

Distracted Road Use: A Literature Review

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Executive Summary

This report provides a comprehensive review of distracted road use by drivers, pedestrians, cyclists, and motorcycle riders. The report begins with a discussion on what distraction is, followed by a review of current research on distracted road use to better understand its impact on road safety. Sources of distraction, statistics, estimated crash risk, effects on traffic performance, and road users most at risk will be examined. The next section reviews existing data sources and methods of measurement associated with distracted road use, including experimental methods, naturalistic driving studies, observational studies, survey research, and collision data. Opportunities to improve and collect new data will also be identified. This is followed by a review of current legislation related to distracted road use in Canada, the United States, and other comparable locales. The report concludes with a review of leading and best practices to reduce collisions, injuries, and fatalities where distraction is a factor.

Leading research reveals that distracted road use is a significant road safety concern. Driver distraction is estimated to be a contributing factor in 20-30% of all motor vehicle collisions. Distracted road use occurs when a road user is engaged in a competing activity that diverts attention away from the primary traffic task (driving, cycling, walking, or riding). Common sources of distraction include talking on cell phones, texting, manipulating portable electronic devices, conversing with passengers, and looking at external roadside objects. Experimental studies provide converging evidence that engaging in secondary tasks while driving is detrimental to driving performance. All forms of distraction, including visual, auditory, physical, and cognitive can contribute to a phenomenon known as “inattention blindness,” in which drivers fail to process critical information in the forward roadway. This can lead to poor time and distance estimation, slowed reaction times, and reduced ability to maintain appropriate speed and lane position. The effects of talking on hand-held cell phones are revealed to be similar to that of hands-free phones, suggesting that the cause of distraction is cognitive, rather than from physically holding the phone. Cognitive distraction is further found to induce “tunnel vision,” in which a driver’s ability to detect and respond to hazards in the periphery is reduced.

Naturalistic driving studies show that drivers have a higher crash risk when performing visual-manual secondary tasks that take the driver’s eyes off the road for more than two seconds, such as dialing a hand-held cell phone or using a personal digital assistant (PDA). Observational studies indicate that at any given moment, approximately 30% of drivers are engaged in a secondary task while driving. Cell phone use varies from 2% to 6%. Findings from surveys reveal a gap between attitudes towards distracted driving and driver behaviour. For example, in a 2014 telephone survey conducted in Edmonton and surrounding area, a large majority of drivers stated that it was unacceptable to engage in distracted driving, however many drivers were willing to engage in such behaviour.

Young drivers in the age group of 16-30 years are revealed to be most at risk for a distraction-related collision. Possible reasons for this include a high inclination to use electronic devices and lack of driving experience. Research also indicates that young drivers are particularly susceptible to the influence of peer passengers in the vehicle. In light of these findings, preventive measures to reduce distraction, such as education programs and awareness campaigns, should be aimed at new and young drivers.

Research on the nature and extent of distracted walking, cycling, and riding is currently sparse, indicating a need for further research in these areas. Nevertheless, based on the few studies available, the mechanisms and sources of distraction among other road users appear to be similar to that of distracted drivers. A review of the most recent literature suggests that 20-30% of pedestrians, cyclists, or riders are involved in a distracting activity during road use. Experimental and observational studies show that talking on cell phones, texting, and wearing headphones while walking or cycling can adversely impact road safety, particularly at intersections and crosswalks. Distracted pedestrians and cyclists are more likely to cross too slowly or not look both ways before crossing than those who are not distracted.

To combat distracted driving, legislation against the use of cell phones and other electronic devices while driving has been introduced worldwide. Currently, 139 countries restrict the use of hand-held cell phones while driving, and an additional 31 countries restrict both hand-held and hands-free phones. Under the Alberta distracted driving legislation, all drivers, bicyclists, and motorcyclists are prohibited from using hand-held cell phones, portable electronic devices, entering information on GPS units, reading, writing, and personal grooming. However, research shows that enactment of the law alone is insufficient to maintain changes in driver behaviour over the long-term. Evidence concludes that an integrative approach of targeted enforcement, awareness raising, and education about the dangers of distracted driving is needed to effectively reduce the use of cell phones and other electronics while driving and maintain it over time.

Strategies to reduce distracted road use are identified through the 5 E's of traffic safety: education, enforcement, engineering, engagement, and evaluation. Educational initiatives to inform and promote safe road user behaviours include road safety campaigns, conferences, and education programs. Courses on the dangers and effects of distracted road use are recommended as part of the curriculum in schools and driver/rider training programs. Targeted enforcement should be conducted on an ongoing basis to maintain compliance with distracted driving laws, and combined with education and awareness efforts. In road design, engineers should ensure that external sources of distraction, such as advertising billboards or signs, are properly placed along the roadway. For example, billboards that are highly salient and attention-grabbing should not be located in traffic areas that demand high levels of concentration, such as traffic circles or busy intersections. Engagement may be enhanced through the implementation of community-based initiatives focused on distracted road use within schools, workplaces, neighbourhoods, and other community organizations. These community initiatives include youth events, presentations targeted to specific community groups, use of social media, and public consultations. Collaboration among road safety stakeholders is also encouraged to facilitate the exchange of knowledge and best practices to curb distracted road use. Finally, evaluation of all road safety programs and initiatives is needed to ensure their effectiveness and efficiency in changing road user behaviour. The report concludes that an integration of these five strategies should be considered when attempting to reduce distracted driving, walking, cycling, and riding.

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1. Introduction

In recent decades, distraction among road users has become a growing concern. Much like drivers, pedestrians, cyclists, and riders also experience distraction, placing them at risk for a traffic collision. These road users are particularly vulnerable given the lack of external protection in the event of a collision. With the rapid emergence of technologies such as smartphones, portable entertainment systems, navigation systems, voice-activated interfaces, touchscreen displays, and other in-vehicle devices, distracted road use is expected to become more prevalent. The potential for environmental distraction is also on a rise as the traffic environment becomes more complex, with increasing numbers of vehicles, pedestrians, cyclists, signs, advertising billboards, and other visual information.

While considerable research has been conducted on distracted driving, other types of distracted road use including distracted walking, cycling, and riding have received notably less attention. This report aims to provide a review of: (1) leading research in the area of distracted road use by drivers, pedestrians, cyclists, and riders, (2) existing data sources and methods of measurement, (3) leading legislation related to distracted road use, and (4) evidence-based strategies to prevent and reduce collisions where distraction is a factor.

2. Leading Research

2.1. What is Distracted Road Use?

Driving, walking, cycling, and riding are complex traffic tasks that involve a continuous process of perception, cognition, and action (Dewar, Olson, & Alexander, 2002; Wickens et al., 1998). For example, when a road user approaches an intersection with a stop sign, perception guides visual attention to the sign. Once the meaning of the sign is retrieved from memory, the road user must make a decision to stop at the intersection. Once the relevant decision is made, a braking response is initiated (or in the case of a pedestrian, their walking pace is slowed). As illustrated in Figure 2.1, attention is needed for all three stages of processing involved in the traffic task.

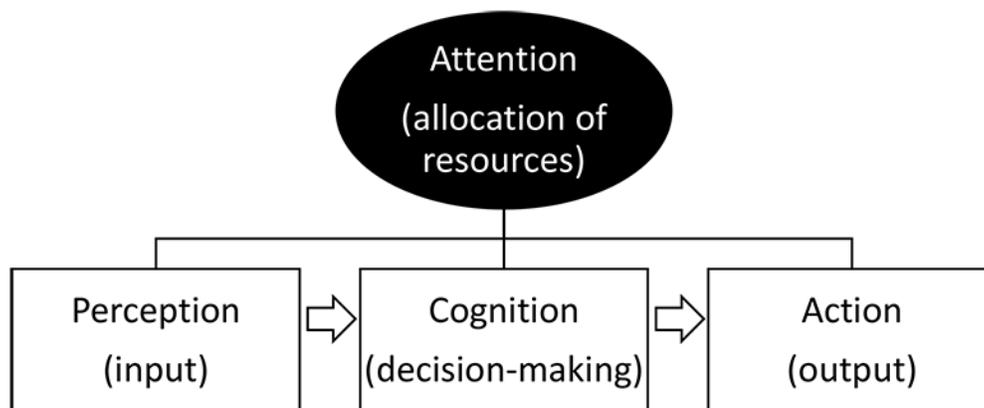


Figure 2.1. The three-stage information processing model (simplified from Wickens et al., 1998).

However, it is widely considered that human attention has a limited capacity (Kahneman, 1973; Wickens, 1980). When attending to multiple sources of information, not all task-relevant information is processed (e.g., a stop sign) and not all distracting information is ignored (e.g., an advertising billboard). Likewise, when doing two things at the same time, we may fail to notice something right in front of us – particularly if it is something we do not expect – because we are focused on something else. Known as “inattention blindness,” this is a phenomenon that road users often experience when they are distracted (Strayer & Drews, 2007).

Driver distraction has been defined as “the diversion of attention away from activities critical for safe driving toward a competing activity” (Lee et al., 2009). It is distinguished from inattentive driving (caused by driver states such as fatigue or drowsiness) by the presence of a triggering event that compels or induces attention away from the driving task (Regan et al., 2011; Stutts et al., 2005a). This definition applies to not only drivers, but also pedestrians, cyclists, and riders as they engage in activities that draw attention away from the walking, cycling, and riding task, respectively. Because these vulnerable road users are not protected by a vehicle shell, are much smaller than a vehicle, and rely on good visibility to be seen by drivers, they run a higher risk of being involved in a serious collision.

Distracting activities that draw attention away from the traffic task include cell phone use (Strayer & Drews, 2004), interacting with passengers (Koppel et al., 2011), eating and drinking (Young et al., 2008), listening to music (de Waard, 2011), adjusting in-vehicle controls (Stutts et al., 2003), using portable electronic devices (Chisholm et al., 2008), and environmental distractions (Stutts et al., 2003).

2.2. Mechanisms of Distraction

As depicted in Figure 2.1, attention is needed for activities at the perceptual, cognitive, and action stage for safe performance of a traffic task. This attention is drawn from a limited resource pool as shown in Figure 2.2. When a non-traffic related activity is performed at the same time, it competes with the traffic task for limited attentional resources. Distraction occurs when the road user fails to allocate sufficient attention to the traffic task, and is no longer able to maintain an acceptable level of traffic performance (Young & Regan, 2007). For example, a driver may fail to notice a pedestrian crossing the street because he or she is reading a text message. Likewise, a pedestrian may fail to notice an oncoming vehicle when crossing the street because he or she is operating a music device. To that end, distraction results when the attentional resource capacity is exceeded due to the presence of a competing activity.

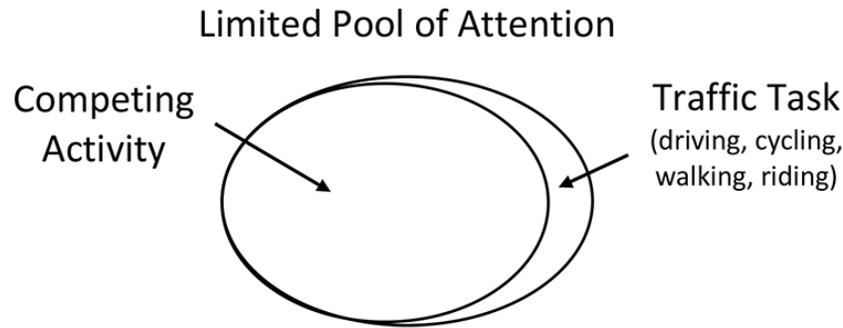


Figure 2.2. Distraction occurs when insufficient attention is allocated to the traffic task.

2.3. Sources of Distraction

Attention can be diverted away from the traffic task voluntarily or involuntarily. Voluntary distraction occurs when road users willingly engage in competing activities, for example, when one chooses to answer a cell phone. On the other hand, involuntary distraction occurs when road users unwillingly attend to competing activities. For example, when a cell phone suddenly rings, it elicits an involuntary shift of attention. Involuntary distractions have the ability to compel attention away from the traffic task because they are unexpected (e.g., when a cup of coffee spills), difficult to ignore (e.g., when a baby is crying), or highly salient (e.g., when a graphic billboard appears) (Regan et al., 2011). Distraction can also be triggered by internalised mental thoughts unrelated to the traffic task, for example, when one is mind-wandering.

Distraction has typically been categorized into four distinct types (Young & Regan, 2007).

- Visual distraction occurs when a road user is looking away from the road, for example, to read a text message on a phone.
- Auditory distraction occurs when a road user is focused on sounds not related to the traffic task, for example, listening to music with headphones.
- Physical distraction occurs when a road user is manually doing something not related to the traffic task, for example, when a driver removes one or both hands off the steering wheel to manipulate a device.
- Cognitive distraction occurs when a road user is thinking about something other than the traffic task, for example, when one is preoccupied with a cell phone conversation.

These types of distraction can occur individually or simultaneously. For example, when attention is captured by an advertising billboard it involves visual and cognitive distraction, while texting can cause visual, physical, and cognitive distraction.

With regards to driving, distraction can further be categorized into sources that are internal or external to the vehicle. Internal distractions derive from inside the vehicle (e.g., using a navigation system), while external distractions derive from outside the vehicle (e.g., looking at a vehicle collision scene).

Table 2.1 summarizes the various technology-related, non-technology, and environmental sources of distraction for drivers and other road users, as well as their type of distraction. Of note is that many distracting activities involve more than one type of distraction simultaneously.

Table 2.1. Potential sources and types of distraction.

Category	Source of Distraction	Type of Distraction
<i>Technology-related</i>	Using a cell phone (hand-held)	
	• Talking on a phone	A, C, P
	• Dialing/picking up a phone	V, P
	• Texting	C, V, P
	Manipulating radio/portable music player (mp3 player, iPod)	C, V, P
	Entering destination into a navigation system	C, V, P
	Using a portable TV/DVD player	A, C, V, P
	Using email/internet (smartphone, PDA)	C, V, P
<i>Non-technology related</i>	Conversing with passengers/other road users	A, C, V
	Adjusting vehicle controls	V, P
	Reaching for objects	V, P
	Eating/drinking	V, P
	Listening to music	A, sometimes C
	Smoking (light, smoke, extinguish)	V, P
	Grooming	V, P
	Daydreaming/lost in thought	C
<i>Environmental</i>	Outside object/event	V, C
	Advertising billboards	V, C
	Vehicle collision scene	V, C
	Scenery/landmarks	V, C
	Other road users	V, C

A = auditory; C = cognitive; V = visual; P = physical
Sources: Stutts et al. (2003); Young and Salmon (2010).

2.4. Statistics and Prevalence

2.4.1. Distracted Driving

Estimates of driver distraction vary depending on the method used to obtain the results, however, it is generally estimated that distraction accounts for 20-30% of all motor vehicle collisions (Robertson, 2011; Stutts et al., 2005).

In 2013, driver distraction was a contributing factor in 10% of all fatal collisions and 18% of injury collisions in the U.S. (NHTSA, 2015). 3,154 people were killed and 424,000 were injured in motor vehicle collisions associated with distracted driving. Of these distraction-related fatalities, 14% were due to the driver using a cell phone at the time of the collision. Drivers under the age of 20 made up the largest proportion of distracted drivers involved in fatal collisions (10%), followed by those aged 20-29 (8%).

In Canada, driver distraction accounted for 23% of fatal collisions and 27% of injury collisions in 2012 (Robertson et al., 2015). Compared to 2006, fatalities involving distraction have increased by 26% and injuries involving distraction have increased by 14%. In the 2014 Edmonton and Area Traffic Safety Culture telephone survey, 20% of respondents reported talking on a hand-held cell phone while driving in the past 30 days (Thue & Grekul, 2015). 42% said they talked on a hands-free cell phone and 11% said they sent a text message or email while driving in the past 30 days. The survey also found that a large majority of respondents (89%) perceived distracted drivers to be a very serious threat to their personal safety. 64% considered drivers talking on hand-held cell phones to be a very serious threat, while 18% considered the same about drivers talking on hands-free cell phones. 88% of respondents perceived drivers who were texting, emailing, or using social media while driving to be a very serious threat.

Results from the 100-Car Naturalistic Driving Study revealed that secondary task engagement was a contributing factor in over 22% of crashes and near-crashes (Klauer et al. 2006). In McEvoy et al. (2007), over 30% of drivers interviewed after a serious crash reported at least one distracting activity at the time of the accident. More recently, an observational study found that 33% of drivers were involved in a distracting activity (Huisingsh et al., 2015). Table 2.2 presents the prevalence of secondary tasks among drivers based on findings from a naturalistic driving study (Stutts et al., 2003) and a more recent observational study (Huisingsh et al., 2015).

Table 2.2. Percentage of drivers engaged in distracting activities.

Distraction	% of Drivers (Stutts et al., 2003)	% of Drivers† (Huisingsh et al., 2015)
Talking on cell phone	30.0	31.4
Texting/dialing cell phone	27.1*	16.6
Conversing with passengers	77.1	53.2
Eating and drinking	71.4	6.8
Reaching for objects	97.1	3.2**
Manipulating radio controls	91.4	2.4
Smoking	7.1	5.5
Grooming	45.7	5.8
Reading or writing	40.0	0.1
External distraction	85.7	20.4

* Dialing only

** Reaching to another seat

† Observational studies often yield lower estimates as data are measured at a single point in time (discussed in section 3.3.1 in Data and Measurement).

Data on the risks and prevalence of distracted walking, cycling, and riding are limited, to date, although new research in these areas are slowly emerging. Collision and injury statistics are also not widely available, making it difficult to quantify the extent of distraction in these areas of road use. Nevertheless, based on the few studies conducted, it is clear that these issues are an important safety concern.

2.4.2. *Distracted Walking*

Using data from the National Electronic Injury Surveillance System, which collects injury reports from hospitals across the U.S., Nasar and Troyer (2013) assessed injuries related to cell phone use among pedestrians. Between 2004 and 2010, the percentage of pedestrian injuries sustained from cell phone use relative to total pedestrian injuries increased from 0.58% to 3.67%. In 2010, there were 1,506 injuries involving pedestrians and cell phone use. Of these injuries, 70% were associated with talking on the phone, while 9.1% were associated with texting. Some of the injuries were caused by being struck by a vehicle, walking into a pole, or falling into a ditch along the road.

A recent study observed pedestrians crossing urban intersections and found that 19% were engaged in a distracting activity while crossing (Violano et al., 2015). 9% were wearing headphones, 8% were using a mobile device (talking, texting, or looking down at it), and 2% were eating or drinking.

Basch et al. (2014) observed pedestrians as they crossed dangerous intersections in Manhattan, New York City. Over one-quarter of pedestrians were using electronic devices while crossing during the ‘walk’ (29%) and ‘don’t walk’ (26%) signals. Using headphones was the most common activity (16%), followed by looking down at a cell phone (7%), and talking on a cell phone (5%).

Thompson et al. (2013) observed pedestrians crossing high-risk intersections and found that nearly 30% were engaged in a secondary task while crossing. 11.2% were using a portable music player with headphones, 7.3% were texting, and 6.2% were talking on a cell phone.

These findings reveal that a substantial number of pedestrians (20-30%) exhibit distracted walking. The most common distractions are using a cell phone and listening to music on a personal device.

2.4.3. *Distracted Cycling*

Cycling is a common means of transportation in many European countries, such as the Netherlands and Denmark, where most roads are designed for cycling. In the Netherlands, over 80% of the population own at least one bicycle and 34% of all journeys less than 7.5 km are made by cycling (Borgman, 2003; Ministry of Transport, Public Works and Water Management, 2009). In the current literature, all studies of distracted cycling are based out of the Netherlands, except for one survey study conducted in Japan.

In Ichikawa and Nakamara (2008), a self-administered questionnaire was used to assess the use of cell phones while cycling among Japanese high school students. The results showed

that 75% of male and 64% of female students reported using a cell phone while cycling in the past month. 20% of males and 19% of females reported a bicycle crash/near-crash experience while using a cell phone in the past month.

In an online survey study by Goldenbeld et al. (2012), 17% of Dutch cyclists reported using an electronic portable device nearly all the time while cycling. 15% said they listened to music and 3% said they used a cell phone each or nearly each bicycle trip. 39% of cyclists listened to music at least occasionally on each trip, while over half (55%) used a cell phone at least occasionally. Nearly 75% of teenage (12-17 years) and young adult (18-34 years) cyclists reported using a portable electronic device while cycling compared to 26% of all middle-aged (35-49 years) and older adult (over 50 years) cyclists. When asked about bicycle crashes, 10% of non-injury crashes and 9% of injury crashes were reported by cyclists to be preceded by the use of a portable electronic device.

Terzano (2013) observed cyclists in the city of The Hague, Netherlands and found that 28% were involved in a distracting activity while cycling through intersections. 9.1% were using a portable music device with headphones, 14% were talking to another cyclist, and 3.5% were using a cell phone.

In De Waard et al. (2015), data from an observational study of cell phone use among Dutch cyclists in 2013 was compared to an earlier observational study from 2008 (De Waard et al., 2011). The results showed that, over a span of five years, the prevalence of cell phone use among cyclists did not change substantially (2.8% in 2008 vs. 3.0% in 2013). However, there was an increase in the number of cyclists who were texting (2.3%) than calling (0.7%). In 2008, this was reversed as 2.2% of cyclists were calling and 0.6% were texting.

These findings suggest that a high proportion of cyclists engage in distracting activities while cycling. However, caution is warranted in generalizing these findings to other populations as the studies are based out of countries where cycling is prevalent.

2.4.4. *Distracted Riding*

Estimates of distracted riding are limited. According to data from the National Highway of Traffic Safety Administration, 10% of motor vehicle fatalities in 2011 involved some form of driver distraction (NHTSA, 2013). Of these fatalities, 6% were motorcycle riders who were distracted at the time of the collision (compared to 8% of distracted drivers in passenger cars). This number has decreased from 12% in 2009 (11% were distracted drivers in passenger cars that year) (NHTSA, 2010a).

In 2011, the Motorcycle Safety Foundation, along with the Virginia Tech Transportation Institute, partnered to conduct the 100 Motorcyclists Naturalistic Study. Similar to the 100-Car Naturalistic Driving Study, the study aimed to provide the first comprehensive data on rider behaviour, exposure, and their involvement in crashes and near-crashes (McLaughlin et al., 2011). As data analysis is still underway, the findings are not published yet.

