening and thinking of an answer and not actual cell phone conversation, the researchers concluded the results may underestimate the distractive impact of cell phone conversation.

Driving alone



Driving with sentence listening

Figure 3. Functional magnetic resonance imaging images. Source: Carnegie Mellon University

The same study also found decreased activity in the area of the brain that processes visual information, the occipital lobe (Figure 2). While listening to sentences on cell phones, drivers had more problems, such as weaving out of their lane and hitting guardrails. This task did not require holding or dialing the phone, and yet driving performance deteriorated. The scientists concluded this study demonstrates there is only so much the brain can do at one time, no matter how different the two tasks are, even if the tasks draw on different areas and neural networks of the brain. The brain has a capacity limit. These fMRI images provide a biological basis of the risks faced by drivers.

How do cell phones differ from talking to passengers or listening to music while driving?

While this paper shows the distraction of cell phone conversation, many people understandably wonder how this risk compares to talking with passengers or listening to a radio.

Drivers talking on cell phones make more driving errors than drivers talking with passengers.

Drivers are more likely to drift out of lanes and miss exits than drivers talking with passengers. Why? Adult passengers often actively help drivers by monitoring and discussing traffic.[37] Passengers tend to suppress conversation when driving conditions are demanding.[38, 39] Although some studies found that passengers did not reduce conversation distraction, so research evidence is mixed.[40]

Talking on cell phones has a different social expectation because not responding on a cell phone can be considered rude. In addition, callers cannot see when a driving environment is challenging and cannot suppress conversation in response.[41, 42] Passengers can see the roadway and may moderate the conversation.[43, 44]

Listening to music does not result in lower response time, according to simulator studies. But when the same drivers talk on cell phones, they do have a slower response time. Researchers have concluded that voice communication influenced the allocation of visual attention, while low and moderate volume music did not.[45]

This discussion does not mean that listening to music or talking with passengers is never distracting. Loud music can prevent drivers from hearing emergency sirens, and cognitive processing can lead to a decrement in vehicle control.[46] Some conversations with passengers can be distracting to drivers.[47] Any task that distracts a driver should be avoided.

Driving Risks of Hands-Free and Handheld Cell Phones

We now understand how our brains have difficulty juggling multiple cognitive tasks that demand our attention. Next we will discuss specific risks that cell phone conversations bring to driving, with an overview of crash risks and driver errors most often associated with both hands-free and handheld cell phones.

Inattention Blindness – Vision is the most important sense we use for safe driving. It's the source of the majority of information when driving. Yet, drivers using hands-free and handheld cell phones have a tendency to "look at" but not "see" objects. Estimates indicate drivers using cell phones look at but fail to see up to 50 percent of the information in their driving environment.[48] Cognitive distraction contributes to a withdrawal of attention from the visual scene, where all the information the driver sees is not processed.[49] This may be due to the earlier discussion of how our brains compensate for receiving too much information by not sending some visual information to the working memory. When this happens, drivers are not aware of the filtered information and cannot act on it.

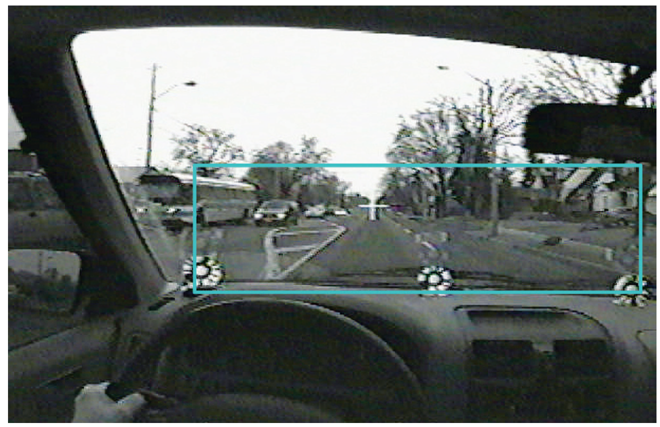


Figure 4.
Where drivers not using a hands-free cell phone looked.
Source: Transport Canada