As part of a 2011 survey used to recruit potential participants for the naturalistic riding study, 229 riders were asked if they use a GPS, cell phone, and other communication devices

while on the motorcycle (McLaughlin et al., 2011). Nearly half of respondents indicated that they use a GPS. 20% reported to using an intercom, 20% reported to using a citizen band radio (CB), and 13% reported to using a cell phone on the motorcycle.

2.5. Crash Risk and Effects on Traffic Performance

2.5.1. *Distracted Driving*

A number of studies using different methodologies have documented the detrimental effects of secondary tasks on driving performance and safety.

As shown in Table 2.3, findings from The 100-Car Naturalistic Driving Study showed that “reaching for a moving object” was associated with the highest crash/near-crash risk with an odds ratio (OR) of 8.8. This indicates that drivers who performed the activity were almost nine times more likely to be involved in a crash/near-crash than that of baseline (undistracted) driving (Klauer et al., 2006). Examples of reaching for moving objects include responding to something sliding off the seat or dashboard, or food/drinks spilling (Dingus & Klauer, 2008).

Complex secondary tasks that required several manual inputs and/or several eye glances away from the road, such as dialing a hand-held phone or using a PDA, increased the risk of a crash/near-crash by three times that of baseline driving (OR=3.1). Moderate secondary tasks that required at most two manual inputs and/or two glances away from the road, such as talking on a hand-held phone, increased the risk of a crash/near-crash by twice that of baseline driving (OR=2.1). Simple secondary tasks that required one or no manual inputs/glances away from the road did not significantly increase the crash/near-crash risk from normal driving (OR=1.2). Additionally, the analysis on eye glance behaviour showed that secondary tasks that took the driver’s eyes off the road for longer than two seconds doubled the risk of a crash or near-crash.

In a more recent naturalistic driving study by Fitch et al. (2013), the risk of safety-critical events (SCEs) was analysed for cell phone use specifically. SCEs included crashes, near-crashes, and other crash-relevant events, such as inadvertent lane departures. The study found that making or ending calls on a hand-held phone was associated with an OR of 3.3, while texting had an OR of 2.1. These findings provide converging evidence that performing visual-manual tasks on a cell phone while driving poses a safety risk to drivers.

Table 2.3 summarizes the relative risks for selected secondary tasks from the 100-Car Naturalistic Driving Study and Fitch et al. (2013) study.

Table 2.3. Relative risk (odds ratio) associated with specific secondary tasks.

	Odds Ratio (100-Car Study; Klauer et al. 2006)	Odds Ratio (Fitch et al., 2013)
Level of secondary task		
Complex secondary tasks (i.e., dialing/answering hand-held phone, using PDA, reaching for moving object reading, applying makeup, insect in vehicle)	3.1*	
Moderate secondary tasks (i.e., talking/listening to hand-held phone, handling CD, eating, looking at external object)	2.1*	
Simple secondary tasks (i.e., adjusting radio/other in-vehicle devices, talking to passengers, lost in thought)	1.2	
Individual secondary tasks		
<i>Cell-phone use</i>		
Call-related visual-manual tasks		3.3*
Text-related visual-manual tasks		2.1*
Dialing a hand-held phone	2.8*	
Talking/listening to a hand-held phone	1.3	0.8
Reaching for a phone	1.4	3.7*
<i>Other secondary tasks</i>		
Reaching for a moving object	8.8*	
Insect in vehicle	6.4	
Looking at external object	3.7*	
Reading	3.4*	
Applying makeup	3.1*	
Inserting/retrieving CD	2.3	
Eating	1.6	
Drinking	1.0	
Adjusting radio	0.6	
Passenger in adjacent seat	0.5*	

* Indicates statistical significance from an odds ratio of 1.

Several controlled experiments have linked cell phone use to a deterioration in driving performance. Results from a simulator study by Charlton (2009) revealed that drivers conversing on a cell phone often failed to reduce their speed when they approached a hazard compared to drivers who were not using a cell phone. When they did slow down, they did so later and closer to the hazard, resulting in more collisions and close calls. In Strayer and Drews (2004), drivers talking on a cell phone were 18% slower to react to a vehicle braking ahead and were involved in more rear-end collisions than drivers not using a cell phone. In another simulator study, Strayer and Drews (2007) found that compared to driving only, drivers involved in cell phone conversations remembered fewer objects in the driving scene, even when eye-tracking data revealed that the drivers' eyes were directed at the objects. These findings suggest that talking on cell phones divert attention away from the driving environment to the context of the phone conversation, causing "inattentive blindness."

Studies have generally found that talking on a hand-held or hands-free phone have similar effects on driving performance (e.g., Consiglio et al., 2003; Horrey & Wickens, 2006; Strayer & Johnson, 2001; Patten et al., 2004). This seems to indicate that the cause of distraction is mainly cognitive, rather than due to the physical aspect of holding the phone. Cognitive distraction (from conversations or use of in-vehicle systems) has also been shown to cause "tunnel vision," in which drivers fail to scan the driving environment and are more likely to miss objects in the periphery (Engstrom et al., 2005; Harbluk et al., 2007).

A number of studies suggest that conversing with a passenger have similar or less detrimental effects than conversing on a cell phone (e.g., Caird et al., 2008; Charlton, 2009, Consiglio et al., 2003). The 100-Car Naturalistic Driving Study found that the crash risk of passenger interactions was not significantly different from baseline driving. This is likely because passengers can observe the traffic situation and modulate the conversation based on current driving demands, such as slowing the pace of the conversation in busy traffic. However, there is evidence that young drivers are most distracted by peers or friends as passengers. In Lee and Abdel-Aty (2008), certain driver-passenger combinations were examined to determine their crash potential. The authors found that young drivers (16-24 years) were more likely to be involved in crashes when accompanied by young passengers than older passengers. Young drivers also displayed more unsafe driving behaviours (e.g., speeding) in the presence of young passengers. It is likely that young drivers are more willing to engage in risky behaviours due to social pressure and the need to show off when with their peers.

Texting while driving has also been associated with elevated crash risk and impaired driving performance. Studies have shown that drivers are four times more likely to look away from the road when texting compared to when not distracted (Hosking, Young, & Regan, 2006; Olson et al., 2009). In Olson et al. (2009), commercial truck drivers were 23.2 times more likely to be involved in a safety-critical event while texting compared to undistracted truck drivers. Caird et al. (2014) conducted a meta-analysis of experimental studies that examined the effects of texting while driving. Texting was shown to compromise all measures of driving performance, including visual attention to the road ahead, ability to detect and respond to traffic events, and ability to maintain appropriate speed, lane positioning, and headway.

Drivers' use of voice-activated and visual-manual interfaces has been shown to degrade driving performance. Studies have demonstrated that interacting with a speech-based email system can increase brake reaction times (Lee et al., 2001) and reduce or delay the detection of visual stimuli (Harbluk & Leland, 2005). Manipulating a music player has been associated with impaired lateral control, more collisions, and increased response times to hazards (Chisholm et al., 2008; Mitsopoulos-Rubens et al., 2011).

Objects and activities in the environment can also divert attention away from the driving task, particularly advertising billboards. These billboards often feature large, colourful, and conspicuous images and/or slogans to attract attention. Additionally, they are often placed in strategic locations, such as major traffic areas, to draw the attention of passing drivers. In recent years, electronic billboards with dynamic messages/images and bright lights have become increasingly prevalent.

In a naturalistic driving study by Dukic et al. (2013), instrumented vehicles were used to record drivers' gaze behaviour as they passed four electronic billboards on a major road. The study found that drivers diverted significantly more and longer glances toward electronic billboards than other traffic signs on the road. Driving simulator studies have also linked roadside billboards to reduced driving performance. Bendak and Al-Saleh (2010) found that driving performance was significantly worse on a road with advertising billboards compared to an identical road with no billboards, as indicated by more lane wanderings and more reckless crossings of intersections. In a simulator and eye-tracking study, Edquist et al. (2011) found that road sections with advertising billboards reduced eye fixations to the road ahead, delayed response times to road signs, and increased the number of driving errors compared to road sections with no billboards. Chan and Singhal (2013) found that emotional information on billboards were more distracting than neutral billboards. Drivers drove slower in the presence of emotional billboards than neutral ones, and remembered more emotional billboards.

2.5.2. Distracting Walking

The relative risk of specific secondary tasks while walking has not been researched. However, based on the few observational and experimental studies available, pedestrians who engage in other activities tend to have reduced situational awareness, such as failing to notice an approaching vehicle (Violano et al., 2015). This can be particularly dangerous when pedestrians are crossing the street.

In Thompson et al. (2013), pedestrians were observed at high-risk intersections as crossing behaviours were recorded. Both texting and talking on a cell phone significantly increased the mean time to cross the street compared to undistracted pedestrians. Texting increased crossing time by 1.87 seconds (18%), while talking on a hand-held phone or hands-free phone added 0.75 and 1.29 seconds to crossing time, respectively. Pedestrians who listened to music crossed the intersection faster by 0.54 seconds. Pedestrians engaged in texting were 3.9 times more likely to exhibit unsafe crossing behaviour, such as failing to look both ways before crossing or disobeying the traffic lights. These findings show that cell phone use can influence crossing times and behaviour, and that texting is associated with the highest risk of a traffic collision.

Using a virtual environment to simulate street crossing, Stavrinou et al. (2011) examined the impact of cell phone conversations on pedestrian safety. The results showed that pedestrians distracted by a phone conversation displayed riskier behaviours when crossing the street than those not distracted. Distracted pedestrians missed more opportunities to safely cross the street, had more hits/close calls to getting struck by a vehicle, and left less time to spare after safely crossing the street until the next vehicle passed. Moreover, it was shown that the content of the phone conversation did not influence the impact of distraction – both mundane and cognitively-demanding conversations were associated with unsafe pedestrian behaviour.

In Walker et al. (2012), the use of personal music devices (PMDs) was observed among pedestrians at intersections. 22% were listening to a PMD while crossing the street. Male pedestrians using a PMD showed significantly more cautionary behaviours (i.e., looking before crossing) than those who did not use PMDs. Among female pedestrians, cautionary behaviours were not affected by the presence of a PMD. Thus, in this study, listening to music while walking did not reduce cautionary behaviours like using cell phones did in Stavrinou et al. (2011).

Taken together, these findings show that pedestrians are more likely to display unsafe street-crossing behaviours when using cell phones compared to when not distracted. Additionally, listening to music and using cell phones may have different effects on crossing behaviour. More studies on distracted walking are discussed in the Data and Measurement section.

2.5.3. *Distracting Cycling*

In an analysis of bicycle crash risk using self-reported crash data, Goldenbeld et al. (2012) found that using a portable electronic device while cycling was a risk factor for teenage and young adult cyclists, but not for middle-aged and older cyclists. The odds of having a bicycle crash when using an electronic device increased by a factor of 1.6 for teenage cyclists and 1.8 for young adults compared to cyclists who did not use electronic devices.

In an observational study on distracted cycling behaviour, nearly half of all distracted cyclists (using a cell phone, listening to music, or talking to other cyclists) demonstrated some sort of unsafe behaviour while crossing intersections compared to 20% of undistracted cyclists (Terzano, 2013). These unsafe behaviours included not slowing down to look both ways before crossing, riding in the wrong direction in a bicycle lane, or crossing an intersection too slow. Cyclists engaged in other activities were also more likely to force other road users to dodge or go around them to avoid a collision.

In two field studies by de Waard et al. (2010; 2011), the effects of listening to music and using a cell phone was examined on real-world cycling behaviour. The results from the first study showed that texting had the most detrimental effects on cycling performance compared to talking on the phone, listening to music, or when not distracted. Specifically, cyclists showed a larger reduction in speed, swerved more on the cycle path, and had reduced peripheral vision. In the second study, the effects of talking on a phone and listening to music while cycling on auditory perception was assessed. Both tasks reduced the amount of auditory information

processed compared to when not distracted, with music listening having the largest negative effect.

Together, these findings show that distracted cycling compromises road safety and cycling behaviour. Additionally, talking on a cell phone and listening to music induces auditory distraction by interfering with the perception of auditory information. This has important implications for cyclists as they often rely on traffic noise to identify the presence of vehicles, such as a vehicle approaching rapidly from behind (Stelling-Konczak et al., 2015). Additional studies on distracted cycling are discussed in the Data and Measurement section.

2.5.4. *Distracted Riding*

Research on the crash risk, types, and prevalence of distracting activities among riders has not been published; however, a few experimental studies have examined the relationship between distracting activities and riding performance.

Many motorcycles are equipped with Advanced Rider Assistance Systems (ARAS), such as speed alert, frontal collision warning, and curve warning systems. These systems are designed to help the rider and reduce the probability of collision. However, it has been suggested that ARAS may actually distract riders and increase the risk of a collision, particularly if the system emits an auditory warning or use flashing lights (Will & Schmidt, 2014). Similarly, On-Bike Information Systems (OBIS) that operate via touchscreen, such as a navigation system, may distract rather than aid the rider by inducing visual-manual distraction.

In Will and Schmidt (2014), a motorcycle simulator study was conducted to examine the effects of different types of secondary tasks on riding performance. Riders rode a simulator with no secondary task, while counting targets in an audiobook (auditory), while responding to targets presented in the periphery (visual), and while navigating through a layer of menus using a touchscreen display (visual-manual). Riders also reported on the workload experience of each condition. Riding while performing the visual-manual task was associated with increased workload, reduced speed, and increased lane variability compared to the other conditions. While further research is needed to validate these findings, they have important implications regarding the use of OBIS and other visual-manual tasks while riding. Additional studies on distracted riding are discussed in the Data and Measurement section.

2.6. Risk Factors

Road users that are occupied with distracting activities often show a significant degradation in traffic performance. The extent that road users are susceptible to the effects of a distracting activity may be due to a number of factors, including secondary task complexity, current traffic demands, and the age and experience of the road user.

2.6.1. *Complexity of Secondary Task*

The degree to which a secondary task interferes with the traffic task depends on the extent to which the secondary task competes for the road user's attention.

In a comprehensive study by Strayer et al. (2013), the effects of varying levels of cognitive tasks were examined on driver behaviour using a driving simulator and an instrumented vehicle. A combination of performance measures were collected, including driving performance, reaction time and accuracy in response to a peripheral detection task, workload measures from the NASA Task Load Index, eye movements, and electroencephalographic (EEG) activity. The compiled data showed that compared to baseline driving (no distraction), driving while listening to the radio led to a small increase in cognitive distraction. Talking to a passenger and talking on the phone (hand-held or hands-free) showed similar levels of distraction and resulted in a moderate increase in cognitive distraction. More complex tasks, such as interacting with a speech-to-text interface, led to a significant increase in cognitive distraction. Similar effects were found in the laboratory and in the real world.

These findings and others (e.g., Blanco et al., 2001; Chisholm et al., 2008; Harbluk et al., 2007) demonstrate an inverse relationship between the complexity of the secondary task and the amount of resources available for the driving task. More demanding secondary tasks draw more resources away from the traffic task, leading to higher levels of distraction.

2.6.2. Traffic Task Demands

Task demands associated with the traffic environment, such as the complexity of the roadway, traffic density, and weather conditions, can influence the potential for distraction from secondary tasks.

When driving on a monotonous road where driving task demands are low, engaging in an additional task may not necessarily lead to distraction, as spare attentional resources may be available for competing activities. However, when driving in a busy city where a large amount of attention is required, distraction is likely to arise, as little spare capacity remains for competing activities. In situations where the demands of traffic suddenly change, for example, when a pedestrian steps into the street unexpectedly, secondary task engagement can be extremely hazardous, as it may be difficult to switch full attention back to the driving task and rapidly respond to the critical situation. Supporting this, studies have found that complex driving courses (Horberry et al., 2005; Strayer & Johnson, 2001) and high traffic density (Strayer et al., 2003) interact with secondary tasks to produce higher levels of distraction compared to less demanding driving scenarios.

Adverse weather conditions can also interact with secondary tasks to influence driving performance. In Cooper and Zheng (2002), drivers drove an instrumented vehicle in a test track with other experimental vehicles present. Half of the drivers drove on normal pavement, while the other half drove on wet pavement. In several left turn scenarios, drivers had to judge whether it was safe to make a turn by estimating the gap size of approaching vehicles. When they felt it was safe they were instructed to press the accelerator pedal (the transmission was in neutral and the parking brake was on so no actual turn was made). Drivers performed the task while listening/responding to complex messages and while not distracted. The study found that on wet road conditions, drivers made twice as many gap errors when they were distracted than when not distracted. The authors suggest that distracted drivers fail to factor in aspects of the driving environment, such as road surface conditions, in the decision-making process, leading to unsafe decisions.

2.6.3. Age and Experience

Statistics show that young drivers (under 30 years) are overrepresented in collisions involving distraction. In 2013, drivers aged 15-19 made up 6% of drivers in all fatal collisions, but are 10% of the distracted drivers in fatal collisions. Drivers aged 20-29 made up 23% of drivers in all fatal collisions, but accounted for 27% percent of the distracted drivers involved in fatal collisions (NHTSA, 2012a).

A few reasons may account for this. First, there is evidence that young drivers are more likely to engage in secondary tasks while driving than middle-aged and older drivers (e.g., Young & Lenné, 2010). In a recent survey, an overwhelming majority (90%) of young drivers aged 18-29 reported using a cell phone and/or texting while driving at least some of the time (Hill et al., 2015). 78% used a GPS and 70% used a portable music player while driving at least some of the time. Young drivers also perceive distracting activities to be less risky than older drivers (McEvoy et al., 2006), which may increase their propensity to engage in these activities while driving.

Second, because young drivers are often inexperienced, they may need to devote a larger amount of attention to the driving task, leaving less attentional resources to spare for competing activities. Older or experienced drivers may be more effective in dividing their attention because the driving task is now automated, freeing up attention for competing activities. Older drivers also tend to adopt compensatory strategies when engaged in secondary tasks, such as increasing the following distance or reducing speed (Horberry et al., 2005). In Greenberg et al. (2003), the effects of in-vehicle tasks on driving performance was assessed among teenage drivers (16-18 years) and drivers aged 26-55. The study found that teenage drivers had poorer driving performance than their older counterparts when engaged in secondary tasks. Specifically, they detected fewer events in the driving scenario when dialing a hand-held phone (46.2% accuracy vs. 86.4% for adults) and made more lane violations when accessing voice mails on a phone (3.9 violations/hour vs. 2.5 for adults).

Research has also shown that young drivers are more susceptible to distraction when driving with peer passengers in the vehicle. In a recent study by Carney et al. (2015), collision data associated with teenage drivers (16-19 years) was examined. The study found that interacting with passengers was the leading cause of distraction-affected collisions (15%), followed by cell phone use (12%). As reported by Lee and Abdel-Aty (2008), young drivers are more likely to exhibit unsafe driving behaviors, such as speeding, driving after alcohol use, and not wearing seatbelts, in the presence of young passengers than older passengers. This negative influence on driving is likely due to distraction from interacting with peer passengers and an increased propensity to engage in risk-taking due to social pressure.

While young drivers are particularly vulnerable to the effects of distraction, there is also evidence that elderly drivers (over 65 years) are less effective in dividing their attention between multiple tasks. This has been associated with age-related declines in executive functions, including selective attention and working memory abilities (Thompson et al., 2012). Thompson et al. (2012) found that elderly drivers distracted by auditory-verbal information drove slower and spent more time holding the gas pedal than middle-aged drivers. Elderly drivers also

exhibited slower brake reaction times when using a cell phone compared to drivers under the age of 60 (Alm & Nilsson, 1995).

Other groups of drivers that may be more prone to distraction are those that often experience low driving task demands, such as commercial truck drivers, shift workers, and experienced drivers who drive the same route every day or for long hours on stretches of monotonous roads. When drivers are bored or “under-aroused,” they have a greater tendency to engage in distracting activities, such as using a cell phone or dispatch device, to maintain alertness (Bunn et al., 2005; Craft & Preslopsky, 2009; Olson et al., 2009). Research has shown that alternative tasks, such as cooling the inside of the vehicle, taking frequent breaks, drinking caffeine, and engaging in mental trivia tasks, can increase focus on the road ahead without compromising road safety (McKernon, 2008).

Although there is little data on groups of pedestrians, cyclists, and motorcyclists that are more susceptible to distraction, teens and young adults are expected to be most at risk on the road. Based on recent data from the Pew Research Center, 78% of teens (12-17 years) own a cell phone, while 47% own a smartphone (Madden et al., 2013). 98% of young adults (18-29 years) own a cell phone, 86% own a smartphone, and 51% own an mp3 player (Anderson, 2015). The greater level of exposure to electronic devices among these age groups are expected to contribute to higher rates of collisions and injuries on the road, as found with young drivers.

2.7. Summary

Distracted road use by drivers, pedestrians, cyclists, and riders is a significant concern for road safety, as reviewed in this section. Common sources of distraction among these road users include talking on cell phones, texting, and handling portable electronic devices (e.g., mp3 players, iPods).

Driver distraction is estimated to account for 20-30% of all motor vehicle collisions. Multiple studies show that engaging in secondary tasks while driving can degrade driving performance and increase the risk of crash involvement. Cognitive distraction (from cell phone conversations or interactions with electronic devices) can also contribute to “tunnel vision,” in which a driver’s ability to detect peripheral visual information is reduced.

While further research is needed, evidence suggests that the mechanisms and sources of distraction among pedestrians, cyclists, and riders are similar to that of drivers. Findings reveal that 20-30% of pedestrians, cyclists, or riders are engaged in a secondary task during road use. Pedestrians and cyclists who are talking on cell phones, texting, and listening to music with headphones are more likely to display unsafe behaviours at intersections, such as failing to look both ways before crossing the street or crossing too slowly.

Drivers most at risk for a distraction-related collision include young drivers (16-30 years), elderly drivers (over 65 years), and drivers who often experience low driving task demands, such as commercial truck drivers and shift workers. Young pedestrians, cyclists, and riders are also expected to be at greater risk for an injury due to their frequent use of electronic devices. Other risk factors that may increase the potential for distraction are complex secondary

tasks (e.g., tasks that require multiple inputs and/or multiple eye glances away from the road) and increased traffic task demands (e.g., complex roadways, high traffic density, wet roads).

3. Data and Measurement

Various methodologies have been employed to yield different types of data associated with distracted road use. While each method has its benefits, they also have their limitations. In the following section, a review of existing data from sources such as experimental methods (e.g., simulator studies), naturalistic driving studies, observational studies, survey research, and collision data will be conducted. Data unknowns, limitations, and opportunities for enhancement in future research will also be identified.

3.1. Experimental Methods

In an experiment, the researcher manipulates one or more independent variables (e.g., cell phone use while driving) and measures the effect of this manipulation on a dependent variable (e.g., driving performance). This method requires the researcher to control and use randomization as much as possible in order to establish a cause and effect relationship between the variables of interest. To examine the effects of secondary tasks on driving performance, a dual-task paradigm is often employed, in which participants are required to drive while performing a secondary task. Driving performance is then compared against a control condition (single-task), in which participants drive without engaging in any tasks (Young et al., 2009). While a wide range of experimental studies have been conducted on distracted driving, only a few have addressed distracted walking, cycling, and riding; these studies are reviewed in a later section (see section 3.1.5).

Three types of experiments have often been conducted to measure the effects of driver distraction: (1) on-road studies, (2) test track studies, and (3) driving simulator studies.

3.1.1. *On-Road Studies*

On-road studies are conducted outside the laboratory on actual roads. Participants drive along a predetermined route using an instrumented vehicle equipped with sensors to record driving performance, including speed, lane position, steering wheel activity, and brake response. The participant is often accompanied by an experimenter in the vehicle. During certain drive segments, participants are instructed to perform a secondary task (Young et al., 2009).

As part of the HASTE project, Engstrom et al. (2005) conducted an on-road experiment to examine the effects of visual and cognitive load on actual driving performance. This experiment was one of several that tested the impact of in-vehicle information systems (IVIS) on different means of driving. Using an instrumented vehicle, participants drove twice along a 38 km roadway. In half of the drives, they performed a visual and cognitive IVIS task, while in the other half, they did not perform any tasks. The visual IVIS task was performed on a touchscreen mounted in the vehicle and required drivers to take their eyes off the road (target detection task). The cognitive IVIS task did not involve any visual diversion from the road (auditory working memory task). The timing of the tasks was controlled by the experimenter who was present in the vehicle. The results showed that visual and cognitive load had differential effects on driving performance. Visual load reduced speed and deteriorated lateral control, while cognitive load improved lateral control. Cognitive load also increased drivers' gaze concentration to the center of the road.

One of the main advantages of on-road studies over simulator studies is that they provide a more realistic setting to measure the effects of secondary tasks on driving performance. The measures recorded are based on actual driving and drivers have to make real traffic decisions with actual consequences (e.g., stopping for a pedestrian). These benefits provide a more precise assessment of driving performance, improving ecological validity.

While some experimental manipulation is involved in these type of studies, such as the specific route the driver is to follow, the length of the drive, and when the driver interacts with the secondary task, they afford less experimental control than driving simulators (Young et al., 2009). Confounding variables, such as the weather and surrounding traffic, cannot be controlled for, which may produce spurious results. Another concern is that the presence of the experimenter in the vehicle may affect the way drivers behave. Knowing they are being observed, participants might drive more carefully than they normally would, biasing the results (Young et al., 2009). Finally, given the real-world driving setting, there may be risks of potential injuries and collisions to the drivers. For these reasons, driving simulators are often used instead to assess similar research questions.

3.1.2. Test Track Studies

Test track studies are conducted on a closed test track under controlled conditions. In driver distraction research, participants often drive an instrumented vehicle along the test track while engaged in secondary tasks (Young et al., 2009). Like on-road studies, an experimenter is present in the vehicle and controls the timing of the secondary task. Other vehicles and objects, such as traffic signals, may be staged on the track.

In a study by Ranney et al. (2005), participants drove an instrumented vehicle on a test track while performing a car-following task and a peripheral target detection (PDT) task. In the car-following task, participants were required to maintain a constant following distance from the lead vehicle. The PDT was displayed on a screen mounted near the dashboard of the vehicle; participants responded when one of several LEDs illuminated by pressing a switch attached to their left index finger. At certain times during the drive participants were required to perform various secondary tasks. Half of the participants performed the tasks on a voice-activated interface, while the other half performed the tasks on a visual-manual interface. The secondary tasks involved simple tasks (dialing a phone number, tuning the radio) and more complex tasks (opening a phone book, creating a voice memo). The results showed that secondary task engagement impaired performance in car-following (longer following distances), peripheral detection (more misses and longer response times), and lane control. Secondary tasks performed on the voice-based interface led to small improvements in peripheral detection and lane control but not car following. These findings suggest that while voice activation may slightly improve peripheral processing in driving, they impair attentional/cognitive aspects of driving, such as following a lead vehicle.

Like on-road experiments, test track studies are conducted on real roads, and therefore provide a higher degree of realism with regards to the driving environment. They also afford greater experimental control over factors such as road surface, timing of traffic lights, number of other vehicles present, and even weather (Young et al., 2009). Thus, the main advantage of test tracks over on-road experiments is the ability to stage certain scenarios, such a car following task

(Ranney et al., 2005) or adverse weather conditions (Cooper & Zheng, 2002; study described in section 2.6.2).

However, the test track environment can sometimes be unrealistic, particularly if the track is small and/or circular. Additionally, if there is minimal traffic, visual clutter, or obstacles on the track, drivers may devote little attention to the driving task, while focusing more on the secondary task (Young et al., 2009). For these reasons, the ecological validity of these studies is often lower than those conducted on-road. Finally, like on-road studies, the potential for injuries and collisions can still occur on test tracks.

3.1.3. Driving Simulator Studies

Driving simulator studies are conducted in a controlled laboratory setting. A typical simulator consists of a seat, steering wheel, gas/brake pedals, and visual display (computer monitor or projector). Like instrumented vehicles, simulators can provide objective measures of driving performance, such as speed, lane-keeping, steering wheel activity, headway, and brake responses. They can also be used to measure the detection and reaction times of critical events, such as stop signs, traffic lights, pedestrians, and lead vehicles braking.

A handful of studies have used driving simulators to examine the effects of secondary tasks while driving. In Chisholm et al. (2008), participants drove alone (single-task) and drove while performing easy and difficult tasks on an iPod (dual-task). Easy tasks involved one or two steps, such as turning off the iPod, pausing, or skipping songs. Difficult tasks involved multiple steps, such as finding a specific song from 900 titles on the iPod. In the driving task, participants were presented with a number of hazards, such as a pedestrian suddenly emerging, a vehicle pulling out, and a lead vehicle braking. The study found that drivers were involved in more collisions and had slower response times to the hazards when performing the difficult iPod tasks compared to the easier tasks and control conditions.

In Strayer and Drews (2004), a car following paradigm was used, in which participants drove alone (single-task) and drove while conversing on a cell phone (dual-task). The phone conversations were led by a confederate and conducted in a naturalistic manner. In the driving task, participants followed a pace car that would brake occasionally. The results showed that drivers in the dual-task conditions had 18% slower brake reaction times, 12% greater following distance, and were involved in more rear-end collisions than drivers in the single-task conditions.

In the set of simulator studies within the HASTE project, participants drove alone (single-task) and drove while performing visual and cognitive IVIS tasks that varied in difficulty (dual-task) (Engstrom et al., 2005). The results were similar to those reported in the on-road experiment. Visual load was associated with slower speed and increased lane variability. On the other hand, cognitive load was associated with reduced lane variability and increased gaze concentration towards the center of the driving scene.

When used in conjunction with an eye-tracker, driving simulators can measure the viewing time of traffic signs or other visual stimuli, as well as the visual scanning pattern of drivers. In Strayer and Drews (2007), participants were given a surprise recognition memory test of objects in the driving scene following a drive session. The results showed that drivers

conversing on a cell phone remembered fewer objects than when not talking on the phone – even when eye-tracking data showed that they had looked at the objects directly. In Pradhan et al. (2014), the visual scanning behaviour of adolescent drivers was examined when driving with a passenger compared to driving alone. The study found that drivers' visual scanning was significantly narrowed in the presence of a passenger, causing “tunnel vision.” These effects are similar to findings on cognitive distraction, suggesting that passengers may increase cognitive load in drivers.

A few simulator studies have integrated cognitive neuroscience techniques, such as event-related potentials (ERP) and functional magnetic resonance imaging (fMRI), to measure the brain activity of drivers. Multiple brain regions have been identified during baseline driving, including the parietal and occipital lobes. These regions have been implicated in navigation, spatial processing, and visual processing (Just et al., 2008; Schweizer et al., 2013). In a simulator and fMRI study, Schweizer et al. (2013) found that when drivers performed an auditory task simultaneously, these regions decreased in activation, while the prefrontal and auditory areas increased in activation. These findings suggest that during distraction, neural resources are diverted away from brain regions important for safe driving to regions that are implicated for secondary task performance.

ERP studies have also shown that the amplitude of the P300 – a brainwave component associated with attentional engagement – is reduced towards a simulated driving task when participants are conversing on a cell phone compared to just driving (Strayer & Drews, 2007). These findings provide additional support of inattention blindness caused by cell phone conversations, in which cell phone users fail to “see” the driving environment. Together with simulators, these cognitive neuroscience techniques can offer new insights into the neural processes underlying driver distraction and substantiate previous behavioural findings.

One of the main advantages of driving simulator studies is that they afford a high degree of experimental control (Young et al., 2009). This makes it possible to evaluate all drivers under the same conditions, while controlling for factors, such as road type, weather, traffic density, number of vehicles, etc. The elimination of extraneous and confounding variables ensures that no alternative explanations are plausible for the observed outcome, other than the experimental manipulation. This high control also makes it easy for researchers to replicate the study in exactly the same way.

Another advantage of simulator studies is the opportunity to measure driving performance in potentially dangerous driving situations. Given the safety concerns associated with driver distraction, simulators can provide a safe and relatively realistic environment to examine these issues without physically putting participants at risk. Hazardous or difficult driving scenarios can be generated to examine how secondary task engagement and driving performance vary under high task demands.

The flexibility of simulators also provides the opportunity to assess driving performance in a wide variety of driving scenarios. Various circumstances can be modified, including weather (e.g., fog, rain, snow), lighting (e.g., day, dusk, night), environment (e.g., rural, urban), road curvature, road surface, presence of vehicles and pedestrians, etc. Driving simulators also enable

researchers to examine the effects of road elements that do not exist (Kaptein et al., 1999). For example, in Chan and Singhal (2013), roadside billboards with positive, negative, and neutral words were generated to investigate their potential for distraction. The results showed that driving performance was differentially affected by the emotional valence (positive vs. negative) of the billboard content. Driving speeds were slower in the immediate presence of emotional words compared to neutral words, and this effect lasted longer with positive words only. Thus, compared to negative information, positive information had both immediate and lingering effects on driving performance, which could be potentially dangerous for drivers.

Driving simulators have also been shown to be a valid tool for assessing driving performance. Behavioural validity refers to the extent to which driving behaviours from the simulator corresponds to the same behaviours that occur when driving in the real world (Mullen et al., 2011). This is determined by comparing driving performance in simulators and on real roads under the same conditions. Behavioural validity can be further expressed in absolute and relative terms. Absolute validity is obtained when the simulator produces the same numerical values as on-road driving. Relative validity is obtained when the simulator produces similar effects (same magnitude and direction) as on-road driving. For a driving simulator to be a useful tool, relative validity must be established, however absolute validity is not necessary (Tornros, 1998). Research has shown that driving simulators can provide good relative (behavioural) validity, demonstrating that their use in driving research is appropriate (Bédard 2010; Lee et al., 2003; Lew et al., 2005; Mullen et al., 2011).

Finally, compared to other research methods, simulator studies are less costly to conduct and data can be easily collected. For instance, the data do not have to be extracted from sensors or cameras.

3.1.4. Limitations and Future Directions

While on-road, test track and driving simulator studies offer many advantages, they also have their limitations. First, the artificiality of some of the secondary tasks may limit the generalizability of the results. For example, in the on-road and simulator studies by Engstrom et al. (2005), the visual and cognitive tasks served as surrogate IVIS tasks, rather than actual in-vehicle systems. The visual task involved searching for a target arrow in an array of non-targets, while the cognitive task involved counting the number of target sounds heard among non-targets. To that end, they do not represent actual secondary tasks performed in real-world driving. In Strayer and Johnson (2001), participants performed a word-generation task over a cell phone while driving. They were instructed to say a new word that began with the last letter of the word read by a confederate over the phone. Other simulator studies have used short-term memory tests (e.g., n-back task) or cognitive tasks (e.g., math problems) to examine the effects of cognitive load on driving performance. Another common task is the peripheral detection task (PDT), a method used to measure the detection of events while driving. Although these artificial secondary tasks often do increase the workload of drivers as intended, they are not a natural part of driving.

Thus, one approach to improving the quality of distraction-related data is to use more realistic secondary tasks that resemble those performed in the real world, such as having participants enter actual destinations or coordinates into a navigation system. Cell phone

conversations should be conducted between participants and confederates more naturally and in a less structured format. For example, some studies use a semi-structured approach that allows the conversation to flow naturally based on the participants' response to questions such as "What is your hometown" or "What is your favorite movie" (e.g., Stavrinou et al., 2011). A similar approach should be applied to driving experiments to better assess the effects of realistic cell phone conversations.

The quality of distraction-related data can also be improved by ensuring the location of the in-vehicle secondary task is accurately placed (Young et al., 2009). For example, when assessing the effects of using a touchscreen interface while driving, the display should be located at precisely the same reaching distance and visual angle as in a real vehicle. This ensures that drivers' downward viewing angle to use or glance at the visual display can be generalized to real-world driving situations. The design of the in-vehicle system should also be as realistic as possible. For example, when examining driver interactions with a music player, such as an iPod, the one used in the study should have the same functions and layout as a standard iPod. Likewise, when examining driver interactions with an on-screen information system, the graphical user interface should consist of the same elements as a real system in terms of windows, menus, and controls.

Another concern with driving simulators is that given the novelty of performing the driving task and secondary task simultaneously, there may be effects of "cognitive overhead" (Jamson et al., 2004). This can occur when participants are unfamiliar with one or both tasks, resulting in reduced driving performance. This extraneous factor can distort the results and lead to incorrect conclusions about the effects of the secondary task on driving performance. One strategy to overcome this is to ensure participants are well-practiced on both the driving task and secondary task and that they can manage both tasks at the same time. However, future research is needed on the amount of training required to address "cognitive overhead."

One particular concern of driving simulator studies is that absolute validity is rarely established. This is often due to differences in the fidelity of simulators. Fidelity refers to the overall realism of the simulator, which can vary from low, medium, and high. The closer the simulator reproduces real-world driving in terms of technical, physical, environmental, and psychological aspects, the greater its fidelity. Low-fidelity simulators are rudimentary, have a static base, and limited image resolution (Kaptein et al., 1996). On the other hand, high-fidelity simulators consist of a moving base, larger field-of-view, high image resolution, surround sound, and presence of vestibular and proprioceptive motion cues. For these reasons, high-fidelity simulators are assumed to have greater absolute validity, although they are more expensive to develop and implement.

For purposes of assessing driving performance, there is often too much emphasis on the fidelity of driving simulators (Godley et al., 2002). Research has shown that high-end simulators do not guarantee absolute validity (de Winter et al., 2007). Moreover, it is believed that relative validity may be more important for behavioural research than absolute validity. According to Tornros (1999), this is because in driving research we are often more interested in comparing the effects between conditions (e.g., driving with a cell phone vs. driving without a cell phone), rather than obtaining the same numerical values in simulated and real world environments. Lee

(2004) further states that “low-fidelity simulators or simulators that intentionally distort the driving experience may be more effective than those that strive for a veridical representation of the driving environment and vehicle dynamics.” In Engstom et al. (2005), the effects of visual and cognitive load on drivers produced similar results with a fixed-based and moving-based simulator, suggesting that both types of simulators are valid for distraction research.

To that end, one approach to improving the quality of simulator data is to determine what aspects of simulator fidelity are important for the research and use it as a guide to optimize the simulator (Young et al., 2009). Given that secondary tasks have been shown to influence lateral control, it may be important to provide motion and visual cues in simulators. In McLane and Wierwille (1975), participants drove a simulator with different numbers of motion and audio cues. The result showed that participants had better lateral control with increasing number of motion cues. This suggests that motion cues may be an important criteria for simulator design. On the other hand, sound cues did not improve performance. Another important finding is that secondary task performance tends to influence the visual scanning behaviour of drivers, particularly the detection of events in the periphery (Young et al., 2009). Accordingly, it may be necessary to use a wider visual display to capture this behaviour in driver distraction research.

Another limitation of driving simulators is that there are no real risks or consequences associated with driver behaviours. As a consequence, the process of allocating attentional resources between the driving task and secondary task may differ in simulated driving compared to real-world driving (Young et al., 2009). Drivers may spend more time engaging in the secondary task while driving a simulator, such as looking away from the road for longer periods of time, because they know collisions have no real adverse effects. To alleviate this limitation, one approach has been to impose penalties on the drivers for collisions, near-collisions, driving off-road, or other violations. These penalties can be monetary or in the form of points.

Finally, driving simulators can sometimes produce simulator sickness (similar to motion sickness). The symptoms include nausea, headache, vertigo, eye strain, fatigue, and postural instability. These symptoms have been associated with sensory conflict between visual and vestibular cues, which can occur when the visual driving scene is moving, but the driver is stationary (Kennedy, Hettinger, & Lillenthal, 1988). The most common approach to mitigating simulator sickness is the use of adaptation. Ample studies have shown that repeated, controlled simulator exposure within or between days can reduce symptoms (e.g., Domeyer et al., 2013; Hill & Howarth, 2000; Howarth & Hodder, 2008).

While an impressive number of experimental studies exists on driver distraction, a few topics warrant future research as listed below (note: this is not an exhaustive list):

1. Although a large body of experimental research has examined the many aspects of cell phone use (e.g., talking, texting, hand-held vs. hands-free, simple vs. complex conversations), the knowledge of other secondary tasks on driver attention and performance pales in comparison. This includes, but is not limited to, using navigation systems, manipulating and viewing TV/DVD players, looking up information on the internet, listening to podcasts/audiobooks, and wearing smartwatches or fitness bands. Further research is needed to substantiate previous findings and obtain additional

information on these distractions – such as the effects of performing different subtasks on a navigation system (i.e., entering destination, following destination, landmark recognition, and error recovery). Smartwatches allow people to text, make calls, check emails, and access the internet, while fitness trackers monitor the 24-hr activity of people, such as heartrate and distance travelled. Both devices send out notifications and alerts that could potentially be distracting to drivers.

2. With the rise of social media, future experiments should explore the effects of accessing social networks (Twitter, Facebook, Instagram, YouTube, etc.), taking selfies, sending voice, picture, or video messages (Snapchat), playing games, and using other apps on smartphones while driving, particularly among young drivers.
3. Research is needed to understand the effects of personality on driver distraction. Studies have shown that personality factors can lead to different driving profiles (Fine, 1963; Taubman-Ben-Ari & Yehiel, 2012). Individuals who score high on Extraversion tend to drive more recklessly, while those that score high on Agreeableness and Conscientiousness tend to drive more safely (Taubman-Ben-Ari & Yehiel, 2012). It has also been reported that extraverts incur more traffic accidents and violations than introverts (Fine, 1963). Future experiments should include personality measures (such as the Eysenck Personality Questionnaire) to determine how individual differences in personality would interact with secondary tasks to influence driving performance.
4. Future research should examine the effects of mindfulness on distraction and driving performance. Similar to meditation, mindfulness is a practice used to train the mind to increase attention and awareness to the present moment (Kass et al., 2011)). Evidence shows that mindful drivers tend to have better situational awareness and driving performance than controls (Kass et al., 2011). Whether mindfulness can be used to overcome distraction in driving has not been ascertained. In Feldman et al. (2011), the relationship between mindfulness and frequency of texting while driving was examined. Mindfulness was assessed with the Cognitive and Affective Mindfulness Scale. The results showed that individuals who scored low on mindfulness reported more frequent texting while driving than individuals who scored high on mindfulness. To date, this is the only known study to examine the relationship between mindfulness and distracted driving. Future research should investigate this in an experimental setting to determine how mindfulness would influence driving performance under a concurrent secondary task.

3.1.5. Experimental Studies on Distracted Riding, Walking, and Cycling

Motorcycle (riding) simulators consist of a motorcycle mock-up with a seat, handlebars, foot pedals, and visual display. Like driving simulators, they provide objective measures of riding performance, including speed, lateral control, headway activity, acceleration, and brake reaction time.

In a motorcycle simulator study, Megias et al. (2011) examined the effects of emotional advertising billboards on riding behaviours. Participants rode in the presence of billboards that evoked negative emotions (e.g., pictures of mutilations), positive emotions (e.g., pictures of

romance) or neutral emotions (e.g., picture of a book). The eye-tracking data showed that riders looked at emotional billboards more often and for longer periods of time than neutral ones. These findings indicate that emotional content can interfere with safe riding by diverting attention away from the forward road.

In Di Stasi et al. (2010), the effects of emotional auditory sounds were examined on riding performance. Participants rode while going through several hazardous situations, such as vehicles coming from the side or unexpected obstacles on the road. Some of the hazards were cued by a neutral beep or emotional sound (e.g., a scream or laugh). The authors found that hazardous situations preceded by a beep reduced the likelihood of collisions. The beep also decreased speed and directed gaze to relevant regions of the scene (e.g., the road ahead, mirrors, etc.). On the other hand, emotional sounds did not improve riding performance and, in fact, increased the risk of accidents. These findings have important implications for rider assistance systems that use auditory warnings; the authors suggest that emotional sounds should be avoided as they may be counter-productive to riding safety.

In Will and Schmidt (2015), riding performance was examined under four conditions. Participants rode with no secondary task, while counting targets in an audiobook (auditory), while performing a peripheral detection task (visual), and while navigating through a set of menus on a touchscreen (visual-manual). The results showed that riding performance was associated with the highest workload in the visual-manual condition, as indicated by high subjective ratings of workload, reduced speed, and increased lane variability compared to the other conditions. These findings advise caution in using on-bike information systems and other touchscreen interfaces while riding.