Distracted drivers experience inattention blindness. They are looking out the windshield, but do not process everything in the roadway environment necessary to effectively monitor their surroundings, seek and identify potential hazards, and to respond to unexpected situations. Their field of view narrows.[50] To demonstrate this, Figure 4 is a typical representation of where a driver would look while not using a phone. Figure 5 shows where drivers looked while talking on hands-free cell phones.[51]

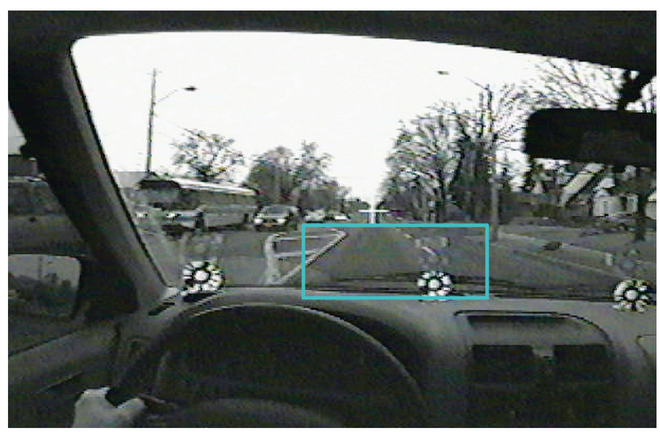


Figure 5.
Where drivers using a hands-free cell phone looked.
Source: Transport Canada

Drivers talking on hands-free cell phones are more likely to not see both high and low relevant objects, showing a lack of ability to allocate attention to the most important information.[52] They miss visual cues critical to safety and navigation. They tend to miss exits, go through red lights and stop signs, and miss important navigational signage.[53] Drivers on cell phones are less likely to remember the content of objects they looked at, such as billboards. Drivers not using cell phones were more likely to remember content.[54]

The danger of inattention blindness is that when a driver fails to notice events in the driving environment, either at all or too late, it's impossible to execute a safe response such as a steering maneuver or braking to avoid a crash.[55]

To explore how cell phone use can affect driver visual scanning, Transport Canada's Ergonomics Division tracked the eye movements of drivers using hands-free phones, and again when these drivers were not on the phone. The blue boxes in Figures 4 and 5 show where drivers looked.[56] In addition to looking less at the periphery, drivers using hands-free phones reduced their visual monitoring of instruments and mirrors, and some drivers entirely abandoned those tasks. At intersections, these drivers made fewer glances to traffic lights and to traffic on the right. Some drivers did not even look at traffic signals.[57]

Slower Response Time and Reaction Time – Response time includes both reaction time and movement time. Reaction time involves attentional resources and information processing, while movement time is a function of muscle activation. Cell phone use has been documented to affect reaction time.[58]

Due to the "attention switching" costs discussed earlier, it makes sense that driver reactions may be slower when using cell phones. For every information input, the brain must make many decisions: whether to act on information processed, how to act, execute the action and stop the action. While this process may take only a fraction of a second, all of these steps do take time. When driving, fractions of seconds can be the time between a crash or no crash, injury or no injury, life or death.

Numerous studies show delayed response and reaction times when drivers are talking on hands-free and handheld cell phones (Appendix A). Reaction time has shown impairment in a variety of scenarios:

- A University of Utah driving simulator study found drivers using cell phones had slower reaction times than drivers impaired by alcohol at a .08 blood alcohol concentration, the legal intoxication limit.[59] Braking time also was delayed for drivers talking on hands-free and handheld phones.

- Drivers talking on hands-free phones in simulated work zones took longer to reduce their speed when following a slowing vehicle before them and were more likely to brake hard than drivers not on the phone. Many braking scenarios included clues that traffic was going to stop. Side-swipe crashes also were more common. Work zones are challenging environments for all drivers, and rear-end collisions are a leading type of work zone crash, putting workers and vehicle occupants at risk. Driver distraction is a significant contributing factor to work zone crashes.[60]

- Hands-free phone use led to an increase in reaction time to braking vehicles in front of drivers, and reaction time increased more and crashes were more likely as the traffic density increased.[61]

- Testing of rear-end collision warning systems showed significantly longer reaction time during complex hands-free phone conversations.[62]

Drivers in reaction time studies tended to show compensation behaviors by increasing following distance. However, drivers in three studies who attempted to compensate for their reduced attention this way found increased headway often was not adequate to avoid crashing.[63]