While riding simulators are useful for assessing the potential for distraction without placing participants at risk, little is known about their validity, particularly for low and medium fidelity simulators. One study compared the validity of two types of riding simulators – reduced motion simulators and dynamic simulators (Benedetto et al., 2014). Reduced motion simulators are low-cost, consist of a seat, handlebars, pedals, and a small screen, and provide little tilting motion. Dynamic simulators use a real motorcycle, provide motion feedback, and allow leaning of the bike. The study concluded that dynamic simulators have higher validity, by capturing more realistic aspects of on-road riding. While low-fidelity riding simulators appear to be useful for training purposes (e.g., Vidotto et al., 2011), whether the effects of distraction transfer to real-world riding is unknown.

Another limitation of motorcycle simulators is that collisions and errors have no actual adverse consequences. As a result, participants may allocate their resources to the secondary task and riding task differently in simulators than they normally would on a real motorcycle. For example, given the absence of actual crash risk associated with simulators, participants may spend more time looking at billboards than otherwise. Motorcycle simulators also do not fully replicate the real dangers associated with motorcycles. The impact of collisions in riding are typically more serious or fatal than motor vehicle collisions, however the experience of vulnerability in simulated riding is absent. To that end, the results of distracted riding may not generalize as well to real-life situations.

To study distracted walking, immersive virtual environments have been used to examine the relationship between secondary task engagement and pedestrian behaviour. The virtual environments are typically displayed on computer monitors or projectors around the participant. To simulate street crossing, participants first watch the traffic in a first-person point of view as they stand on a “curb” (such as one constructed from plywood). As they step down the curb to cross, the traffic switches to a third-person point of view so that participants can see all elements of the environment while they walk (Schewebel et al., 2008).

In Stavrinos et al. (2011), participants crossed a simulated street environment while conversing on a cell phone or with no distraction present. Participants spoke with a confederate over the phone who kept the conversation as natural as possible. The study found that pedestrians involved in cell phone conversations displayed more risky behaviours when crossing the street than those not distracted. Distracted pedestrians missed more opportunities to safely cross the street, had more hits/close calls to getting struck by a vehicle, and left less time to spare after safely crossing the street until the next vehicle passed.

In the second experiment, different phone conversations were examined on pedestrian behaviour. Participants crossed the street with no distraction, while engaged in a naturalistic phone conversation, while engaged in a spatial task over the phone, and while engaged in a mental arithmetic task over the phone. The study revealed that all forms of cognitive distraction led to the same risky behaviours that were reported in the first study. Both mundane and more cognitively demanding conversations, such as performing spatial and arithmetic tasks, induced similar levels of distraction among pedestrians.

In Neider et al. (2010), a treadmill was used in conjunction with a virtual street-crossing environment to examine the effects of distraction on pedestrian behaviour. Participants walked on the treadmill (synced to the virtual environment) while conversing on a cell phone, while listening to music, or without distraction. The phone conversations were led by a confederate in a naturalistic manner. The study found that pedestrians were less likely to safely cross the street without getting hit by a vehicle when engaged in a cell phone conversation compared to listening to music or when not distracted. Cell phone users also took longer to initiate their crossing compared to pedestrians in the other conditions.

In Schwebel et al. (2012), participants crossed a virtual street under four conditions: (1) while conversing on a cell phone, (2) while texting, (3), while listening to music, or (4) without distraction. The phone conversations and text messages were naturally conducted with a confederate. The results showed that all distracted pedestrians were more likely to look away from the virtual street than when not distracted. In addition, pedestrians who listened to music or texted were more likely to be hit by a vehicle compared to when not distracted. These findings differ from those reported by Stavrinos et al (2011) and Neider et al. (2010), where cell phone conversations were found to increase the risk of getting hit by a vehicle. Additional research is necessary to elucidate these inconsistencies, which may be due, to part, to differences in the sample of pedestrians, the rendering of the virtual environment, or the way the phone task was carried out.

A main advantage of virtual environments is that distraction can be studied without putting pedestrians in danger. As a result, pedestrians can be exposed to risky scenarios, such as street crossing, which would be dangerous, if not unethical, to examine in the real world. Additionally, virtual environments afford a high degree of control over factors such as the length of the crosswalk and flow of vehicles passing by. In particular, the virtual environments used in Stavrinos et al. (2011), and Schwebel et al. (2012) have been validated in its ability to represent pedestrian behaviour in the real world (Schwebel et al., 2008).

However, there are concerns as to whether pedestrians would engage in cell phone conversations the same way (even when conducted naturally) when in a simulated environment as in the real world. Given the lack of real danger associated with getting struck by a vehicle, pedestrians may prioritize the secondary task over crossing safety. Data could be improved by implementing a reward-penalty system among pedestrians. For example, pedestrians could be rewarded for safety crossing the street and penalized for instances of hits or close calls.

In two of the studies reviewed, listening to music did not play a major role on walking performance, however this finding should be cautiously interpreted. Neider et al. (2010) suggests that listening to music may be less cognitively demanding than conversations, which may interfere less with the crossing task. However, other studies have shown that listening to music can reduce the perception of auditory stimuli, such as while cycling (de Waard, 2011). In situations where auditory information is critical to the safety of the pedestrian, such as the sound of vehicles approaching from behind, listening to music may be potentially hazardous. Future research is warranted to examine the role of listening to music (and more complex materials, such as podcasts) on auditory perception among pedestrians.

As with many distraction-related experiments, there is a need for caution in generalizing the results to real-life situations given the artificiality of some of the secondary tasks. In Stavrinos et al. (2011), pedestrians performed cognitively challenging tasks such as spatial and mental arithmetic tasks over the phone. However, these tasks do not reflect the nature of real conversations.

On the topic of distracted cycling, only two known experimental studies have been published, both by de Waard et al. (2010; 2011). These studies were conducted outside the laboratory on actual bicycle paths. Speed was measured with a GPS device and lateral control was measured offline from video data. In the first field study, cyclists rode with no distractions (control condition), while listening to music, and while using a cell phone. Cyclists talked on the phone or entered a text message. The results showed that, compared to the music and control conditions, using a cell phone impaired cycling performance. Talking on a cell phone reduced cycling speeds and peripheral vision. Texting had an even larger effect on cycling performance, as speed was reduced even further. Lateral control and peripheral vision were also impaired while texting.

In the second field study, cyclists rode with no distractions, while listening to music, and while talking on a phone. Participants listened to music using one standard earbud, two standard earbuds, or two in-earbuds. Auditory perception was assessed by having cyclists count the number of times a bicycle bell was heard. The authors found that talking on a cell phone and

listening to music both reduced the number of auditory stimuli detected compared to when not distracted. In particular, listening to music using in-earbuds had the most detrimental effect on auditory perception.

While these findings are novel and provide a starting point for more experiments on distracted cycling, one of the major limitations is that the phone tasks used were not naturalistic, and may perhaps be more complex than normal conversations and text messages. In both studies, cyclists performed math calculations over the phone, such as subtracting 7 from each number, starting from 846. Cyclists also texted the following phrase on the phone: Lang zal ze leven, lang zal ze leven, lang zal ze leven in de gloria (a birthday song in Dutch). To that end, the artificiality of the phone tasks warrants caution in generalizing these findings to actual conversations and text messages while cycling. Another limitation is that the cycling conditions were all performed with no other traffic present. Accordingly, the cycling task demands are likely lower than in real-life situations.

From this review of experimental studies on distracted walking, cycling, and riding, it is clear that further research is needed to not only validate these findings, but to obtain additional information on the nature and extent to which distracting activities interfere with traffic performance. Many open questions remain for future experiments on distracted road use by pedestrians, cyclists, and riders, including, but not limited to:

1. What are the effects of other potentially distracting activities, such as eating/drinking, navigating with a GPS, conversing with other road users, looking at roadside objects (e.g., advertising billboards), and using email, internet, and social media?
2. How do different types of distraction (visual, cognitive, auditory, and visual-manual) influence the effects of traffic performance?
3. What are the effects of secondary task distraction on other cognitive processes such as decision-making, hazard detection, working memory, and motor initiation?
4. What compensatory strategies do pedestrians, cyclists, and riders use to minimize the effects of distraction?
5. How do changes in the traffic environment influence the potential for distraction? For example, navigating through a busy intersection vs. a quiet one in a residential area?
6. What is the relationship between age/experience and susceptibility to distraction?

3.2. Naturalistic Driving Studies

Naturalistic studies are conducted in the natural environment without any manipulation of variables by an experimenter. In naturalistic driving studies, drivers drive an instrumented vehicle on real roads for an extended period of time. The instrumented vehicles are equipped with unobtrusive video cameras and on-board sensors that track speed, lane position, steering wheel activity, acceleration, brake response, and headway. Data is continuously recorded as

drivers perform their everyday driving activities. Unlike on-road studies, the driver can drive anywhere and freely choose to engage in any secondary activities without instructions or interference from an experimenter. In driver distraction research, naturalistic driving studies are often used to obtain in-depth information on the types and prevalence of distracting activities engaged in by drivers, and the contribution of these activities on driving performance and crash risk (Young & Regan, 2009).

While several large-scale naturalistic driving studies have been conducted to assess driver distraction, no naturalistic studies have investigated the exposure of distracting activities among pedestrians and cyclists (see section 3.2.2 for more on this). In 2011, the Motorcycle Safety Foundation and Virginia Tech Transportation Institute initiated the first large-scale motorcycle naturalistic study, known as the 100 Motorcyclists Naturalistic Study. While the findings are not published yet, the study is expected to provide better information on rider behaviour and how different events and factors contribute to the risk of crashes and near-crashes (McLaughlin et al., 2011).

Naturalistic driving studies have several advantages. A major benefit is the opportunity to examine driver behaviour in the real world. Accordingly, these studies tend to have high ecological validity. The video data allows capture of all distracting activities exhibited by drivers, as well as the frequency and duration of these activities (Dingus, 2014). Sensors and eye-tracking systems in the vehicle can provide additional information on driving performance and eye glance behaviour during distracting events. The opportunity to obtain pre-crash data sheds light on the events and factors leading up to a crash or near-crash, such as whether the driver was drowsy or distracted. More importantly, this information can be used to calculate the increased risk of being involved in a crash or near-crash when engaged in specific secondary tasks. This is reported as odds ratio, which measures, for example, cell phone use during crash/near-crash events and non-events (normal, baseline driving). Odds ratio is used as an approximation of relative crash/near-crash risk and can be calculated with the following equation (Dingus & Klauer, 2008):

Odds Ratio = $(A \times D) / (B \times C)$, where:

A = the number of crashes/near crashes where drivers were involved in a secondary task

B = the number of crashes/near crashes where drivers were attentive

C = the number of baseline epochs where drivers were involved in a secondary task

D = the number of baseline epochs where drivers were attentive

An odds ratio of 1.0 indicates no significant risk from baseline driving. An odds ratio of over 1.0 indicates increased risk of secondary task engagement. An odds ratio of less than 1.0 indicates the risk of secondary task engagement is less than that of baseline driving (Dingus & Klauer, 2008). Finally, eye glances away from the forward road can be measured to determine if the risk of secondary task involvement is related to glance behaviour.

One of the first large-scale naturalistic driving studies was conducted by Stutts et al. (2003). In the study, cameras were installed in the vehicles of 70 drivers over the age of 18. The

drivers were monitored for a 1-week period and 3 hrs of video data were coded and analysed per driver to determine their exposure to distracting activities (a total of 207 hours coded).

The results showed that drivers spent over 15% of the total time that the vehicle was moving conversing with passengers. Excluding the time spent talking to occupants, drivers were engaged in at least one distracting activity up to 16% of the total time that the vehicle was moving. Drivers spent the most time eating and drinking, attending to an internal distraction (e.g., manipulating vehicle controls, reaching or looking for something in the vehicle), attending to an external distraction (e.g., looking at something outside the vehicle), and smoking. On the other hand, when the vehicle was stationary, drivers were more likely to be grooming, reading or writing, dialing a cell phone, and talking on a cell phone. These findings suggest that for some activities, drivers choose to engage in them when it is “safer” on the road. In terms of driving performance, most distractions were associated with longer eye glances off the road, driving with one or no hands on the steering wheel, and more lane wanderings.

In the 100-Car Naturalistic Driving Study, video data from 100 instrumented vehicles were recorded (Klauer et al., 2006). Drivers aged 18-72 years were monitored for 1 year and a total of 2,000,000 miles were driven. The study garnered 42,300 hours of data, including data for 69 crashes, 761 near-crashes, and 8,295 incidents. The types of distracting activities engaged in by drivers were quantified and the relative crash/near-crash risk (odds ratio) associated with a given distracting activity was calculated.

The results showed that driver distraction attributed to secondary task engagement contributed to over 22% of crashes and near-crashes. Eye glances that totaled more than two seconds away from the forward road were found to significantly increase crash/near-crash risk. As summarized in Table 2.3 (in section 2.5.1), three categories of secondary tasks were analyzed, based on the manual/visual complexity of the tasks: complex secondary tasks, moderate secondary tasks, and simple secondary tasks (Klauer et al., 2006). Complex secondary tasks were those that required multiple button presses and/or multiple eye glances away from the road (e.g., dialing a hand-held phone, using a PDA, reaching for a moving object). Moderate secondary tasks were those that required at most two button presses and/or two eye glances away from the road (e.g., talking on a hand-held phone, inserting a CD). Simple secondary tasks required at most one button press and/or glance away from the road (e.g., adjusting the radio, talking to a passenger, lost in thought). The odds ratio was 3.1 for complex secondary tasks, 2.1 for moderate secondary tasks, and 1.0 for simple secondary tasks. This indicates that drivers engaged in a complex secondary task were three times more likely to be involved in a crash/near-crash than when not distracted. Drivers engaged in a moderate secondary task were two times more likely to be involved in a crash/near-crash. Finally, engaging in simple secondary tasks did not show any significant risk from baseline driving.

Other significant findings were that pure cognitive secondary tasks, such as lost in thought, were generally less risky than visual-manual secondary tasks. Talking with a passenger was also less risky than talking on a hand-held cell phone (Dingus & Klauer, 2008). This was a significant study as it was the first to provide a comprehensive picture of relative crash risk associated with specific secondary tasks while driving. Using real-world data, the study provided

direct evidence that engaging in complex visual-manual tasks is a significant risk factor for crashes/near-crashes.

In Olson et al. (2009), two naturalistic driving studies were conducted to examine the role of distraction in commercial truck drivers. In the first study, 103 instrumented trucks were monitored for 18 months, while 100 trucks were monitored for four weeks in the second study. The data were combined for a total of 62,500 hours recorded and 4,452 safety-critical events (SCEs), occurring in the form of crashes, near-crashes, and other crash-relevant events (e.g., unintentional lane departures). The results showed that drivers were engaged in secondary tasks in 71% of crashes, 46% of near-crashes, and 60% of all SCEs. The most risky task was texting, which had an odds ratio of 23.2. Other high-risk tasks were using a dispatching device (OR=9.9), dialing a cell phone (OR=5.9), using/reaching for an electronic device (OR=6.7), and reaching for other objects (OR=3.1). The eye glance analysis also revealed that tasks with high odds ratios were associated with more and longer eye glances away from the forward road. Texting (OR=23.2) was shown to take the driver's eyes off the road for up to 4.6 s.

In the Naturalistic Teenage Driving Study, 42 teenage drivers (all 16 years of age) were monitored while driving instrumented vehicles for 18 months (Klauer et al., 2014). 31 crashes and 136 near-crashes were included in the analyses. Data from this study was compared with the 100-Car data set, which consisted of adult drivers. The results showed that several secondary tasks significantly increased the risk of a crash/near-crash, including dialing a hand-held phone (OR=8.3), reaching for a phone (OR=7.1), texting (OR=3.9), reaching for other non-moving objects (OR=8.0), looking at an external object (OR=3.9), and eating (OR=3.0). In contrast, only dialing a hand-held phone was associated with elevated crash/near-crash risk among adult drivers in the 100-Car Study (texting was not measured in the 100-Car study). These findings show that crash risk is higher for certain secondary tasks for teenage drivers than adult drivers, particularly tasks that required the driver to look away from the road. This is likely due to inexperience and lack of residual attentional resources to allocate between the driving task and secondary task (Dingus, 2014).

The largest and more recent naturalistic driving study is the second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study (NDS). The study monitored 3,147 drivers aged 16-80 over a 3 year period (2010-2013), with most drivers participating for 1 to 2 years (Campbell, 2012). This resulted in 49.7 million miles travelled and over 1 million hours of data. Using the SHRP 2 NDS data set, Victor et al. (2015) recently examined the relationship between driver inattention and crash risk in rear-end crashes. Because SHRP 2 data collection was still ongoing at the time of the study, the analyses included 46 rear-end crashes and 211 near-crashes. The findings regarding secondary tasks replicated those reported in Klauer et al. (2006). Additionally, the study found that the odds ratio for the combined category of Portable Electronics Visual-Manual tasks was 2.7, while texting was 5.6, an indication of their high crash risk.

3.2.1. Limitations and Future Directions

While naturalistic driving studies have many advantages, they also have their limitations. One particular concern is that the coding of secondary tasks relies heavily on the subjective interpretation of the analysts. Accordingly, the coding may be subject to bias and errors. In the

study by Stutts et al. (2003), a low inter-coder reliability was noted (65-70%) due to issues in objectively coding certain types of distracting activities (McEvoy & Stevenson, 2009). Additionally, cognitive distraction cannot be reliably identified from the video footage. As a result, the prevalence and crash risk of pure cognitive distractions, such as mind-wandering, presence of passengers, or thinking about an external distraction may be inaccurate or not reported.

Another area of concern is that the presence of cameras in the vehicle may cause drivers to behave differently. Knowing they are part of a study, drivers may exhibit fewer unsafe driving behaviours, or minimize their exposure to distracting activities. Consequently, the prevalence and frequency of secondary task use found in these studies may not be representative of all drivers, and in fact, may be underestimated.

Naturalistic driving studies are also extremely costly and time-consuming to conduct (can take several months or years). As a result, the sample size is often small, which raises questions about how accurate the sample is of the general driving population. There may also be problems associated with the cameras and data collection equipment in the vehicle. In the 100-Car study, several issues were encountered including equipment malfunctions and the large amount of data that needed to be stored and analyzed (hours of driving data) (McEvoy & Stevenson, 2009).

Another challenge of naturalistic driving studies is that the data collected contains a vast amount of variables, including weather, light conditions, road type, traffic density, driver behaviour (e.g., distraction), and driver states (e.g., fatigue) (Dozza et al., 2013). Thus, unlike experiments, where each variable is controlled for, the diversity of driving situations in naturalistic driving studies requires separating out each variable in order to extract the ones of interest. For example, extracting measures, such as eye glance duration, in which the driver was engaged in a specific distracting activity and then aggregating the measure across segments. This must be performed before data analyses (e.g., the calculation of certain parameters to assess crash risk). However, traditional methods often fail to account for the length of the segment when extracting certain variables of interest, which can introduce bias in the results (Bärgman, 2015).

The quality of naturalistic driving data can be improved by using a method called chunking that can reduce this bias. Chunking is used when one needs to extract and aggregate measures across certain conditions (e.g., using a cell phone) (Bärgman, 2015). Dozza et al. (2013) describes chunking as “[dividing the] data into equivalent, elementary chunks of data to facilitate a robust and consistent calculation of parameters.” Thus, parameters such as eye glance duration and lane deviation are analysed on segments of the same length. Another advantage of chunking is that it provides the opportunity to match baseline events (e.g. undistracted driving) and exposure events (e.g., using a cell phone) according to variables such as weather, lighting, road type, etc. In Dozza et al. (2013), the authors applied chunking to a naturalistic driving study and compared it to traditional methods use in previous naturalistic driving studies such as the 100-Car Study. While details of the procedure are beyond the scope of the report, briefly, chunking and traditional methods were used to extract speed velocities over 70 km/h before data analyses. A comparison of the results showed that chunking led to more consistent calculations of parameters and increased statistical power.

Another limitation is that only a small number of crashes are recorded in naturalistic driving studies. According to Guo et al. (2010), even large naturalistic driving studies with thousands of vehicles would still result in approximately 1,000 crashes. Compared to the number of crashes found in crash databases, this is a relatively small number. To overcome this, the 100-Car Study combined the number of crashes (69) with near-crashes (761). While it has been shown that near-crashes are a sufficient surrogate for crashes (Guo et al., 2010), this combined data set has raised a number of questions that remain unsolved.

First, there are questions as to whether the estimates of risk are the same for near-misses and more serious crashes that result in injury. There are also concerns about aggregating crashes of different levels of severity. According to Dingus (2014), crashes that differ in severity often have different contributing factors that lead up to the crash. For example, fatal crashes are often associated with physical force factors that impact the human body, such as excessive speeding or not wearing a seatbelt. These factors are less influential in crashes that are minor or property damage-only. As a result, it is unclear how these different factors may affect the estimate of risk in the 100-Car study. Finally, a third unknown is whether the estimates of risk from the 100-Car data set are representative of all crash types, such as rear-end crashes, head-on crashes, or intersection crashes (Victor et al., 2015). Future research should examine this to provide a more comprehensive picture of the contribution of secondary task engagement to different types of crashes.

Another limitation of the 100-Car Study is that the data was collected in metropolitan and urban areas only. As a result, the findings cannot be generalized to the general driving population. Future research should examine the frequency of distracting activities and their associated risk in rural areas to determine if crash/near-crash risk is more or less likely to occur. Research has shown that rural areas have a higher risk of motor vehicle fatalities and a different traffic safety culture compared to urban areas (Rakauskas et al., 2009). Drivers in rural regions tend to have lower perceptions of risk associated with risky driving behaviours than urban drivers; how this would interact with secondary task engagement and crash risk is currently unknown.

Additional research is also needed on how specific driving contexts would influence the frequency and risk of secondary task distraction. A recent naturalistic driving study examined drivers' propensity to engage in visual-manual phone tasks based on driving context, such as light conditions (daytime, dusk, night), driving speeds, making turns, changing lanes, the presence of a lead vehicle, and the presence of a passenger (Tivesten & Dozza, 2015). The study found that drivers were more likely to engage in visual-manual phone tasks (i.e., texting, dialing, and reading) when the vehicle was stopped, and less likely while driving at high speeds or when a passenger was present. Light conditions did not influence drivers' willingness to engage in visual-manual phone tasks. When a lead vehicle was present, drivers engaged in visual-manual phone tasks adopted compensatory strategies by increasing the following distance. Drivers also adjusted the timing of secondary task use until after a turn or lane change had been made. These findings suggest that drivers use information in the driving context to decide when to engage in visual-manual phone tasks. Further research is needed to substantiate these findings. Additionally, future naturalistic driving initiatives should be taken to examine how unexpected critical events, such as a lead vehicle suddenly braking or a pedestrian unexpectedly stepping

into the road, would influence drivers' ability to respond appropriately when engaged in visual-manual phone tasks or other secondary tasks.

Naturalistic driving studies have consistently shown an increased risk of crash/near-crash from performing visual-manual tasks on a cell phone but not from conversing on a cell phone (Fitch et al., 2013; Klauer et al., 2006; Olson et al. 2009). According to Fitch et al. (2015), this reduction in risk may be due to the inclusion of scenarios in the analyses where driving task demands are low, and as such, the driver has enough attentional resources to allocate to both the driving task and phone conversation.

Using naturalistic driving data, Fitch et al. (2015) examined the risk of a safety-critical event (SCE) associated with cell phone use in different driving contexts. Commercial motor truck drivers and light vehicle drivers were compared. The driving contexts were based on traffic density and proximity to intersections and merge ramps. The study found that as driving task demands increased (i.e., increased traffic density and near an intersection or merge ramp), truck drivers conversed less frequently on a cell phone. However, light vehicle drivers did not modulate their conversations based on driving task demands. There was also an interaction of driving context on cell phone use and its associated risk of a SCE. In some driving contexts (non-junction road segments with low traffic density), SCE risk was increased from performing visual-manual subtasks. On the other hand, SCE risk was decreased from conversing on cell phones when near an intersection or merge ramp. The authors advise caution in interpreting these results because the cognitive load imposed by the phone conversations may not have been high enough to increase the risk of a SCE.

As this is the first study to examine the influence of driving context on the risk of a SCE associated with secondary task use, further research is needed to validate and extend these findings. In particular, more research is needed to delineate the findings of reduced risk from talking on cell phones. Future research is also warranted to assess the extent to which driving context changes the SCE risk of other secondary tasks, such as reaching for objects, conversing with passengers, using in-vehicle systems, and looking at external objects in naturalistic driving.

3.2.2. Naturalistic Studies on Distracted Walking, Cycling, and Riding

To date, no naturalistic studies have investigated the exposure of distracting activities while walking and cycling, and only one naturalistic study has looked at this while riding. Below is a list of priorities for future research on distracted walking, cycling, and riding:

1. Naturalistic studies are needed to assess the prevalence, frequency, and duration of actual secondary tasks engaged by pedestrians, cyclists, and riders.
2. Real-world data is needed to identify the events and factors leading up to crashes and near-crashes involving pedestrians, cyclists, and riders.
3. Research is needed to establish the risk of a crash or near-crash when vulnerable road users are engaged in specific secondary tasks.
4. Naturalistic studies should examine the risk of a crash or near-crash associated with secondary task distraction in different traffic contexts (e.g., busy roads vs. quiet roads).

One study examined actual pedestrian behaviours using video data from instrumented vehicles (Tian et al., 2013). 110 vehicles were equipped with forward-facing cameras that captured what the driver saw. This data was used to analyze the walking gait of pedestrians as they crossed roads. Video clips with pedestrians were identified using a pedestrian detection algorithm, and tagged for analyses and coding. Future research could use a similar methodology to collect naturalistic data on the prevalence of secondary tasks engaged by pedestrians while walking and their subsequent effects on real crossing behaviour.

Johnson et al. (2010) used instrumented bicycles to capture naturalistic data on cyclist behaviour. The bicycles were equipped with cameras, a GPS, and brake/pedal sensors. While the study aimed to identify risk factors for crashes and near-crashes, such as biking too fast or being near an intersection, secondary tasks were not assessed. Future research should use a similar methodology to investigate cyclists' exposure to distracting activities and the contribution of these activities to crash causation.

In the 100 Motorcyclists Naturalistic Study, 100 participants were recruited to ride an instrumented motorcycle for 8-12 months over a 3.5 year period (Williams, 2014) The instrumentation included cameras, helmet and gaze tracker, lane tracker, brake sensors, speed sensors, accelerometer, turn signal tracker, GPS, and forward radar. As provided by the NHTSA, the following is a list of some research questions the study hoped to address (McLaughlin et al., 2011):

1. What are riders looking at when they have crashes and near-crashes?
2. What is the relation between exposure and crash and near-crash involvement?
3. Does the number of crashes and near-crashes increase with exposure?
4. What is the interaction between riding experience and exposure?
5. What is the prevalence of secondary tasks in crashes and near-crashes?
6. What is the sequence of events and factors leading up to crashes and near-crashes?

3.3. Observational Studies

Like naturalistic driving studies, observational studies (also known as roadside surveys) are conducted in real traffic. The main difference is that, in observational studies, trained observers stand on the roadside and record the behaviour of drivers that pass the observation site. As there is no intervention by an experimenter, these studies tend to have high ecological validity.

In driver distraction research, roadside observational studies are often used to measure the types and prevalence of distracting activities engaged by drivers at a single point in time. This information is important for developing countermeasures to minimize distraction. Additionally, observational data can be collected before and after the implementation of a countermeasure to determine its effectiveness. Although several observational studies have investigated the prevalence of distracting activities engaged by drivers, only a few studies have examined this among pedestrians and cyclists (reviewed in section 3.3.2). No observational data are available on the prevalence of secondary task use among riders.

A major advantage of observational studies over naturalistic driving studies is that driver behaviour can be observed without relying on drivers to drive instrumented vehicles over an extended period of time. Therefore, observational studies are usually less time-consuming and less costly to conduct. They also provide a large amount of data, with some studies having sample sizes over 100,000. Another advantage of these types of studies is that driver behaviour can be observed without having to use cameras. Consequently, changes in behaviour caused by the presence of cameras can be avoided (Huisingsh et al., 2015).

In a 2006 observational study conducted in Canada, hand-held cell phone use from 133,577 vehicles was observed in rural and urban communities (Burns et al., 2008). The results showed that 2.8% of drivers in rural areas, and 5.9% in urban areas were observed using a cell phone while driving. Cell phone use was highest in urban Alberta (11.7%), which was twice the national average for urban areas. Phone use was lowest in Nova Scotia for both rural (0.8%) and urban areas (2.2%). 6.7% of drivers using a cell phone were under 25 years, while 4.5% were 25-29 years old. Drivers aged 50 and older (2.4%) were least likely to use a cell phone. Slightly more females (4.5%) were using a cell phone while driving than males (4.0%), however this difference was not significant. At the time of the study, only Newfoundland and Quebec prohibited the use of hand-held cell phones while driving.

In Melbourne, Australia, an observational study conducted in 2002 found that 2.0% of drivers observed were using a hand-held cell phone while driving (Taylor et al., 2003). At the time of the study, hand-held phone use while driving was banned in the state of Victoria. In 2005, additional restrictions on drivers' use of phones were introduced, including stricter penalties and increased enforcement. The study was conducted in exactly the same way in 2006 to assess the change of phone use while driving (Taylor et al. 2007). The results showed that 1.6% of the drivers observed were using a hand-held cell phone while driving. The authors suggested the slight decrease may be attributed to the stricter legislation and increased enforcement against cell phone use while driving.

In 2012, the National Occupant Protection Use (NOPUS) Survey observed drivers' use of electronic devices from 37,813 vehicles in the U. S. (Pickrell, 2014). The study found that 5.0% of drivers were holding a cell phone to their ears while driving. This usage was highest among drivers aged 16-24 years, and lowest among drivers aged 70 and over. 0.5% of drivers observed were talking on a headset and 1.5% were visibly manipulating an electronic device (e.g., texting/surfing the internet on a smartphone or PDA). At the time of the study, 11 states had a law limiting the use of hand-held cell phones by drivers.

In a recent study by Huisingsh et al. (2015), the prevalence of distracting activities other than cell phone use were observed in 3,265 vehicles in metro Birmingham, Alabama. Nearly 33% of drivers observed were engaged in a secondary task. The most common distractions were interacting with another passenger (53.2%, when a passenger was present), talking on a cell phone (31.4%; hand-held or hands-free), external-vehicle distractions (20.4%), and texting/dialing a phone (16.6%). No state limitations were placed on drivers' use of cell phones at the time of the study.

In another recent study, Sullman et al. (2015) observed 10,984 vehicles in the city of St. Albans, UK. 17% of drivers observed were involved in a distracting activity. The most common activities were talking to a passenger (8.8%), smoking (1.9%), and talking on a cell phone (hands-free: 1.7%; hand-held: 1.0%). The use of hand-held cell phones by drivers was prohibited at the time of the study, which may explain the lower usage rate found here compared to the previous two studies in Canada and the U.S.

In Girona, Spain, 6,578 vehicle were observed in urban locations (Prat et al., 2014). About 20% of the drivers observed were engaged in a distracting activity while driving. The most common activities were conversing with a passenger (11.1%), smoking (3.7%), and talking on a hand-held cell phone (1.3%). There were no gender differences, however young drivers (under 30 years) were significantly more likely to be using electronic devices (talking on a cell phone, texting, manipulating audio controls or a navigation device) than older drivers (over 50 years). At the time of the study, a law prohibited the use of cell phones and any electronic/communication devices while driving.

Collectively, observational data indicate that a substantial proportion of drivers engage in secondary tasks (up to 33%). Cell phone use varies, on average, from 2% to 6%, depending on the country and whether a cell phone ban was in effect during the observations. These numbers are concerning and suggest that further efforts may be needed to reduce driver distraction.

3.3.1. Limitations and Future Directions

While observational studies allow for the direct observation of drivers from the roadside, they also suffer from a few limitations. One particular concern is that the observations are often made at controlled intersections or on roads with lower speeds (Young & Regan, 2009). Because of this, the estimates of secondary task use may not be representative of usage at other traffic/roadway locations. It is possible that drivers are more likely to engage in secondary tasks when stopped at intersections or on lower speed areas because driving task demands are lower. How this would generalize to freeways or highways where a higher level of attention is required for the driving task is in question. Future research should attempt to address this to better understand the exposure of distracting activities on other types of roads.

Another concern is that the roadside observations are often made during the daytime. Because of this, the estimates of secondary tasks may not be representative of usage at night. Observational data can be improved by conducting more studies that assess the use rate of distracting activities at night. This is important as nighttime driving is believed to be more dangerous than day time driving. Studies have also found that significantly more motor vehicle fatalities occur after dark than otherwise (e.g., Plainis et al. 2006). Factors that contribute to this include poor vision from reduced visibility, lack of street lighting, fatigue, and alcohol use.

One of the few observational studies to examine drivers' use of cell phones at night used specialized night vision equipment to record the behaviour of drivers (Vivoda et al., 2008). 7,076 drivers were observed in Indiana from 9:30 PM to 5.45 AM over a series of days. The equipment used by observers were military night vision goggles with infrared illuminators. The study found that 5.8% of drivers observed were talking on hand-held cell phones at night. The highest usage rate was among females between 16-29 years of age compared to other combinations of gender

and age. The overall use rate of cell phones by drivers at night is on par with findings conducted during the day time. Given the known risks of driving after dark and the elevated risk of using a cell phone while driving, these results have important implications for the development of countermeasures that target nighttime distracted driving (Vivoda et al., 2008). Future research should continue to examine the use of cell phones at night, as well as other distracting activities, to provide a more comprehensive picture of the prevalence of driver distraction during all hours of driving.

Observational studies also tend to provide lower estimates of prevalence than what has been reported in naturalistic driving studies. This is because driver behaviours are measured at a single point in time, while naturalistic driving studies collect information on drivers for an extended period of time (several months or years) (Young & Regan, 2009). Observational studies are also limited in that they can only provide information on the prevalence of driver distraction, while naturalistic driving studies can provide additional exposure information, such as the frequency and duration of secondary task engagement (Young & Regan, 2009).

Another limitation is that only distracting activities that are seen by the observers are recorded. Given that hands-free devices are more difficult to identify than hand-held devices, there may be a tendency to underestimate the use of hands-free devices. Likewise, it is difficult to determine if the distracting activities observed are reliably recorded. For example, a driver talking on a headset may be talking to themselves or singing (Young & Regan, 2009). Short-duration behaviours, like manipulating vehicle/climate controls, may be missed and underreported (Huisinigh et al., 2015).

One approach to improving the reliability of observational data is to use multiple trained observers at the same road site. A measure of inter-observer reliability (the extent to which different observers code a behaviour the same way) should be calculated to ensure all distracting activities are categorized in a consistent manner. Cohen's kappa coefficient is the most common statistic used to calculate the level of agreement among observers (Viera & Garrett, 2005). Generally, a kappa coefficient of over 0.57 is considered "good" agreement. Given that few studies report this statistic, the validity of many observational studies in the driver distraction literature is in question. When reported, the inter-observer reliability can vary for different distracting activities. For example, in Sullman et al. (2015), the coefficient for each activity was over 0.60, except for adjusting vehicle controls (0.43). In Prat et al. (2014), the coefficients were all over 0.60, with some activities having coefficients over 0.80 or 0.9, indicating a high level of agreement between observers. Accordingly, future research should include this statistic for each distracting behaviour to ensure the validity of the study.

Another limitation is that the observations are often conducted in one geographic region. As a result, caution is needed when extrapolating the findings to the general driving population. Finally, because there is no manipulation of variables by an experimenter, observational studies cannot establish cause and effect relationships. These studies are thus descriptive in nature only – although they give an idea about the prevalence of secondary task use while driving, they offer little into the context and consequences of distracted driving. As reviewed in the next section, surveys are often conducted to probe further into these issues.

3.3.2. *Observational Studies on Distracted Walking, Cycling, and Riding*

To date, no observational data are available on the use of secondary tasks among riders. However, a few observational studies have investigated the prevalence of secondary tasks engaged by pedestrians and cyclists, and their resultant effects on behaviour. In general, the results seem to indicate that distracted walking and cycling is associated with reduced awareness, supporting the findings in experimental studies.

In a recent study by Violano et al. (2015), 1,362 pedestrians were observed at two high-volume intersections in New Haven, Connecticut. The study found that 19% of pedestrians observed were engaged in a distracting activity while crossing both intersections. 9% were using earbuds/headphones, 8% were using a mobile device (talking, texting, looking at it, or reading something on it), and 2% were eating or drinking.

In Thompson et al. (2013), 1,102 pedestrians were observed at 20 high-risk intersections in Seattle, Washington. These intersections were chosen as they were associated with a high number of pedestrian injuries in the past three years. The study found that nearly 30% of pedestrians observed were involved in a secondary task while crossing the street. 11.2% were listening to music with earphones, 7.3% were texting, and 6.2% were talking on a hand-held phone.

The relationship between secondary task use and crossing time/behaviours was also examined. The results showed that undistracted pedestrians took approximately 10.4 s to cross the average intersection. As compared, pedestrians who were texting significantly increased the crossing time by 1.87 seconds (18%). Using a hand-held phone or hands-free phone significantly increased crossing times by 0.75 and 1.29 s, respectively. Listening to music reduced the crossing time by half a second (0.54 s). With regards to crossing behaviours, pedestrians who were texting were 3.9 times more likely exhibit at least one unsafe behaviour, such as not looking both ways before crossing, not crossing at a crosswalk, or disobeying the traffic lights. While pedestrians who listened to music crossed the intersection faster they were less likely to look both ways before crossing. Overall, these findings show that texting and talking on a cell phone (hand-held or hands-free) increase the time to cross an intersection. Texting appears to be associated with the highest risk, as indicated by an 18% increase in crossing time and several unsafe pedestrian behaviours.

In Hymen et al. (2010), 317 pedestrians were observed and categorized based on whether they were walking: (1) with no electronics, (2) while listening to music, (3) while talking on a cell phone, or (4) in pairs. Pedestrian behaviours were recorded as they crossed a diagonal path of a plaza square in Bellingham, Washington. The results showed that pedestrians talking on the phone walked more slowly, changed directions more frequently, and were less likely to acknowledge other people compared to those in the other conditions. In a second study, 151 different pedestrians were observed along the same path. Near the path a clown on a unicycle was staged. Pedestrians were observed based on the same categories as the first study. After pedestrians had crossed the path, they were asked by an experimenter whether they had seen anything unusual while walking through the square. The study found that using a cell phone was associated with “inattentive blindness” – over 75% of pedestrians on the phone reported not

noticing any unusual activities in the environment compared to half of pedestrians in the other conditions.

Other observational studies provide converging evidence that cognitive distraction from cell phone conversations lead to a number of unsafe crossing behaviours, such as crossing slowly, failing to look both ways before crossing, or not waiting for traffic to stop (Bungum et al., 2005; Hartfield & Murphy, 2007; Naser et al., 2008). While additional research is needed to validate the increased risk associated with texting, which has only been recorded in two studies (Thompson et al., 2013; Violano et al., 2015), this finding may not be surprising as texting involves visual, manual, *and* cognitive distraction.

In Walker et al. (2012), the effects of using personal music devices (PMDs) was observed among 264 pedestrians at two busy crosswalks at the University of British Columbia. The study found that 22% of pedestrians observed were listening to a PMD while crossing. Male pedestrians with a PMD showed significantly more cautionary behaviours (looking before crossing) than those who without a PMD. For females, cautionary behaviours were not affected by the presence of a PMD. The authors suggest that listening to music while walking may not reduce cautionary behaviours like using cell phones has been reported to. Additional research is needed to investigate the relationship between different types of distraction and walking behaviours.

One limitation of these studies is that all of the observations were recorded during the day time and restricted to one geographic region (often urban areas). As a consequence, there is an overrepresentation of secondary task distractions during the daytime which may not be representative of pedestrian behaviours at night. Likewise, pedestrians in one region may not accurately represent those in rural areas or other cities/towns. Finally, the observations were often conducted at busy or risky intersections with high traffic volume.

Future research should examine pedestrians at other locations with less traffic to determine if distracted walking is more or less likely to occur. Research is also needed to determine the rate of secondary task use by pedestrians at night. Evidence indicates that fatal collisions are significantly more likely to occur at night than during the day, with many involving vulnerable road users (Plainis et al., 2006). It has been reported that pedestrians are three to seven times more likely to be involved in fatal collisions at night than during the daytime (Sullivan & Flannagan, 2002). This risk is expected to increase when combined with distraction. Before developing countermeasures, observational data are needed to give an idea about the scope of the problem. Thus, future research is merited to assess the prevalence of distracted road use by pedestrians at night.

To date, only three observational studies have examined distracted cycling and all were conducted in the Netherlands. In Terzano (2013), 1,360 cyclists were observed at six intersections in the city of The Hague, Netherlands. The authors found that 27.6% of cyclists were involved in a distracting activity while cycling through the intersections. 9.1% were using a portable music device with headphones, 14% were talking to another cyclist, and 3.5% were using a cell phone. Nearly half of all distracted cyclists (48.9%) exhibited some sort of unsafe behaviour compared to 20.8% of undistracted cyclists. These unsafe behaviours included failing

to slow down to look both ways before crossing, riding in the wrong direction in the bicycle lane, or crossing an intersection too slow. Cyclists engaged in other activities were also more likely to force other road users to evade or go around them to avoid a collision.

In De Waard et al. (2015), cell phone use among 7,102 cyclists were observed in the city of Groningen, Netherlands in 2013. Data from the present study was compared to an earlier observational study conducted in the same city in 2008 (De Waard et al., 2011). Cyclists were classified as “calling” if they were holding a phone to their ear and “operating the screen” if they were texting, reading, or looking down at the phone. The results showed that, over a period of five years, the prevalence of cell phone use among cyclists did not differ significantly (2.8% in 2008 and 3.0% in 2013). However, there was a change in how cell phones were used. In 2013, more cyclists were operating the screen of the phone (2.3%) than calling (0.7%) – a complete reversal from 2008 where 2.2% of cyclists were calling and 0.6% were operating the screen. The authors suggest that this has important implications for safety policies as more cyclists are now looking away from the road and down towards a phone screen, likely due to the rise of touch screen devices since 2008.

A major limitation of these two studies is that they were conducted in The Netherlands, a country known for its bicycle culture and extensive cycling infrastructure. Over 80% of the Dutch population own at least one bicycle and 34% of all commutes less than 7.5 km are made by bicycle compared to 36% by vehicle (Borgman, 2003; Ministry of Transport, Public Works and Water Management, 2009). In light of this, it is highly likely that the sample in these studies are not representative of the cycling population in other countries, such as the U.S. or Canada, where cycling is less common. It is also likely that cyclists in the Netherlands are more skilled and experienced with the daily bicycle commute; accordingly they may be more adept at engaging in other tasks because less attention is required for the cycling task. For these reasons, the generalizability of the results may be limited.

Observational studies provide important information on the prevalence of distracted road use by pedestrians and cyclists, which can help with the development of countermeasures. Based on this review, it is clear that the amount of data on distracted walking and cycling is less extensive than that on distracted driving. However, research in these areas is only just starting to emerge. The majority of studies on distracted walking and cycling are recent, with the earliest ones published in 2005 and 2008, respectively. As the use of electronic devices continues to rise, observational studies on distracted walking and cycling are expected to grow. Listed below are some directions for future research:

1. To date, no studies have observed the behaviours of distracted riders. Thus, there is a clear need to obtain observational data in order to identify the types and prevalence of distracting activities engaged by riders.
2. There is a need to conduct more observational studies on distracted pedestrians outside of the U.S. and distracted cycling outside the Netherlands in order to draw more general conclusions about these issues.