Problems Staying in Lane – "Lane keeping" or "tracking" is the driver's ability to maintain the vehicle within a lane. While most cell phone driver performance problems involve significant reaction time impairment, there are minor, less significant costs with lane keeping. It is suggested that lane keeping may depend on different visual resources than responding to hazards by reacting. In addition, avoiding hazards requires drivers to watch for unexpected events, choose an appropriate response and act. This requires information processing and decision-making that is more cognitively demanding than lane keeping tasks, which is more automatic.[64]

Still, when we are driving at roadway and freeway speeds with vehicles spaced less than a few feet from each other in parallel lanes, the margin of error for decision-making and response time to avoid a crash is very small. Perhaps drivers who create a hazard by straying from their lanes must depend on other drivers around them to drive defensively and respond appropriately, and it may be those reacting drivers whose cell phone use should be of concern.

Cell Phone Conversation Brings 4 Times Crash Risk – Beyond the driver performance problems described above in controlled simulator and track studies, increased injury and property damage crashes have been documented. Studies conducted in the United States, Australia and Canada found the same result:

Driving while talking on cell phones – handheld and hands-free – increases risk of injury and property damage crashes fourfold.[65, 66] Research evidence is compelling when studies of varying research designs are conducted in different cultures and driving environments and have similar results.

Recent naturalistic studies[67, 68] have reported a risk of crashing while talking on a cell phone to be significantly less than the fourfold risk found in the above epidemiological studies. This new methodology, although offering great promise in the endeavor to understand what really goes on in a vehicle prior to a crash, has significant limitations, including:

- Very small number of observed crashes.
- The use of "near-crash" data to calculate crash risk.
- Inability to collect all near-crash occurrences.
- Inability to observe or measure cognitive distraction.
- Inability to observe hands-free phone use.

All methodologies have strengths and significant limitations. There is no "gold standard" of research methodology. Each research method provides valuable knowledge. In this case, experimental studies have been used to measure the risks of cognitive distraction, because other methods, particularly naturalistic research methods, cannot effectively measure it. In making decisions about laws, vehicle and roadway improvements, and driver behavior, the entire body of research should always be considered. When doing so, it is clear that the risk of crashing when engaged in a hands-free phone conversation is about 4 times greater than when not using a phone while driving.

Are Drivers Able to Reduce Their Own Risk?

There is evidence that people are aware of distracted driving risks to drivers, in general. In a AAA Foundation for Traffic Safety survey, 83 percent of respondents said drivers using cell phones is a "serious" or "extremely serious" problem. It was rated a serious or extremely serious problem more often than aggressive drivers, excessive speeding and running red lights. Only alcohol-impaired driving was rated as a serious problem by more people.[69] But do these people recognize their own risks of using cell phones while driving? Despite their stated belief in the dangers, more than half of the same survey respondents reported talking on cell phones while driving during the previous 30 days. Seventeen percent admitted this behavior "often" or "very often."

Furthermore, due to how our brains filter information, as discussed earlier, we are never aware of the information that was filtered out. This may add to the lack of awareness of our limitations. Some researchers have studied whether distracted drivers are aware of their decrease in safe driving performance. Findings show distracted drivers may not be aware of the effects of cognitive distraction[70] and using cell phones while they are driving.[71-74] Also, drivers perceived they were safer drivers when using hands-free phones, but actually showed decreased performance while using hands-free phones.[75] One study found drivers who thought the task was easy tended to perform the worst.[76]

It is well-known from many traffic safety issues with a long history of injury prevention strategies – impaired driving, teen driving, speeding, safety belts and child safety seats – that even when people are aware of the risks, they may not easily change behaviors to reduce the risk.

Drivers believe their own crash risk is lower than other drivers.

What are Possible Prevention Steps?

Eliminating driver distraction due to cell phone use faces significant challenges, even beyond combating drivers' desire to be connected and productive. Drivers can help avoid this by informing frequent callers that they will not participate in phone conversations while driving. When facing multiple demands for their cognitive attention, drivers may not be aware they are missing critical visual information, and they may not be aware of the full impact of that oversight. This lack of awareness of the distraction could prolong it. Widespread education is needed about the risks of hands-free devices, conversation and cognitive distraction.