3. Research is needed to examine the usage rate of distracting activities at night. Given that vulnerable road users rely heavily on being seen by vehicles, dim conditions may put these distracted road users at an elevated risk of a collision (e.g., not hearing a vehicle approaching from behind because a cyclist is listening to music with headphones). Information on the types and prevalence of distracting activities engaged by pedestrians, cyclists, and riders at night may be important for developing countermeasures to limit the use of certain activities after dark.
4. Further observational data are needed to study the association between different types of distraction (i.e., visual, cognitive, auditory, and visual-manual) and traffic behaviours by pedestrians, cyclists, and riders.
5. Given the proliferation of portable and/or wearable technologies in recent years, future observational studies should investigate the prevalence of these devices among pedestrians, cyclists, and riders. These include, but are not limited to, digital cameras, tablets (e.g., iPads), activity trackers (e.g., Fitbits), GPS/location trackers, and smartwatches.

3.4. Survey Research

Cross-sectional surveys are used to obtain information from a representative sample at one particular point in time. They are often administered by telephone, mail, online, or face-to-face. The advantages of these surveys are that they are quick to conduct, cost-effective, and it is possible to obtain a vast amount of data from a large sample in a short period of time (Young & Regan, 2009).

In driver distraction research, cross-sectional surveys are used to obtain information on drivers' patterns of secondary task use while driving. Surveys can assess how often drivers engage in secondary tasks, which age groups are more likely to engage in these tasks, drivers' experiences with these tasks, and the proportion of collisions reported by drivers to involve distraction (McEvoy & Stevenson, 2009). Cross-sectional surveys can also be used to obtain information on attitudes and opinions towards various distracted driving issues. This data is often gathered to understand the culture of traffic safety. Culture refers to the "beliefs, values, norms, and things people use, which guide their social interactions in everyday life" (Moeckli and Lee, 2007, p. 62). Thus, traffic safety culture refers to the social-cognitive determinants that underlie society's proclivity to engage in safe or risky behaviours in traffic (Ward et al., 2015). These determinants include attitudes, social norms, self-efficacy, perceptions of risk, awareness of and support for countermeasures. Because improving road safety largely depends on changing the way people think and behave, changing the culture of traffic safety is an important part of the process. Although many surveys have covered a range of distracted driving topics, only a few have included topics on distracted walking, cycling, and riding; these surveys are reviewed in section 3.4.2.

In 2012, the NHTSA National Survey on Distracted Driving Attitudes and Behaviours was conducted on 6,015 American drivers (Schroeder et al., 2013). The telephone survey found that almost half of drivers (48%) admitted to talking on a cell phone while driving at least some

of the time. 58% of drivers said they continued their phone conversation while driving, while only 11% said they pulled over to continue the conversation. Texting while driving was less common. 10% reported texting or emailing while driving at least sometimes and 14% reported reading texts or emails while driving at least sometimes.

When asked about their perceptions of safety, half of all drivers reported that talking on a cell phone made no difference in their driving performance compared to when not talking on the phone. However, 18% said they drove more slowly, 17% said they were distracted and not as aware, and 5% indicated they were more focused and paid more attention to their driving when on the phone. One-third of drivers reported no difference in their driving performance when sending texts or emails compared to when not texting or emailing. However, 24% admitted that they were distracted and not as aware, 21% admitted that they drove more slowly, and 11% said that they drifted out of their lane more.

When asked about their perceptions of safety as a passenger with a distracted driver, 42% of respondents said that they would feel very unsafe if their driver was talking on a hand-held phone. A large majority stated that they would feel very unsafe if their driver was reading (85%) or sending texts or emails (86%). An overwhelming majority indicated that they would feel very unsafe if the driver was watching a movie (96%), using a laptop (95%), or reading (95%) while driving.

Overall, these results reveal that many drivers use cell phones while driving (nearly half of respondents) and a substantial proportion of drivers (50%) do not believe it makes a difference in their driving performance. However, a large majority would feel very unsafe as a passenger if their driver was engaged in other tasks while driving.

Using information from a 2011 NHTSA telephone survey conducted in the U.S., cell phone use among young drivers was examined (NHTSA, 2012a). The results showed that young drivers aged 18-20 reported the highest level of cell phone use (13%) at the time of a crash or near-crash. 8% stated they were reading a text or email, 3% stated they were sending a text or email, and 2% said they were talking on the phone. 44% of drivers aged 18-20 reported texting while driving, while 49% of drivers aged 21-24 reported this. This percentage dropped considerably for drivers aged 25-34 (26%), 35-44 (19%), and 45-65 (8%). When young drivers were asked about their driving performance when talking on cell phones, over half of young drivers (61%) reported that it made no difference on their driving (63% for drivers aged 21-24 and 57% for drivers 25-34). However, only 20% of young drivers believed that sending texts or emails did not affect their driving compared to 27-29% of drivers aged 21-34. Supporting previous research, these results show that young drivers are more likely to be involved in crashes or near-crashes when using cell phones compared to drivers in other age groups.

In 2014, the AAA Foundation for Traffic Safety conducted the Traffic Safety Culture Survey on a sample of 2,705 drivers in the U.S (AAA Foundation for Traffic Safety, 2015). Drivers were asked about their attitudes and behaviours on various topics related to distracted driving, impaired driving, drowsy driving, speeding, and using seatbelts. The survey found that a large majority of respondents (85%) felt that distracted drivers were a somewhat or much bigger

problem today compared with three years ago, while 42% said that about drunk driving and 61% said that about aggressive drivers.

Over half of drivers (52%) perceived talking on cell phones while driving to be a very serious threat to personal safety. 66% of drivers also said it was unacceptable to talk on a hand-held phone while driving, compared to 33% who said the same about hands-free phones. When asked about texting or emailing while driving, 79% of drivers perceived it to be a very serious threat to personal safety. An overwhelming majority of respondents (96%) also said it was unacceptable to text or email while driving.

Despite these numbers, a large number of drivers (69%) reported talking on a cell phone while driving in the past 30 days. 36% reported reading a text or email, and 27% reported sending a text or email while driving in the past 30 days. When asked about how strongly they supported or opposed a ban against talking on a hand-held cell phone, a good majority (68%) strongly supported it. Even more drivers (89%) supported a ban against texting or emailing while driving. However, less supported (40%) a total ban on hand-held and hands-free cell phones. Overall, the results of the survey show that cell phone use is prevalent among drivers, however many are aware of the dangers associated with the activity and support legislative bans against cell phone use.

In an Australian telephone survey, the prevalence and effects of distracting activities beyond cell phone use were assessed among 1,347 drivers (McEvoy et al., 2006). The most frequent distractions reported by drivers during their most recent driving trip were lack of concentration (daydreaming or thinking about other things) (72%), adjusting in-vehicle controls (69%), outside people, objects, or events (58%), and talking to passengers (40%). When asked about crashes in the last three years, distraction was a contributing factor in 21% of reported crashes. Young drivers (18-30 years) were significantly more likely to report distraction-affected crashes (7.7%) than older drivers (31-49 years: 5.0%, 50-65 years: 2.3%).

In Canada, a number of prevalence and traffic safety culture surveys have focused on distracted driving-related topics. In the 2011 Road Safety Monitor (RSM) survey, 1,208 Canadians were asked various topics related to distracted driving over the telephone or through an online survey (Marcoux et al., 2012). The results showed that 37% of Canadians reported using a cell phone while driving in the past seven days. Compared to earlier RSM surveys, this number increased from 21% in 2001 and 31% in 2005. When asked about their level of concern about distracted drivers, a large number of respondents (74%) perceived distracted drivers to be a very serious or extremely serious problem. 66% perceived drivers who use cell phones to be a very serious or extremely serious problem, while 85% perceived drivers who text on cell phones to be a very serious or extremely serious problem. When asked about their level of support for legislative measures to reduce distracted driving, the majority of Canadians (67%) agreed or strongly agreed that the use of cell phones while driving should be banned.

In 2011, the use of cell phones while driving was assessed among 1,203 respondents in Alberta, Canada in a telephone survey (Nurullah et al., 2013). The results showed that more than half of Albertans (52%) reported using a cell phone while driving in the past year. 23% said they used a cell phone sometimes, while 11% said they used it very often. Significantly more males

(62%) than females (53%) used their cell phones while driving. When asked about their perceptions of risk associated with cell phone use, 93% said that they strongly agreed that texting while driving is dangerous. 71.2% of respondents strongly agreed that using a cell phone while driving is more likely to result in a collision, and 42% strongly agreed that cell phone use is as dangerous as drinking and driving. Overall, these results indicate that cell phone use while driving is widespread in Alberta, with over half of respondents (52%) reporting doing so in the past year. More alarming is that drivers continue to use cell phones while driving, even when they are aware of the dangers associated with the activity.

This survey was conducted just prior to the Alberta distracted driving legislation that came into effect in September 2011. The legislation restricts the use of hand-held cell phones and other electronic devices while driving. Following the enforcement of the law, the 2014 Edmonton and Area Traffic Safety Culture Survey was assessed among 1,000 respondents in the City of Edmonton, Alberta and surrounding area (Thue & Grekul, 2014).

The telephone survey found that a large majority of respondents (89%) perceived distracted drivers to be a very serious threat to their personal safety. 64% perceived drivers talking on hand-held cell phones to be a very serious threat, while only 18% considered the same about drivers talking on hands-free cell phones. An overwhelming majority of respondents (88%) perceived drivers who were texting, emailing, or using social media while driving to be a very serious threat. When asked about the acceptability of talking on a hand-held cell phone while driving, 72% viewed it as completely unacceptable. Respondents were more accepting of hands-free cell phones as only 22% viewed it as completely unacceptable. A vast majority (92%) felt that texting, emailing, or using social media while driving was completely unacceptable.

Despite these findings, 20% of respondents said they talked on a hand-held cell phone while driving in the past 30 days. 42% said they talked on a hands-free cell phone and 11% admitted to sending a text or email while driving in the past 30 days. Finally, when asked if they supported or opposed a law against using a hands-free cell phone while driving, less than half of respondents (45%) supported the legislation (Thue & Grekul, 2014). The findings from this survey reveal that many individuals in Edmonton and surrounding areas perceive distracted drivers (talking on a cell phone, texting, and using social media) to be a threat to their safety. The majority of respondents also state that it is unacceptable to engage in these activities while driving. Despite these perceptions, many drivers continue to engage in these activities.

Based on this review of survey studies, there is converging evidence that drivers commonly use cell phones while driving. The 2012 NHTSA survey indicates that half of drivers do not believe that using cell phones affect their driving performance, however, their perceptions of safety is different as a passenger. Surveys on traffic safety culture in the U.S. and Canada also reveal discrepancies between attitudes towards distracted driving and actual driving behaviours.

3.4.1. Limitations and Future Directions

While surveys can be a valuable tool to obtain self-reported behaviour and attitudes, they are not without their limitations. In order for surveys to be useful, the sample selected must be representative of the general population. However, sampling bias can arise for a number of reasons. First, the sample selection process may be non-random. This occurs when certain

members of the population are overrepresented or underrepresented. For example, drivers in rural areas or aged 70 or older may be underrepresented in an online survey because they do not have access to the internet. Likewise, working individuals may be underrepresented in a telephone survey administered during daytime hours on a week day. Second, the sample may be biased if the response rate is low. This occurs when several individuals in the sample refuse to take part in the survey or cannot. The outcome is that the few who responded may differ from those who did not respond, creating non-response bias. Finally, there may self-report bias due to “social desirability” – a tendency for respondents to distort their responses so that they are viewed more favourably by others. As there are often negative implications associated with distracted driving, respondents may underreport the use of cell phones or other distracting activities while driving. Together, these limitations can lead to survey errors and undermine the external validity of the findings.

Survey data can be improved by minimizing the above errors. Prior to administering the survey, researchers should specify the population of interest and ensure the sample surveyed represents the true population. In the driver distraction literature, some surveys require all respondents to have a valid driver’s license and/or have driven in the past number of days. Other surveys require respondents to reside in specific areas if the sample is based on a regionally representative sample.

The use of stratified sampling can also minimize sampling error. This technique is often used if the population is heterogeneous or if there are sub-populations. The target population is divided into groups (strata) based on shared characteristics (e.g., age, gender, socioeconomic status, education, residing community, etc.). Random sampling is then used to select samples from each stratum, proportional to the size of the stratum. An advantage of this sampling technique is that under and overrepresentation of certain sample characteristics, such as all male respondents, is minimized.

To improve the quality of distraction-related survey data, surveys should continue to be administered on a periodic basis to track changes in attitudes and behaviour over time. For example, the 2014 Edmonton and Area Traffic Safety Culture Survey was conducted approximately three years after Alberta introduced its first distracted driving law in September 2011. In January 2016, the fine for distracted driving was increased and demerit points were added. The new law also prohibited drivers from reading, writing, and grooming (along with using hand-held electronics). In light of this, future research should re-administer the survey (e.g., next year) to determine if traffic safety culture towards distracted driving has changed with the new law.

Survey data can also be improved by assessing the statistical relationship between attitudes and behaviour towards distracted driving. One approach is to use structural equation modeling (SEM) to examine how attitudes and behaviour are related and what factors influence the relationship. SEM is a statistical technique used to assess underlying relationships between observed and latent variables (Li et al., 2014). Latent variables cannot be measured or observed directly from the data, but are constructed from observed variables.

In a survey study by Li et al. (2014), SEM was used to estimate the association between distracted driving attitudes, experiences, and behaviour. The four latent variables representing the culture towards distracting driving in the model were distractibility, self-reported distracted driving behaviour, personal acceptability of distracted driving, and prediction of possible collisions caused by distraction. These variables were constructed based on individuals' responses to a 2011 traffic safety culture survey conducted in Iowa. The results from the SEM showed that distracted driving attitudes, experiences, and behaviour were highly correlated. Drivers who reported frequent engagement in secondary tasks while driving were less likely to view distracted driving as a serious safety concern compared to other drivers. These same drivers also had a higher acceptance of distracted driving behaviours and predicted fewer collisions caused by distraction. Factors, such as age and household income, also influenced the culture towards distracted driving. Young drivers and high-income drivers had the most direct effects on the relationship among distracted driving attitudes, experiences, and behaviour (i.e., were more likely to engage in distracted driving). As evident in this study, the major advantage of using SEM is the ability to examine underlying relationships that would not be possible otherwise.

Finally, few surveys, outside of McEvoy et al. (2006), have assessed drivers' usage patterns and traffic safety culture around distracting activities beyond cell phone use, such as using electronic devices (e.g., GPS systems, video games, tablets, laptops, TV/DVD players, and smartwatches), driving with children in the backseat, talking to passengers, reading/writing, grooming, and looking at roadside objects. Future surveys are warranted to assess a wider range of distractions in order to provide a more comprehensive picture of behaviours, experiences, attitudes, and perceptions towards distracted driving.

3.4.2. Surveys on Distracted Walking, Cycling, and Riding

Few surveys have examined topics related to distracted walking, cycling, and riding, indicating a need for future research to conduct more special topic surveys on these issues. Below is a review of all known survey findings on distracted walking, cycling, and riding.

In the 2014 Edmonton and Area Traffic Safety Culture Survey, 17% of pedestrians reported that they made or answered a call with a hand-held phone at least sometimes. 25% said that they used an mp3/iPod/music device while walking or running at least sometimes.

In the 2013 Pedestrian Volume and Opinion Survey conducted in Vancouver, BC, pedestrians were asked about negative behaviours of other road users that they felt should be changed (City of Vancouver, 2015). The top concern (19%) was poor cyclist behaviour (riding on sidewalks, not obeying traffic laws, not wearing helmet, etc.). 11% felt that pedestrians blocking others or not paying attention was a concern, and 5% felt that distracted driving/walking/cycling was a concern.

In the 2012 NHTSA National Survey of Bicyclist Attitudes and Behaviours conducted in the U.S., 21% of respondents who rode a bicycle within the past year reported that they used electronic devices (cell phones or mp3 players) during at least some of their bicycle trips (Schroeder & Wilbur, 2013).

In Ichikawa and Nakamara (2008), a self-administered questionnaire was conducted to assess the use of cell phones while cycling among 3,266 Japanese high school students. Only bicycle commuters responded to the survey. The authors found that 75% of males and 64% of females reported using a cell phone while cycling in the past month. 20% of males and 19% of females reported a bicycle crash/near-crash experience while using a cell phone in the past month. When asked about their perception of danger in using a cell phone while cycling, male cyclists reported significantly lower levels of perceived danger than females. 21% of males reported slight or no danger compared to 9% of females reporting this. A significant relationship was found between usage of phones while cycling in the past month and perception of danger in using phones while cycling. Those who reported higher levels of perceived danger were less likely to use a cell phone while cycling compared to other cyclists.

In a 2009 online survey conducted in The Netherlands, 17% of cyclists reported using an electronic portable device during nearly all bicycle trips (Goldenbeld et al., 2012). 15% said they listened to music and 3% said they used a cell phone each or nearly each trip. 3% sent or read a text message and 1.7% looked for information on a phone each or nearly each trip. 39% of cyclists reported listening to music at least occasionally on each trip, while over half (55%) said they used a cell phone at least occasionally. Male and female cyclists did not differ in their usage of electronic devices. Nearly 75% of teenage (12-17 years) and young adult (18-34 years) cyclists used a portable electronic device at least occasionally while cycling compared to one-third of middle-aged cyclists (35-49 years) and only one-fifth of older adult cyclists (over 50 years).

17% of cyclists reported a bicycle crash in the past 12 months. 5% reported a crash that resulted in an injury. When asked whether the bicycle crash was preceded by the use of a portable electronic device and/or some other distraction, 10% of non-injury crashes and 9% of injury crashes were reported by cyclists to be preceded by at least the use of a portable electronic device. More teenage (19%) and young adult (16%) cyclists reported this than middle-aged (5%) and older adult (0%) cyclists.

As part of a 2011 survey used to recruit volunteer riders for the 100 Motorcyclists Naturalistic study, 229 riders were asked if they used a GPS, cell phone, and other communication devices while on the motorcycle (McLaughlin et al., 2011). Nearly half of respondents indicating using a GPS, 20% reported using an intercom, 20% reported using a citizen band radio (CB), and 13% reported using a cell phone on the motorcycle.

Based on these limited findings, there is a clear need to conduct more surveys on topics that concern distracted walking, cycling, and riding. Important issues to assess include, but are not limited to:

1. The prevalence and frequency of various self-reported secondary tasks engaged by pedestrians, cyclists, and riders.
2. Road users' experiences with secondary task engagement, such as whether the secondary task contributed to a crash or near-crash.
3. Age groups that are more likely to report secondary task engagement while walking, cycling, and riding.

4. The attitudes and beliefs towards various aspects of distracted walking, cycling, and riding (such as perceptions of risk, levels of safety concern, support for countermeasures, etc.). This information is crucial to understanding the traffic safety culture around other forms of distracted road use.

3.5. Collision Data

Motor vehicle collision data are collected and maintained in state/provincial collision databases. The data compiled are based on collision reports completed by police officers at the site of the collision. The information on the report often includes the description of the collision, the people and vehicle(s) involved, environmental/road factors, and human factors that contributed to the collision (e.g., distraction, speeding, fatigue, etc.) (Council et al., 2007). In driver distraction research, collision data are used to estimate the number of collisions involving distraction and to identify the circumstances of distraction-related collisions (Eby & Kostyniuk, 2003).

One database that has often been examined is the National Automotive Sampling System Crashworthiness Data System (CDS). The CDS contains detailed information on a nationally representative sample of police-reported collisions in the U.S., where the collision involved a passenger vehicle, and at least one vehicle was towed from the collision scene (Stutts et al., 2001). 5,000 police-reported collisions are included in the sample each year. Additional information is gathered from collision investigators at the scene of the collision, interviews with the collision victims and witnesses, and medical records. In 1995, specific driver inattention and distraction codes were added to the database, as listed in Table 3.1.

Table 3.1. Coding categories for the “Driver’s Distraction/Inattention to Driving” variable in the Crashworthiness Data System.

Driver Attention Status	Driver Distraction
1. Attentive	1. Eating or drinking
2. Distracted	2. Outside person, object or event
3. Looked but did not see	3. Adjusting radio, cassette, or CD
4. Sleepy or fell asleep	4. Other occupants in vehicle
5. Unknown or no driver	5. Moving object in vehicle
	6. Smoking related
	7. Talking or listening on cellular phone
	8. Dialing cellular phone
	9. Using device/object brought into vehicle
	10. Using device/controls integral to vehicle
	11. Adjusting climate controls
	12. Other distraction
	13. Unknown distraction

Source: Stutts et al. (2001).

Eby and Kostyniuk (2003) examined data from the year 2000 in the CDS and found that 13% of collisions were identified with one of the distraction codes. However, over half of the collisions (52%) were coded as “unknown” for the driver attention status variable. An examination of the CDS using 4 years of data (2000-2003) showed that 11.6% of collisions were identified with one of the distraction codes (Gordon, 2009). Likewise, a large number of collisions were coded as “unknown” for the driver attention status variable or the information was missing. Given these issues, the number of distraction-related collisions is likely underreported in the CDS (Gordon, 2009).

Another database is The National Automotive Sampling System (NASS) General Estimates System (GES), which contains data on a nationally representative sample of all types of police-reported collisions in the U.S., including property damage only, injury, and fatal collisions (NHTSA, 2015). The GES is based on a sample of 50,000 police-reported collisions each year. In 1990, the data element “Driver Distraction” was added to the GES and expanded in 1999. Table 3.2 lists the attributes for “Driver Distracted By” that is currently used in the GES.

Table 3.2. Attributes for the “Driver Distracted By” element in the GES and FARS databases.

Driver Distracted By
1. Not distracted
2. Looked but did not see
3. By other occupants
4. By moving objects in vehicle
5. While talking or listening to phone
6. While dialing phone
7. While adjusting climate control
8. While adjusting radio, cassette or CD
9. While using other devices integral to vehicle
10. While using or reaching for other devices
11. Sleepy or fell asleep
12. Distracted by outside person or object
13. Eating or drinking
14. Smoking related
15. No driver present
16. Not reported
17. Inattentive or lost in thought
18. Other distraction or inattention
19. Unknown

Source: NHTSA (2015). *Traffic safety facts: Distracted driving 2013* (Report No. DOT HS 812 132).

Eby and Kostyniuk (2003) examined data from the year 2000 in the GES and found that 35% of collisions were coded as “not distracted,” 45% were “not reported,” and 3% were “unknown.” When distraction was coded, the categories were often “inattentive or lost in thought” (11.5%), “looked but did not see” (2.5 %) and “sleepy or asleep” (1.1%). The rest of the categories combined to less than 1.0%. The authors conclude that based on the small number of cases associated with other types of distraction, caution should be used when using the GES to estimate distraction-related collisions.

Neyens and Boyle (2007) used 2003 data from the GES to examine different types of distraction-related collisions among teenage drivers, including cell phone, in-vehicle, cognitive, and passenger-related distractions. The authors found that only 0.6% of collisions in the GES were identified as cell phone-related, while 2.6% of collisions were identified as in-vehicle distractions. Like Eby and Kostyniuk (2003), the authors advise caution in using the GES to draw conclusions on driver distraction as these estimates are considerably lower than those found with other methods of measurement. Based on these examinations, distracted driving collision data appear to be underreported in the GES database.

The Fatality Analysis Reporting System (FARS) contains a census on all fatal motor vehicle collisions in the U.S. The information is obtained from police collision reports, driver licensing files, vehicle registration files, state highway department data, emergency medical reports, medical examiner/coroners reports, and death certificates (NHTSA, 2014a). Prior to 2010, all distracting behaviours were coded as “Inattentive (talking, eating, etc.).” Since 2010, the FARS adopted the same coding system used in the GES to identify distraction (see Table 3.2). The advantage of the FARS over the GES and CDS is that the data are based on a census rather than a sample, therefore any sampling issues are avoided (NHTSA, 2015). An examination of distraction-related collisions in the FARS and GES from 2011 to 2013 is summarized in Table 3.3.

Table 3.3. Estimated fatal and injury collisions from FARS and GES.

		Overall Collisions	Distracted Driving Collisions (% of Total Collisions)	Collisions Involving Cell Phone Use (% of Distraction Collisions)
2011	Fatal Collisions (FARS)	29,867	3,047 (10%)	354 (12%)
	Injury Collisions (GES)	1,530,000	260,000 (17%)	15,000 (6%)
2012	Fatal Collisions (FARS)	31,006	3,098 (10%)	380 (12%)
	Injury Collisions (GES)	1,634,000	286,000 (18%)	21,000 (7%)
2013	Fatal Collisions (FARS)	30,057	2,910 (10%)	411 (14%)
	Injury Collisions (GES)	1,591,000	284,000 (18%)	24,000 (8%)

Source: NHTSA (2015). Traffic safety facts: Distracted driving 2013 (Report No. DOT HS 812 132).

In Canada, several provinces/territories now report on distraction-related factors, particularly using cell phones, in their crash report forms (World Health Organization, 2011). In 2009, the NHTSA conducted a survey to member countries belonging to the International Road Traffic and Accident Database (IRTAD) group (NHTSA, 2010b). The survey examined how collision data involving distraction were collected in different countries. As shown in Table 3.4, 11 out of 16 countries who responded to the survey identified distraction in their police report forms.

Table 3.4. Identification of distracted driving collision data across countries.

Country	Total Collisions	Fatal Collisions	Injury Collisions	Does Not Report
Austria		X		
Canada	X	X	X	
Finland		X		
France		X	X	
Great Britain	X	X	X	
Hungary		X	X	
Japan	X	X	X	
New Zealand	X	X	X	
Spain		X	X	
Sweden		X		
Switzerland	X	X	X	
Australia				X
Belgium				X
Germany				X
Greece				X

Source: NHTSA (2010b). *Traffic safety facts: Overview of results from the international traffic safety data and analysis group survey on distracted driving data collection and reporting* (Report No. DOT HS 811 404).

Using collision data from the British Columbia Traffic Accident System (TAS), Asbridge et al. (2013) conducted a study to determine if cell phone use while driving increased collision culpability (i.e., responsibility for the collision). The TAS contains data on all police-reported collisions in the province. Information in the police reports include details of the collision and driver, vehicle, and environmental factors that may have contributed to the collision.

From a pool of 118,447 collisions from 2005 to 2008, 312 drivers were identified to have been explicitly using a cell phone at the time of the collision. 936 collisions where drivers did not use a cell phone were matched and used as control cases. Collision culpability was measured by assessing seven categories: road type, driving conditions (road surface, visibility, and weather), vehicle condition, unsafe driving actions, contribution from other parties, type of collision, and type of task involved. Each category was given a score specifying their level of responsibility for the collision. The study found that compared to collisions without cell phones, collisions with cell phones increased the risk of a culpable collision by 70% (odds ratio=1.70). The association

held true for male drivers and drivers aged 26 to 65 years. To date, this is the only known study in Canada to use collision data to assess the odds of a culpable collision when distracted. However, care should be exercised when interpreting these results as collision data have several limitations, as reviewed below.

3.5.1. Limitations and Future Directions

One of the main limitations of collision data is that they rely heavily on police-derived collision reports. Collision report forms can vary across jurisdictions, leading to inconsistencies in the level of reporting (Ascone et al., 2009). Some report forms have a coding system to indicate whether distraction was involved, while others do not. In cases where the report form may not have requested much or any details regarding distraction, police officers must collect the information from the drivers themselves. However, self-reports are prone to bias, and drivers may often fail to report negative behaviours, such as distracted driving, to the officer (Ascone et al., 2009). Drivers may also not remember or were unaware of being distracted at the time of the collision. If the driver was involved in a fatality, police officers must rely on findings from the collision investigation team to report on distraction; however the investigation team may not have enough information to determine if distraction was involved, due to lack of physical evidence or insufficient witness testimonies (Ascone et al., 2009).

Another drawback is that collision reports rely heavily on the subjective judgments of police officers who only see the collision after it occurred (Council et al., 2007). Given that many officers are not experts in certain areas, such as driver distraction, the information reported may be misclassified or missed. A review on the validity of police collision reports showed that data associated with the description of the collision (i.e., location, time of day, number of vehicles, and number of drivers/passengers) were most reliable, while data on indirect human causes (i.e., fatigue, driver inexperience) were least reliable (Shinar et al., 1983). Together, these limitations can contribute to the underestimation of distraction-related collisions in collision databases.

The other limitation is that collision data can only provide information on what occurred *after* the collision (Ascone et al., 2009). Collisions identified with one of the distraction codes suggest that distraction may have been a contributing factor but it does not establish it as the *cause* of the collision. To obtain better information on the events leading up to a collision, the National Motor Vehicle Crash Causation Survey (NMVCCS) was conducted. The NMVCCS was a national survey from 2005 to 2007 that investigated light passenger vehicle collisions across the U.S. (NHTSA, 2008). On-scene investigations were conducted on 6,950 vehicles by researchers to determine the factors and events leading up to a collision. Information on the driver, vehicle, and environment were collected. In cases where the driver was attributed as the critical reason underlying the collision, distraction was identified in the survey (coded as inattention, internal distraction, or external distraction). In addition, there was a factor related to engaging in interior non-driving activities (similar to secondary tasks). Overall, the survey found that 3% of collisions were associated with inattentive driving, 11% were associated with internal distraction, and 4% were associated with external distraction. In addition, 18% of collisions were attributed to secondary task engagement. The most common activity was conversing (12%), either with a passenger or with someone on a cell phone.

A comparison of a set of collisions common in the CDS, GES, and NMVCCS was conducted by Mynatt and Radja (2013). 379 collisions and 653 vehicles that were recorded in all three databases were examined. Common vehicles with a distraction coded in each of the three databases were compared. As shown in Table 3.5, distraction among the same vehicles is considerably underreported in the CDS and GES.

Table 3.5. Common vehicles with distraction reported.

Distraction	GES	CDS	NMVCCS
Yes	11%	14%	28%
No	60%	46%	48%
Unknown	30%	40%	24%

Source: NHTSA (2015). *Traffic safety facts: Distracted driving 2013* (Report No. DOT HS 812 132).

In Canada, Transport Canada’s National Collision Database (NCDB) contains national data on all police-reported collisions each year; however, information on distraction-related collisions is not readily accessible. Likewise, provincial and territorial data on collisions involving distraction are not widely shared. There is also little to no information on the coding structure used to identify distraction in collision report forms across Canadian jurisdictions. Future research is needed to investigate the NCDB and provincial/territorial data to determine how distraction-related factors are collected and reported in collision reports. Future initiatives are also needed to evaluate the extent and characteristics of distraction-related collisions in Canada. According to a recent 2015 report by the Traffic Injury Research Foundation, the two greatest unknowns in Canada are the types of distraction that are most strongly associated with collisions and the characteristics of collisions involving distraction (Robertson et al., 2015).

Given the limitations of existing collision data, it is clear that new approaches are needed to improve the way distraction-related collision data is collected. One particular area of concern is the lack of a standard collision report form used by all law enforcement/police agencies.

In 1998, the Model Minimum Uniform Crash Criteria (MMUCC) was developed to standardize reporting across the U.S. and to “generate uniform crash data that are accurate, reliable and credible for data-driven highway safety decisions within a state, between states and at the national level” (NHTSA, 2003, p. iii). The MMUCC guideline is a minimum, standardized data set for describing collisions and is used by many states in their collision reports. The guideline was revised in 2003 to improve the collection of collision data related to a number of safety issues, including distracted driving. To obtain better distraction-related data, the MMUCC added a new data element to identify distraction. As seen in Table 3.6, a standard definition is provided and the new attributes are more clearly defined than the ones used in the CDS, GES, and FARS databases.

Table 3.6. “Driver Distracted By” MMUCC data element.

Driver Distracted By	
Definition	Distractions which may have influenced the driver performance. The distractions can be inside the motor vehicle (internal) or outside the motor vehicle (external).
Attributes	<ul style="list-style-type: none"> • Not Distracted • Electronic Communication Devices (cell phone, pager, etc.) • Other Electronic Device (navigation device, palm pilot, etc.) • Other Inside the Vehicle • Other Outside the Vehicle • Unknown

Source: NHTSA (2003). *Model Minimum Uniform Crash Criteria (MMUCC) guideline* (2nd edition) (Report No. DOT HS 809 577).

While many states have started to include this element in their collision reports, its reliability has not been examined (Stutts et al., 2005b). Thus, there is a need for future research to assess the usefulness and reliability of the revised MMUCC guideline, particularly with regards to how distraction-related data is collected.

In countries where the MMUCC is not used, the collision report form should be standardized across law enforcement/police agencies and revised to improve the coding structure for distraction. The following is a list of important factors to consider when classifying distraction, as compiled by Gordon (2009):

- Separating out driver distraction from driver impairment caused by alcohol, fatigue, or drugs.
- Specifying whether the source of distraction is driving-related or non-driving related.
- Specifying whether the source of distraction is inside or outside the vehicle.
- Specifying whether the source of distraction is an object/event or a behavioural action involving the object/event.
- Specifying whether the source of distraction is technology-related or non-technology-related.

Another approach to enhancing the quality of distraction-related collision data is to improve the training of police officers and collision investigators in collision reporting, evidence gathering, and awareness of distracted driving issues (Stutts et al., 2005b). Accuracy and completeness of collision report forms should be emphasized and steps should be taken to ensure police officers understand how distraction-related factors are classified. For example, a workshop may be held to train police officers on the coding of distracted driving, after which the accuracy and completeness of actual collision report forms may be compared before and after the

training (Boodlal et al., 2010). Police reports should also be periodically reviewed to ensure their accuracy and thoroughness (Shinar et al., 1983). Such assessments could be performed by supervisors of the police officers or other personnel in the reporting agency. Helpful feedback should be given regarding specific errors on the report form and sections where information is missing or cited as “unknown.”

The availability of collision data is also a concern. Future initiatives are needed to ensure that collision data are widely shared and easily accessible. Data may be made available online through electronic reports or hands-on query tools (Boodlal et al., 2010).

Finally, as an alternative to collision-based studies, naturalistic driving studies can be conducted as an alternative to obtain more accurate estimates of collisions and near-collisions involving distraction. Unlike collision data, these studies can provide in-depth information on driver behaviour and the events and factors leading up to a collision or near-collision. Another advantage is that all collisions and near-collisions are examined, while collision databases contain only police-reported collisions. Typically, only serious collisions that involve injury or death are reported to the police, leading to an under-sampling of minor and property damage-only collisions.

Using instrumented vehicles that allowed capture of all distracting activities exhibited by drivers, the 100-Car Naturalistic Driving Study obtained information on 69 crashes and 761 near-crashes (Klauer et al., 2006). The study found that over 22% of crashes and near-crashes were associated with drivers performing at least one distracting activity, such as talking/listening on a hand-held cell phone (2.56%), reaching for a moving object (0.71%), and eating/drinking (0.61%). These estimates are considerably higher than those found in the CDS and GES databases, another indication that distracted driving collisions are underestimated in collision data.

Based on this review, evidence suggests that the actual number of collisions involving distraction is likely higher than those reported in collision databases. As a result, caution should be exercised when using police-reported collision data to draw conclusions. Naturalistic collision data should be compared to obtain more accurate estimates.

3.5.2. Collision Data on Distracted Walking, Cycling, and Riding

Few collision data are available on the number of injuries and fatalities involving distracted pedestrians, cyclists, and riders.

As reviewed earlier, the FARS contains a census on all fatal motor vehicle collisions in the U.S. This includes data on non-motor vehicle occupants involved in fatalities (NHTSA, 2014a). Table 3.7 outlines two possible distraction-related codes that may be used to report on distracting activities engaged by a person that is not a motor vehicle occupant, such as a pedestrian or cyclist (Mwakalonge et al., 2014). Because motorcycle riders are considered to be motor vehicle occupants, distracted riders are coded under the “Driver Distracted By” variable (see Table 3.6).

Table 3.7. Coding attributes for distraction at the person (not motor vehicle occupant) level in FARS.

Data Element	Attribute
Related factors – person	Portable Electronic Device
Non-motorist action/ circumstances at time of crash	Inattentive (e.g., talking, eating, etc.)

Sources: Mwakalonge et al. (2014); NHTSA (2014b). *Traffic safety facts 2012: A compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimates system* (Report No. DOT HS 812 032).

Mwakalonge et al. (2015) examined the FARS database for pedestrian fatalities attributed to portable electronic use from 2008 to 2011. The authors found a total of 23 cases of pedestrian fatal collisions where portable electronic use was a contributing factor. There was one case of distracted walking in 2008 and eight cases in 2011. 61% of cases involved males, however there were no differences in age (50% split for those below 34 years and those over 35 years).

In a collision study, Lichtenstein et al. (2012) aimed to identify cases where a pedestrian-vehicle collision occurred in which the pedestrian was wearing headphones. The authors searched four databases – the National Electronic Injury Surveillance System, the U.S. Consumer Product Safety Commission, Google News Archives, and the Westlaw Campus Research – for reports from 2004 to 2011 for pedestrian injuries or fatalities involving a motor vehicle or train collision. The results showed 116 cases of headphone-related death or injury of pedestrians. The majority of victims were males (68%) and under the age of 30 (67%). 55% of cases involved train collisions and 89% occurred in urban areas.

Naser and Troyer (2013) examined the National Electronic Injury Surveillance System database (NEISS) for injury reports from 2004 to 2010 involving cell phone use among pedestrians. The NEISS contains injury-related data from a sample of 100 hospitals in the U.S. The results showed that between 2004 and 2010, the percentage of pedestrian injuries sustained from cell phone use relative to total pedestrian injuries increased from 0.58% to 3.67%. In 2010, there were 1,506 cases of pedestrian injuries due to using a cell phone, compared to 559 cases in 2004. On the other hand, there were 41,000 total pedestrian injuries in 2010 and 97,000 total injuries in 2004. Further examination of the data revealed that 70% of cell-phone related injuries were associated with talking on the phone, while 9.0% were associated with texting (Nasar & Troyer, 2013). More young pedestrians were injured from cell phone use than older pedestrians (55% of injuries occurred in pedestrians under age 31). A limitation of using injury data from hospitals is that not all patients may report the cell phone-related injury to the doctor (Naser & Troyer, 2013). Pedestrians may also not attend a hospital in some cases – for example, if the injury was minor, they may choose to go to a clinic instead. To that end, the real number of pedestrian injuries sustained from cell phone use may be underestimated in hospital data.

With regards to collision data involving distracted cycling, Mwakalonge et al. (2014) searched the FARS database from 2005 to 2007 for fatal collision involving both cycling and the

use of a portable electronic device. Only five cases were found. Details on these cases were not reported.

No collision data is currently available on the involvement of distraction in motorcycle collisions. Based on this review, it is clear that more sufficient collision data on distracted walking, cycling, and riding is needed. Little is known about how hospitals and police agencies collect and report on distraction-related injuries and fatalities among vulnerable road users. Additionally, little information is available on the circumstances of collisions involving distracted pedestrians, cyclists, and riders. Thus far, conclusions about the magnitude of distracted road use by pedestrians, cyclists, and riders cannot be drawn from the limited data available (Mwakalonge et al., 2015).

The lack of collision data may be related to the novelty of distracted walking, cycling, and riding and lack of publicity towards these issues. As collision data are based on police collision reports, it is likely that police officers were not aware of these subjects in the first place. Future initiatives are needed to increase the training and awareness of these issues so that better distraction-related collision/injury data are collected and reported on among pedestrians, cyclists, and riders.

3.6. Summary

Different methods of measurement provide different kinds of data and insight into the role of distraction among drivers and other road users. Experiments are often used to assess the *effects* of distracted road use. Observational studies shed light on the *prevalence* of distracting behaviours in real traffic. Naturalistic driving studies provide accurate and detailed information on drivers' exposure to distracting activities and subsequent *crash/near-crash risk*. Surveys provide vital insight into the *behaviours, attitudes, and perceptions* towards distracted road use. Finally, collision data provide *statistics* on collisions involving distraction.

Different methods vary with regards to their degree of validity, experimental control, and variability of measurements (Romo & Yang, 2015). Validity refers to the extent to which the results accurately predict behaviour in the real world. Control relates to the use of randomization, manipulation of variable(s), and a control group in order to establish cause and effect relationships. Variability of measurements refer to the extent to which the measurements are consistent and yield the same results each time under similar conditions (important for tracking behaviour over time) (Romo & Yang, 2015).

There are often trade-offs between experimental control and validity, as the more structured and controlled a study is, the less realistic it becomes. Figure 3.1 compares the degree of validity, experimental control, and variability of measurements for each research method. As quoted by Dr. Susan Chrysler from the National Advanced Driving Simulator (NADS) at the University of Iowa "There is no perfect method that can account for every aspect of behavior research. There are various factors that can influence the type and quality of data being collected and, ultimately, the study findings." Thus, the choice of method often depends on what the research question is.

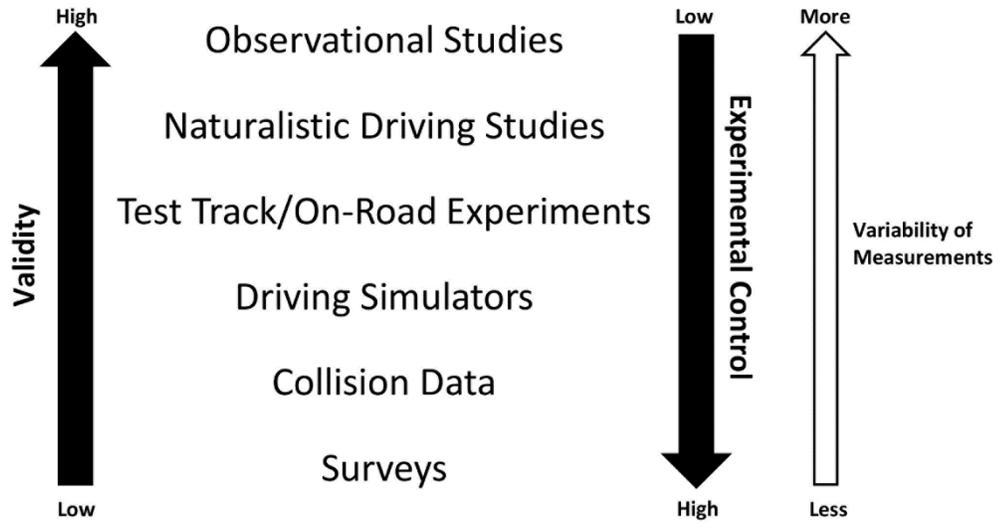


Figure 3.1. Methods of measurement and their relationship to validity, experimental control and variability of measurements. Adapted from Romo and Yang (2015).

4. Distracted Driving Legislation

Based on the research reviewed, it is clear that driver distraction is an important road safety issue. Secondary task engagement while driving is prevalent worldwide, particularly using cell phones behind the wheel. Surveys show that nearly half of all drivers at some point in the United States or Canada report talking on a cell phone while driving at any given moment. Observational studies reveal that a substantial proportion of drivers are involved in at least one distracting activity while driving (up to 30%), and that cell phone use rates vary on average, from 2% to 6%. These numbers are expected to rise with the rapid growth of built-in technologies in vehicles and portable electronic devices.

In recent years, considerable steps have been taken globally to prevent and reduce collisions, injuries, and fatalities where distraction is a factor. The most notable action has been the passage of legislation imposing sanctions, such as fines and demerits, for offenses of distracted driving. Legislation concerning the use of hand-held cell phones while driving has been introduced in a number of countries, including Canada, the United States, Europe, and Australia. Some legislation goes beyond cell phones and prohibits the use of other electronic devices while driving.

Laws against distracted driving can be specific or general (Avenoso, 2012). Specific laws explicitly state the source of distraction that is prohibited by drivers (e.g., “using hand-held cell phones is illegal”). General laws address driver distraction under the general scope of driving “carelessly” or “without due care and attention” (Harbluk et al., 2010). For example, in some jurisdictions, while the use of navigation systems, music players, and TV/DVD players are not explicitly prohibited, drivers may be issued a ticket if it leads to careless driving.

Based on a recent 2015 report by the World Health Organization, 139 countries have legislation against the use of hand-held cell phones while driving, while an additional 31 countries prohibit both hand-held and hands-free phones (WHO, 2015). Table 4.1 is a list of countries that restrict the use of hand-held phones while driving. In most countries, infractions carry a fine and/or demerit points. However, convicted drivers may face jail time in some countries, such as New Delhi (India), Saudi Arabia, and Ireland (for a second offense of texting and driving).

Table 4.1. Countries that prohibit the use of hand-held cell phones while driving.