There is a shared responsibility among all involved in cell phone conversations to avoid calling and talking while driving – including drivers, callers and the people that drivers may call. Vehicle manufacturers are including more wireless and voice recognition communications technologies in vehicles, but their impact on distraction has yet to be fully studied. Consumers should consider their exposure to cognitive distraction and increased crash risk while using these in-vehicle technologies.

But even when people are aware of the risks, they tend to believe they are more skilled than other drivers, and many still engage in driving behaviors they know are potentially dangerous. Prevention strategies should consider how people behave in reality, not only how they should behave. We know from other traffic safety issues – impaired driving, safety belts, speeding – that consistent enforcement of laws is the single most important effective strategy in changing behavior. Therefore, prevention strategies that may show the most promise are legislative and corporate policies, coupled with high-visibility enforcement and strict consequences. Technology solutions can go even further by preventing calls and messages from being sent or received by drivers in moving vehicles. To provide safety benefits and provide a positive influence on reducing crashes, injuries and deaths, these efforts – including education, policies, laws and technology – must address the prevention of both handheld and hands-free cell phone use by drivers.

Appendix A
Studies Comparing Hands-Free and Handheld Cell Phones

Authors	Title	Publication/ Organization, Issue, Year	No. of Study Participants	Setting	Phone Task	Road Complexity	Phone Type	Measured Outcomes	Key Findings	Publication Type
Abdel-Aty, M.	Investigating the relationship between cellular phone use and traffic safety	ITE Journal 73 (10) 2003	20	Simulator	Conversation	Low/high	HH, HF	Lane deviation, leaving road, crossing median, disobeying speed limit, crashing, failing to stop, wrong way, and hitting pedestrian	Results show no significant difference between using a hands-free or a handheld cell phone, although both were related to significantly higher error rates than baseline. Lane deviation and crossing the median were significantly more likely to occur than other errors. Crashing and failing to stop were significantly less likely to occur than other errors. Also, distraction-related errors did not end with termination of the phone call. Drivers with higher citation rates and lower levels of experience tended to make more errors while driving and using a phone.	Original research
Alm, H. Nilsson, L.	Changes in driver behaviour as a function of hands-free cell phones – a simulator study	Accident Analysis and Prevention 26 1994	40	Simulator	Information processing	Low/High	HF	Reaction time, lane position, speed level, and workload	Findings show a mobile telephone task negatively affected reaction time and led to reduction of speed level. When drivers had to perform a difficult driving task, findings showed a mobile telephone task had an effect only on the driver's lateral position. The mobile telephone task led to increased workload for both the easy and the difficult driving task.	Original research
Alm, H. Nilsson, L.	The effects of a mobile telephone task on driver behaviour in a car following situation	Accident Analysis and Prevention 27 1995	40	Simulator	Information processing	N/A	HF	Choice reaction time, headway, lateral position, and workload	A mobile telephone task had a negative effect on drivers' choice reaction time, and the effect was more pronounced for elderly drivers. Subjects did not compensate for increased reaction time by increasing their headway during the phone task. The subjects' mental workload, as measured by the NASA-TLX, increased as a function of the mobile telephone task. No effect on the subjects' lateral position could be detected.	Original research
Beede, K.E. Kass, S.J.	Engrossed in conversation: The impact of cell phones on simulated driving performance	Accident Analysis and Prevention 2, 415-421 2006	36	Lab	Cognitive	N/A	HF	Traffic violations (e.g., speeding, running stop signs), driving maintenance (e.g., standard deviation of lane position), attention lapses (e.g., stops at green lights, failure to visually scan for intersection traffic), and response time	Performance was significantly impacted in all four categories when drivers were concurrently talking on a hands-free phone. Performance on the signal detection task was poor and not significantly impacted by the phone task, suggesting that considerably less attention was paid to detecting these peripheral signals. However, the signal detection task did interact with the phone task on measures of average speed, speed variability, attention lapses, and reaction time.	Original research
Brace, C.L. Young, K.L. Regan, M.A.	Analysis of the literature: The use of mobile phones while driving	Monash University Report No. 2007: 35 2007	N/A	N/A	N/A	N/A	N/A	Visual search pattern, reaction time, speed, lateral position, and throttle control	Using a cell phone can distract drivers visually, physically, and cognitively. Distraction caused by talking on a cell phone, regardless of handheld or hands-free application, impairs drivers' ability to maintain appropriate speed, throttle control, and lateral position of the vehicle. It also can impair drivers' visual search patterns, reaction time, and decision-making process.	Literature review

Authors	Title	Publication/ Organization, Issue, Year	No. of Study Participants	Setting	Phone Task	Road Complexity	Phone Type	Measured Outcomes	Key Findings	Publication Type
Brookhuis, K.A. De Vries, G. De Waard, D.	The effects of mobile telephoning on driving performance	Accident Analysis and Prevention 23 1991	12	Field	Information processing	Light/heavy/ city	HH, HF	Lateral position speed, following distance, reaction time, number of mirror glances, and heart rate	Results showed no difference in workload between handheld and hands-free. Both types had a significant decrease in changes in lateral positioning while on the phone. Subjects checked the rearview mirror significantly less often while phoning. Reaction time to brake increased (although not significantly) on the phone. Reaction time to speed variations and heart rate increased significantly. When subjects manually dialed numbers, a substantial effect on steering wheel amplitude was apparent. Distraction is not inhibiting at the operational level, but at the tactical level.	Original research
Caird, J.K. Willness C.R. Steel, P. Scialfa, C.	A meta-analysis of the effects of cell phones on driver performance	Accident Analysis and Prevention 40, 1282-1293 2008	~2,000	N/A	N/A	N/A	N/A	Reaction time, vehicle control, and speed	A comprehensive meta-analytical study of effects of cell phone use on driving performance based on 33 independent inquiries. Handheld and hands-free phones produced similar reaction time decrements. A mean increase in reaction time of .25 seconds was found for all types of phone-related tasks. Drivers using either phone type do not appreciably compensate by giving greater headway or reducing speed.	Meta-analysis
Charlton, S.G.	Distractive effects of cell phone use	Land Transport NZ Report No. 349 2008	119	Simulator	Naturalistic	Low/high	HF	Reaction to hazards	Driving performance suffered during cell phone use when compared to in-car passenger conversations and no-conversation controls in terms of speed, reaction times, and avoidance of road and traffic hazards.	Original research
Cooper, P.J. Zheng, Y. Richard, C. Vavrik, J. Heinrichs, B. Sigmund, G.	The impact of hands-free message reception/ response on driving task performance	Accident Analysis and Prevention 35 2003	41	Field	Information processing	Low/High	HF	Reaction time	The results clearly showed a negative impact of the message task on driver decision-making performance when this involved the more complex tasks of weaving, especially left-turning. These decision-making decrements were exacerbated by adverse pavement surface conditions. Overall effect of the messages on the traffic signal task (long trigger) was to produce a more conservative response among subject drivers. When the driving task moved away from the familiar and towards the more demanding, the effect of the cell message intervention on driver performance changed. In the more critical short-trigger weave situation (short spaces between targets), drivers decelerated less when the messages were playing than they did under the no-message condition. Thus, made significantly less speed adjustment and drove substantially faster through the weave maneuver than they did when not exposed to the messages. The time to collision was shorter (less safe) when subjects were listening/responding to messages. Subjects did not adjust their safety margin to account for the wet road when they were listening and responding to messages as they did when not so engaged.	Original research
Horrey, W.J. Wickens, C.D.	Examining the impact of cell phone conversations on driving using meta-analytic techniques	Human Factors 48(1), 196-205 2006	N/A	N/A	N/A	N/A	N/A	Reaction time and lane keeping	A meta-analytical study based on 23 independent inquiries. Hands-free and handheld phones revealed similar patterns of results for both measures of performance. Conversation tasks tended to show greater costs than information-processing tasks.	Meta-analysis

Authors	Title	Publication/ Organization, Issue, Year	No. of Study Participants	Setting	Phone Task	Road Complexity	Phone Type	Measured Outcomes	Key Findings	Publication Type
Iqbal, S.T. Ju, Y.C. Horvitz, E.	Cars, calls, and cognition: Investigating driving and divided attention	CHI 2010 Paper	18	Simulator	Conversation and information processing	Low/High	HF	Collisions, following instructions, sudden braking, and speed	The collision rate in the driving-while-talking condition was significantly higher than in the no-phone driving condition (baseline). High-complexity road conditions were associated with higher collision rates. Talking on a phone increased the number of missed turns and the frequency of sudden braking. Talking on a phone also led to a decrease in speed. Information retrieval (e.g., answering questions) had the most negative influence on driving performance.	Original research
Ishigami, Y. Klein, R.M.	Is a hands-free phone safer than a handheld phone?	Journal of Safety Research 40, 157–164 2009	N/A	N/A	N/A	N/A	N/A	Speed, lane maintenance, and reaction time	Talking on the phone, regardless of phone type, negatively impacts driving performance, especially in detecting and identifying events. Performance while using a hands-free phone was rarely found to be better than when using a handheld phone. Drivers may compensate for the deleterious effects of cell phone use when using a handheld phone but neglect to do so when using a hands-free phone.	Literature review
Lamble, D. Kauranen, Laakso, Summala	Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while driving	Accident Analysis and Prevention 31 1999	19	Field	Information processing	Low	Simulated	Reaction time	The results indicated drivers' detection ability in a closing headway situation was impaired by about 0.5 seconds for brake reaction time and almost 1 second for time-to-collision when they were doing a non-visual cognitive task while driving. This impairment was similar to when the same drivers were dividing their visual attention between the road ahead and dialing series of random numbers on a keypad.	Original research
Lui, B.-S. Lee, Y.-H.	Effects of car-phone use and aggressive disposition during critical driving maneuvers	Transportation Research Part F: Traffic Psychology and Behaviour 8, 369-382 2005	12	On-road	Cognitive	Varied	HF	Task performance (response time, correct rate), driving performance, physiological responses, and compensatory behavior	Analysis of task performance revealed a mean correct rate of 90% for addition tests in the laboratory; however, this decreased to 87.5% in city traffic and 75.8% at intersections. The mean (SD) response time for these additional tests was 3.8 (1.9) seconds in the laboratory, 4.5 (1.9) seconds in city traffic, and 5.6 (2.4) seconds at the intersections. These results confirm the notion that the combination of decision making and car-phone communication at signalized intersections increases crash risk. This study examined compensatory behavior as drivers attempt to reduce workload. Driving speed while passing through green lights and simultaneously performing additional tests was 6.4% lower (45.1 km/h) than in normal driving. This indicates drivers adjust their speeds to keep subjective perception of risk levels constant. When they respond to a red light, distraction causes drivers to react later; to compensate, drivers brake harder.	Original research
Lui, B.-S. Lee, Y.-H.	In-vehicle workload assessment: effects of traffic situations and cellular telephone use	Journal of Safety Research 37 (1), 99-105 2006	12	On-road	Cognitive	Varied	HF	Lateral position, speed, task and driving performance, physiological responses, and compensatory behavior	Analysis of task performance revealed mean response time was markedly increased (11.9%) for driving on urban roads compared with motorways. Mean driving speed only decreased 5.8% during phone tasks in comparison to driving without distractions. Overall physiological workload increased through compensatory behavior in response to phone tasks.	Original research

Authors	Title	Publication/ Organization, Issue, Year	No. of Study Participants	Setting	Phone Task	Road Complexity	Phone Type	Measured Outcomes	Key Findings	Publication Type
Matthews, R. Legg, Charlton	The effect of cell phone type on drivers subjective workload during concurrent driving and conversing	Accident Analysis and Prevention 35 2003	13	Field	Conversation	Low	HH, HF	Workload	All phone types resulted in significantly higher ratings of workload than control, including mental demand, physical demand, temporal demand, performance, effort, and frustration. Intelligibility was lower than the handheld phone for the hands-free speaker, but not the hands-free headset. Significant differences were found in physical demands between the handheld and hands-free phones, and frustration between handheld and hands-free speaker versus hands-free headset phones. No significant differences between the phone types were found for mental demand, temporal demand, performance or effort.	Original research
McEvoy, S.P. Stevenson, M. R. McCartt, A. T. Woodward M. Haworth, C. Palamara, P.	Role of mobile phones in motor vehicle crashes resulting in hospital attendance: A case-crossover study	British Medical Journal 331(7514) 2005	456	N/A	N/A	N/A	N/A	Crashes	Mobile phone use during and up to 10 minutes before the estimated time of crash was associated with a fourfold increase in the likelihood of crashing. Similar results were obtained when we analyzed only the interval up to 5 minutes before a crash. Analyses with paired matching to compare the hazard interval to an equivalent single control interval also showed significant associations between mobile phone use and the likelihood of a crash. Sex, age group, or type of mobile phone did not affect the association between phone use and risk of crash. Both handheld and hands-free phone use while driving was associated with a fourfold increased risk.	Original research
Nilsson, L. Alm, H.	Effects of mobile telephone use on elderly drivers' behavior – including comparisons to younger drivers' behavior	VTI, DRIVE Project V1017 (BERTIE) Report No. 53 1991	20	Simulator	Information processing	Low	HF	Reaction time, speed, lateral position, and mental workload	Cell phone conversation had a negative impact on reaction times for both older and younger drivers. Cell phone use was associated with a reduction in speed and increased variation in lateral position.	Original research
Parkes, A.M. Hooijmeijer, V.	Driver situation awareness and carphone use	Proceedings of the 1st Human-Centered Transportation Simulation Conference (U of Iowa) 2001	15	Simulator	Information processing	Low	HF	Tracking and reaction time	Drivers who talked on a hands-free cell phone showed slower reaction time, particularly at the beginning of the conversation, and reduced awareness of surroundings compared with drivers who were not using a cell phone.	Original research
Patten, CJD. Kircher, A. Östlund, J. Nilsson, L.	Using mobile telephones: Cognitive workload and attention resource allocation	Accident Analysis and Prevention 36(3) 2004	40	Field	Information processing	Low	HH, HF	Reaction time	Participants' reaction times to LED increased significantly when conversing, but there was no significant difference between hands-free and handheld units. Increasing the complexity of conversation significantly increased reaction time for both phone types. Accuracy of peripheral detection was significantly lower for both phone types versus baseline. Handheld usage led to lower means speeds while hands-free usage was associated with increases in mean speed.	Original research
Rakauskas, M. Gugerty, L. Ward, N.J.	Effects of cell phone conversations on driving performance with naturalistic conversation	Journal of Safety Research 35, 453-464 2004	24	Simulator	Conversation	Low/high	HF	Workload demand, tracking, and reaction time	Hands-free cell phone use caused participants to have higher variation in accelerator pedal position, drive more slowly with more variation in speed, and report a higher level of workload regardless of conversation difficulty level.	Original research

Authors	Title	Publication/ Organization, Issue, Year	No. of Study Participants	Setting	Phone Task	Road Complexity	Phone Type	Measured Outcomes	Key Findings	Publication Type
Ranney, T. Watson, G. Mazzae, E.N. Papelis, Y.E. Ahmad, O. Wightman, J.R.	Examination of the distraction effects of wireless phone interfaces using the National Advanced Driving Simulator-Preliminary report on freeway pilot study	NHTSA Pre. No. DOT 809 737 2004	12	Simulator	Cognitive	Low/high	HF, HH	Reaction time, lateral position, headway, speed, and time to collision	There were no statistically significant differences between drivers using hands-free and handheld on the driving performance outcome measures. Handheld phone use was associated with fastest dialing times and fewest dialing errors.	Original research
Redelmeier, D.A. Tibshirani, R.J.	Association between cellular-telephone calls and motor vehicle collisions	New England Journal of Medicine 336(7) 1997	699	N/A	N/A	N/A	N/A	Crashes	Cell phone use is associated with an increased risk of property-damage-only collision compared with no cell phone use.	Original research
Rosenbloom, T.	Driving performance while using cell phones: An observational study	Journal of Safety Research 37, 207-212 2006	24	Field	Conversation	Varied	HF	Speed, gap, and self-reported disturbance	There were no statistically significant correlations between drivers' self-reported driving disturbance and actual disturbances in speed and gap keeping, thus they were not aware of their performance decrements. Speed was not significantly different when drivers were on the phone versus not on the phone. However, safe gap keeping diminished significantly when drivers were on the phone.	Original research
Strayer, D.L. Drews, F.A.	Effects of cell phone conversations on younger and older drivers	Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting pp. 1860-1864 2003	40	Simulator	Conversation	Low	HF	Brake onset time, following distance, speed, and recovery time	Cell phone use in simulated driving slowed braking reaction time by 18 percent, increased following distance by 12 percent, had no impact on speed, and increased speed recovery time by 17 percent compared with driving only.	Original research
Strayer, D.L. Drews, F.A. Johnston, W.A.	Cell phone-induced failures of visual attention during simulated driving	Journal of Experimental Psychology: Applied 9, 23-32 2003	Varied (20-40)	Simulator	Information processing	Low/high	HF	Reaction time	Use of a hands-free cell phone degrades driving performance compared with control conditions. Cell phone conversations increased braking reaction time and impaired both explicit recognition and implicit perceptual memory.	Original research
Strayer, D.L. Drews, F.A.	Profiles in driver distraction: Effects of cell phone conversations on younger and older drivers	Human Factors 46 (4), 640-649 2004	40	Simulator	Naturalistic conversation	Moderate	HF	Reaction time, headway, and speed	Drivers distracted by competing activities (i.e., cell phone conversation) demonstrated poor ability to control their speed and following distance. Cell phone use was associated with a twofold increase in the number of rear-end collisions.	Original research
Strayer, D.L. Drews, F.A. Crouch, D.J.	A comparison of the cell phone driver and the drunk driver	Human Factors 48(2) 2006	40	Simulator	Conversation	Low/high	HFH	Braking response, driving speed, and following distance	Handheld and hands-free cell phone cause similar levels of impairment in driving performance. When drivers were talking on either a handheld or hands-free phone, their braking reactions were delayed and they were involved in more crashes than when they were not talking on a cell phone.	Original research

Authors	Title	Publication/ Organization, Issue, Year	No. of Study Participants	Setting	Phone Task	Road Complexity	Phone Type	Measured Outcomes	Key Findings	Publication Type
Strayer, D.L. Johnston, W.A.	Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone	Psychological Science 12(6) 2001	48	Non-driving	Conversation	N/A	HH, HF	Reaction time and missed signals	Handheld and hands-free both showed significant increases in reaction time, but there were no differences found between decrements for handheld versus hands-free. Probability of missing the simulated traffic signal doubled when subjects were on the phone. Response time slowed significantly for both, but was slower when study subjects were talking than when they were listening. Gender and age did not contribute to differences.	Original research
Törnros, J.E.B. Bolling, A.K.	Mobile phone use – Effects of handheld and handsfree phones on driving performance	Accident Analysis and Prevention 37(5) 2005	48	Simulator	Information processing	Low/high	HF	Peripheral detection, lateral position, and speed	Use of handheld and hands-free phone increased mental workload (peripheral detection), lateral position deviation due to dialing, and decreased lateral position deviation due to talking. Talking on a handheld phone reduced speed (compensatory effect).	Original research
Treffner, P.J. Barrett, R.	Hands-free mobile phone speech while driving degrades coordination and control	Transportation Research Part F7, 229–246 2004	9	On-road	Information processing	Low	HF	Cornering, controlled braking, and obstacle avoidance	While talking on a cell phone, drivers demonstrated brake initiation that was temporally closer to the corner than when not using the phone. During the conversations, drivers had to employ a higher degree of late deceleration, resulting in a harsher style of braking. Under conversation, there was a later onset of mediolateral g-forces, which suggests a delayed or slower anticipatory response under critical conditions such as obstacle avoidance.	Original research
Uno, H Hiramatsu, K.	Effects of auditory distractions on driving behavior during lane change course negotiation: Estimation of spare mental capacity as an index of distraction.	JSAE Review 21, 219-224 2000	16	On-road	Cognitive	Low/high	HF	Speed	Speed control deteriorated when the driver's mental capacity decreased below a certain level (6-7 bits/second) due to an auditory arithmetic task that was communicated via headphones.	Original research
Young, K. Regan, M	Driver distraction: A review of the literature	Australasian College of Road Safety, 379-405 2007	N/A	N/A	N/A	N/A	N/A	Degradations in driving performance	Results showed that although the physical distraction associated with handling the phone can present a significant safety hazard, the cognitive distraction associated with being engaged in a conversation also can have a considerable effect on driving. Indeed, studies have found that conversing on a hands-free phone while driving is no safer than using a handheld phone.	Literature review

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