Africa					
Angola	Botswana	Egypt	Ethiopia	Libya	Morocco
Nigeria	South Africa	Sudan	Uganda	Zimbabwe	
Asia					
Bahrein	Hong Kong	Iraq	Kuwait	Oman	Taiwan
Brunei	India*	Israel	Lebanon	Pakistan*	Thailand
Cambodia	Indonesia	Japan	Malaysia	Singapore	Turkmenistan
China	Iran	Jordan	Nepal	South Korea	United Arab Emirates
Australasia					
Australia	New Zealand				
North American					
Canada*	Dominican Republic	Honduras	Mexico*	USA*	
Europe					
EU:			Non EU:		
Austria	Finland	Latvia	Slovakia	Albania	Norway
Belgium	Hungary	Lithuania	Slovenia	Bosnia and Herzegovina	Russia
Bulgaria	Ireland	Luxembourg	Spain	Croatia	Serbia
Cyprus	Italy	Malta	Sweden	Isle of Man	Switzerland
Czech Republic	France	Poland	Netherlands	Iceland	Turkey
Denmark	Germany	Portugal	United Kingdom		Ukraine
Estonia	Greece	Romania			
South America					
Argentina	Brazil	Chile	Colombia	Ecuador	Peru

*In some jurisdictions only.

Source: World Health Organization (2015).

4.1. Canada

All Canadian provinces and territories have a general law that prohibits “driving without due care and attention” or “driving carelessly” which can cover distracted driving. Penalties for the offense vary by province/territory, but it is punishable by fines, demerit points, or license suspension (Harbluk et al., 2010). In Alberta, the penalty is \$402 and six demerit points (Edmonton Police Service, 2016).

The first province to ban the use of cell phones while driving was Newfoundland in 2003. Quebec and Nova Scotia followed suit in 2008 with their cell phone bans. Alberta was the last province to impose a distracted driving law in 2011.

Appendix A summarizes the penalties and legislation on distracted driving in each province and territory. Currently, all Canadian jurisdictions (except Nunavut) have specific laws against the use of hand-held cell phones while driving. In most provinces, exceptions are made for emergency calls and use by emergency personnel (i.e., police, fire, and ambulance). No province or territory currently restricts the use of hands-free technology by all drivers.

With the recent rise of hand-held technologies that can be brought into the vehicle, several provinces including British Columbia, Alberta, Ontario, New Brunswick, and the Northwest Territories have amended their legislation to prohibit drivers from using any hand-held electronic devices while driving. This includes laptops, portable audio players (e.g., mp3 players, iPods), GPS systems, and video displays (e.g., TV/DVD players). Most recently in January 2016, Alberta extended their distracted driving legislation to restrict drivers from reading, writing, and personal grooming while driving (Government of Alberta, 2016a). The law applies to all motor vehicles (cars, recreational vehicles, farm vehicles, truck tractors, motorcycles) and even bicycles (Edmonton Journal, December 9th, 2015). To date, this is the most comprehensive legislative measure against distracted driving in Canada.

In British Columbia, Saskatchewan, and Yukon, drivers in the graduated driver's license (GDL) program are prohibited from using any hand-held or hands-free devices while driving (Canadian Automobile Association, n.d.).

4.1.1. Current Distracted Driving Situation in Canada

In British Columbia, over 55,000 tickets were issued in 2014 to drivers using an electronic device while driving (Global News, June 30th, 2015). This number is up from 2013 when 53,000 tickets were handed out. In summer 2015, the provincial government began a four-week public consultation on their distracted driving laws. With a fine of \$167 and three demerits, the province had the second lowest penalties for distracted driving. Over the course of the consultation, an overwhelming majority of respondents (over 90%) said they were "very concerned" about distracted driving and supported raising the fine. 96% also expressed wanting to see tougher measures, such as vehicle impoundments and licence suspensions, for repeat offenders (BC Gov News, July 24th, 2015).

According to the Government of Alberta, a total of 87,633 tickets were issued to distracted drivers between September 2011 (when the distracted driving legislation came into effect) and March 31, 2015. Over 27,000 tickets were issued from April 2014 to end of March 2015. 97% of these citations went to drivers operating a hand-held electronic device while driving. Male drivers made up two-thirds of distracted drivers, particularly those between the ages of 22 to 34 years (Government of Alberta, December 10th, 2015). Effective January 1, 2016, drivers incur a penalty of \$287 (up from \$172) and three demerits for distracted driving. Drivers are prohibited from programming a GPS device, reading, writing, or personal grooming, along with using any hand-held communication or electronic devices (such as cell phones, laptops,

video games, cameras, video entertainment displays, and portable audio players) (Government of Alberta, 2016a).

In Saskatchewan, over 3,300 motor vehicles collisions in 2014 involved a distracted driver (SGI, October 1st, 2015). According to a 2015 report by Saskatchewan Government Insurance (SGI), distracted driving is the leading cause of all collisions in the province, and the third most common cause of fatal collisions, following impaired driving (first) and speeding (second). Since January 2010, drivers using an electronic communication device while driving or driving without due care and attention have faced a \$280 fine and four demerits. In June 2014, the province amended their distracted driving law to allow vehicles to be impounded for up to seven days if a driver is caught for a second or subsequent offense of using an electronic communication device while driving within one year, or a third or subsequent offence of driving without due care and attention within one year. Within a year of the law, 35 drivers had their vehicles impounded for the above reasons (SGI, October 1st, 2015).

In summer 2015, Manitoba increased their demerits to five points, on top of a \$200 fine (the highest demerit point penalty for distracted driving in Canada) (CBC News, June 4th, 2015).

In 2015, the Ontario Provincial Police reported that distracted driving remained “the number one killer on Ontario roads” (CBC News, March 11th, 2015). For the seventh straight year, distracted driving was expected to exceed impaired driving as the top contributing factor in fatal collisions. In September 2015, the province raised their fine to \$490, with the maximum at \$1,000, and added three demerits – the second largest fine in Canada for distracted driving (Ontario Ministry of Transportation, 2015).

In Quebec, police officers have reported a rise in distracted driving offenses each year since the province banned the use of cell phones while driving in 2008 (CBC News, April 23rd, 2015). 66,000 tickets were handed out for distracted driving in 2014 compared to 11,000 within the first year of the law. The fine remains at \$115 to \$154 (the lowest in the country), plus four demerits, however the province recently introduced legislation that allows new drivers to lose their license for three months if they receive a citation for texting and driving (CTV News, April 23rd, 2015).

Effective February 2015, drivers in Nova Scotia caught for distracted driving receive a \$233.95 fine for the first offence, a \$348 fine for the second offense, and a \$587 fine for subsequent offenses (Nova Scotia Transportation and Infrastructure Renewal, 2016). While the fine amount for distracted driving is double that for impaired driving, Cape Breton police officers report that 177 tickets were issued for texting while driving compared to 80 charges laid for impaired driving in 2015 (CBC News, January 15th, 2016).

In August 2015, Prince Edward Island tripled their maximum fine to \$1,200 and increased their demerits from three to five. The province currently has the strictest penalties for distracted driving in Canada (CBC News, August 8th, 2015).

In 2014, the Northwest Territories increased their fine to \$322 (from \$110), on top of three demerit points (Government of Northwest Territories, June 20th, 2014). While the changes

are not effective yet, the province updated their distracted driving legislation in late 2015 to allow for license suspensions if a driver is caught using any hand-held electronic devices while driving. Drivers that receive a second, third, or fourth infraction within two years can have their licence suspended for 24 hours, 7 days, or 30 days, respectively (CBC News, October 14th, 2015).

Police officers in Newfoundland and Labrador reported a marked decline in the number of distracted driving offenses over the course of 2015 (CBC News, December 28th, 2015). 322 tickets were issued in January 2015, but only 17 were handed out in September. Approximately 200 tickets were issued in February and March, but this number dropped to just over 50 in April and May. Between January and September of 2015, a total of 1,144 tickets were issued to distracted drivers. The fine has remained at \$100 to \$400 since 2010.

Nunavut remains the only jurisdiction in Canada to have no legislative measure against the use of cell phones while driving. However, most recently, the government is considering updating its Motor Vehicle Act to regulate the use of cell phones, texting, and eating while driving (CBC News, February 9th, 2016).

4.2. United States

Appendix B summarizes the legislation and regulations concerning the use of cell phones while driving in the U.S.

As of 2016, 14 states and D.C. have specific laws that prohibit all drivers from talking on a hand-held cell phone while driving (GHSA, 2016). New York was the first state to pass the law in 2001. Currently, all state laws are primarily enforced, meaning an officer may stop and ticket a driver solely for using a hand-held phone while driving. Most laws allow dialing a hand-held phone and talking on it when the vehicle is stopped at a controlled intersection or parked off the roadway.

A total of 46 states and D.C. have laws that prohibit all drivers from texting while driving. Washington, D.C. was the first state to implement such a law in 2007. All laws are primarily enforced, except in five states where it is secondarily enforced (i.e., the officer may only issue a ticket if the driver was stopped for another traffic offense) (GHSA, 2016).

Several states also restrict the use of both hand-held and hands-free devices by teenage/novice drivers (38 states and D.C.) or school bus drivers (20 states and D.C.). The licensing system for teenage/novice drivers varies across states, but often include those under the age of 18 or 21 and/or holding a learner's or intermediate permit (GHSA, 2016).

4.3. Australia

Under the Australian Road Rules, all states and territories have passed legislation concerning the use of hand-held cell phones while driving since 1999 (Taylor et al., 2007). Drivers are prohibited from talking, texting, emailing, or using a hand-held phone in any way while the vehicle is moved or stationary; however use is allowed if the vehicle is parked away

from traffic (Australian Road Rules, Rule 300). A phone may also be used if it is fixed to a mounting in the vehicle, or does not require the driver to touch any part of the phone. These regulations on hand-held phone use also apply to motorcycle riders with a full license (VicRoads, 2015). Additionally, legislation restricts the installation and use of television receivers or visual display units in any motor vehicles (Australian Road Rules, Rule 299).

In New South Wales, Northern Territory, South Australia, Queensland, and Victoria, novice drivers and riders are prohibited from using any cell phones (hand-held or hands-free) at all while driving or riding.

4.4. Europe

In Europe, the use of certain electronic devices while driving is addressed by specific or general forms of legislation depending on the country (Avenoso, 2012). Specific legislation explicitly states the device that is prohibited. General legislation addresses the use of electronic devices more broadly through legislation on “careless or dangerous driving,” which includes issues of driver distraction. Appendix C summarizes the distracted driving legislation for all EU countries.

Currently, all EU nations have specific legislation against the use of hand-held cell phones while driving. Sweden, the last EU country to follow suit, amended their legislation in December 1, 2013. However, the legislation has come under criticism as the ban on cell phone use while driving only applies if it detrimentally affects driving performance (Radio Sweden, 2016). Consequently, many cases in which drivers were cited for the use of cell phones have gone to court. The head of traffic police in Stockholm states that “The law is toothless, it is really hard to work on the basis of that law” (Radio Sweden, January 6th, 2016). In Greece, Italy, Luxembourg, Malta, and Slovenia, cell phone use is allowed if the phone is in a mounting affixed to the vehicle (Avenoso, 2012).

17 countries prohibit the use of personal navigation devices while driving (Avenoso, 2012). This is covered under general legislation in 13 countries and specifically restricted in 4 countries (Cyprus, Spain, Finland, and Luxembourg).

Manual operation of music players while driving is prohibited in 13 countries, 6 of which specifically restricts their use while driving (Greece, Spain, Finland, Luxembourg, Malta, and Portugal). All of these countries, except Finland, further prohibits the use of headphones while driving (Janitzek et al., 2010).

Manual interaction and watching TV/video players while driving are prohibited in 16 countries (Avenoso, 2012). 10 countries have general legislation, while 6 countries have specific legislation against their use by drivers.

4.5. Legislation on Distracted Walking, Cycling, and Riding

No country/jurisdiction, to date, has enacted legislation prohibiting the use of cell phones or other electronic devices while walking. While some jurisdictions have considered

implementing these policies due to the recent rise of distracted pedestrians, they have not been approved. For example, in New York, a former senator proposed a law in 2007 that would have prohibited pedestrians from using any electronics at crosswalks and intersections, however the measure was never passed. Four other states – Arkansas, Delaware, Illinois, and Utah – have attempted to submit bills banning the use of electronics by pedestrians but were not successful (Mwakalonge et al., 2015).

In Canada, under Manitoba's Highway Traffic Act and Quebec's Highway Safety Code, cyclists are prohibited from wearing headphones or earplugs while cycling. Alberta's distracted driving legislation also applies to motorcycles and bicycles, restricting both operators from using hand-held cell phones and other electronic devices, entering information on GPS units, reading, writing, and personal grooming (Edmonton Journal, December 9th, 2015). In the cities of Vancouver and Whitehorse, local traffic bylaws make it illegal to wear headphones while cycling

In the U.S., seven states – California, Delaware, Florida, Maryland, New York, Rhode Island and Virginia – have legislation restricting the use of headsets or headphones while cycling (Bergal, 2015). Bylaws in the cities of Chicago, Philadelphia, and Bozeman (Montana) ban the use of hand-held cell phones while cycling. Other countries including Belgium, Bermuda, Germany, and New Zealand have legislation prohibiting the use of hand-held cell phones while cycling (De Waard et al., 2010; Mwakalonge et al., 2015).

In most jurisdictions, distracted driving laws that apply to motor vehicles also extend to motorcycles (unless otherwise stated).

4.6. Effectiveness of Distracted Driving Legislation

The effects of distracted driving legislation (usually regarding cell phone use) have been evaluated with a number of different methods. In survey studies, self-reported behaviours of cell phone use are examined among drivers in jurisdictions with cell phone bans and jurisdictions with no such bans. In observational studies, drivers' use of cell phones are measured in jurisdictions before and after the enactment of cell phone bans, and compared with control jurisdictions lacking similar bans. Studies using collision data compare the rate of injuries or fatalities before and after a ban was imposed in a single jurisdiction, or by comparing the rate of collisions in multiple jurisdictions with and without bans. Finally, another approach has been to compare the rate of insurance collision claims before and after the implementation of cell phone bans.

As reviewed below, the majority of studies have been conducted in the U.S. The results from observational studies seem to indicate that laws that prohibit the use hand-held cell phones while driving are effective in reducing phone use in the short-term. However, the long-term impact of cell phone bans is ambiguous. The results from collision and insurance claim data on the effects of cell phone laws are less clear due to certain limitations in these studies. Overall, there is a need for further research, particularly outside the U.S., before conclusions about the efficacy of cell phone bans can be drawn. Given that many jurisdictions have only recently introduced legislation that prohibit texting or use of other electronics while driving, few empirical studies have evaluated the effectiveness of these laws. However, some survey studies

suggest that all-driver texting bans may be effective among young drivers. Finally, there is evidence that distracted driving legislation that is supported by highly publicized and ongoing enforcement efforts can increase compliance with the law and effectively reduce distracted driving.

4.6.1. Effects of Legislation on Drivers' Use of Cell Phones (Talking Only)

In McCartt et al. (2003), the use of hand-held cell phones by drivers in New York were observed before and after a hand-held phone ban took effect in November 1, 2001. The observations were compared with those conducted in Connecticut, a control state with no cell phone legislation at the time of the study. Drivers were observed in both states one month before New York's law took effect (October 2001), shortly after the law was implemented (December 2001) and a second post-law period in March 2002.

The results revealed that 2.3% of drivers observed in New York were using a hand-held cell phone prior to the law. Shortly after the law was in effect, usage significantly declined to 1.1%. The use rate remained at 1.1% in the second post-law observations in March. Meanwhile, in Connecticut, 2.9% of drivers observed were using a hand-held cell phone prior to New York's cell phone law. In the post-law observations, cell phone usage was 2.7% in December and 3.1% in March – more than double the usage rate in New York. These findings show that, as intended, New York's cell phone ban significantly reduced the proportion of drivers using cell phones immediately after the law took effect and three months after (an overall reduction of 56%). Compared to Connecticut, which lacked a similar law, phone use remained high in all three observation periods. The authors suggest that cell phone bans seem to deter drivers from using cell phones in the short-term.

A similar study was conducted in Washington, D.C., where the rate of hand-held cell phone use by drivers was compared before and after a hand-held phone ban took effect in July 2004 (McCartt et al. 2006). The findings were compared with observations in Maryland and Virginia, two nearby states with no cell phone laws at the time of the study. A large percentage of drivers from these two states also travel to and from D.C. Drivers were observed in all three jurisdictions in March 2004 and October 2004 – several months before and after D.C.'s law took effect in July 2004. Observers also recorded information on in-state and out-of-state vehicles based on the license plates in order to account for travelling drivers.

The study found that 6.1% of drivers observed in D.C. were using a hand-held cell phone prior to the law. Usage significantly declined to 3.5% several months after the law took effect – nearly half the pre-law rate. Use rates fell slightly in Maryland (6.3% vs. 5.7%) and increased significantly in Virginia (4.7% vs. 6.2%). The authors suggest that the decline in Maryland may be attributed to the large proportion of D.C. drivers commuting to and from D.C. Like the study in New York, D.C.'s cell phone ban showed a short-term reduction in the number of drivers using cell phones.

In McCartt et al. (2010), the long-term effects of hand-held cell phone bans were examined in D.C., New York, and Connecticut. The rate of cell phone use by drivers was compared before (using pre-existing data) and several years after the enactment of cell phone bans. Poisson regression models were also used to estimate the trend of cell phone use over time

based on actual rates with a cell phone ban and what would have occurred if there was no ban in place.

As summarized in Table 4.2, observations in New York showed that the rate of cell phone use declined immediately following the ban, then rose back to pre-law levels after 18 months. In April 2009, the use rate was 3.7%. The regression model estimated that phone usage was reduced by 47% immediately after the law. If no law had been implemented, the model predicted that the use rate in April 2009 would have been 4.91% – 24% higher than the observed rate of 3.74%.

In Connecticut, the use of cell phones declined from 3.3% in the pre-law observation period to 2.1% in April 2009 – three and a half years after the ban took effect in October 2005. The regression model estimated that cell phone use was reduced by 76% after the ban was implemented. If no ban had been imposed, the model predicted that the usage rate in April 2009 would have been 6.05% – 65% higher than the observed rate of 2.14%.

In D.C., the regression model estimated that cell phone use rates fell by 41% immediately after the ban. If there was no ban, the model predicted that the use of cell phones in April 2009 would have been 7.41% – 43% higher than the observed rate of 4.22%.

Table 4.2. Rates of talking on hand-held cell phones while driving.

	Cell Phone Use Rates			
	Sept. 2001	Dec. 2001/ March 2002	March 2003	April 2009
New York (ban effective Nov. 2001)	2.3%	1.1%	2.1%	3.7%
Connecticut (ban effective Oct. 2005)	2.9%	2.9%	3.3%	2.1%
	March 2004	Oct. 2004	Oct. 2005	April 2009
D.C. (ban effective July 2004)	6.1%	3.5%	4.0%	4.2%

Source: McCartt et al. (2010).

Collectively, these results show that legislative measures in New York, Connecticut, and D.C. that make it illegal to use hand-held cell phones while driving are effective in immediately reducing drivers’ use of hand-held phones. Regression models predict that, in all three states, the usage rate several years later is lower with a ban than what would have been expected without one (24% lower in New York, 43% lower in D.C., and 65% lower in Connecticut).

The authors suggest that the lower effect of cell phone bans in New York (and rise of cell phone use rates back to pre-law levels after 18 months) may be attributed to a decline in ongoing enforcement efforts and reduced compliance with the law, whereas in D.C., the longer-term impact of the cell phone ban may be partly due to their more publicized and vigorous

enforcement campaigns against distracted driving (McCartt & Hellinga, 2007). This suggests that enactment of the law may not be enough to produce long-lasting changes in driver behaviour, but that awareness and stricter enforcement is also needed to maintain compliance with cell phone laws, along with the other E's of traffic safety (discussed in a later section of the report).

Evidence that targeted advertising and rigorous enforcement can be effective was demonstrated by the National Highway Traffic Safety Administration (NHTSA). In 2010 and 2011, the NHTSA implemented four waves of high-visibility enforcement (HVE) demonstration programs in Hartford, Connecticut and Syracuse, New York targeting hand-held phone use (talking and texting) while driving (Cosgrove et al., 2011). During the demonstrations, public awareness of distracted driving and of the HVE program was generated through paid and earned media (radio, TV, and online). Strategies of intensive law enforcement included using stationary patrols, spotters, and roving patrols to detect and ticket drivers who were using cell phones. Observations were conducted before and after the demonstrations took place, and in control areas without such HVE programs, to assess the rate of cell phone use by drivers.

The results showed that, from before the first demonstration to after the last demonstration, the rate of drivers talking on hand-held phones was significantly reduced from 6.8% to 2.9% in Hartford (a 57% reduction). Phone use in Syracuse was significantly reduced from 3.7% to 2.5% (a 32% reduction) (results about texting are discussed later). These findings provide evidence that strategies of strong enforcement, combined with well-publicized education and awareness campaigns, can increase adherence to distracted driving laws, even eight years after the law took effect (in the case of New York's cell phone law). Accordingly, such initiatives should be strongly considered when attempting to deter drivers from using cell phones or engaging in other distracting activities while driving.

Two other studies examined the rate of cell phone use in the United Kingdom before after the introduction of a cell phone ban in December 1, 2003. Johal et al. (2005) found that cell phone use by drivers dropped 50% after the ban (from 1.85% in September/October 2003 to 0.97% in February/March 2004). In a follow-up study, Hussain et al. (2006) examined the impact of the law two years after its enactment in September/October 2005. Overall use of cell phones while driving was 1.6%. The authors concluded that, similar to the study conducted in New York, cell phone usage rose back to nearly pre-law levels and suggest that the UK ban may be only effective in the short term.

A 2002 observational study conducted in Melbourne Australia found that 2.0% of drivers observed were using a hand-held cell phone while driving (Taylor et al., 2003). At the time of the study, hand-held phone use by drivers was banned in the state of Victoria. In 2005, additional restrictions were introduced in the legislation, including stricter penalties and increased enforcement. In 2006, observations were conducted in exactly the same way as the earlier study to assess the change in phone use while driving (Taylor et al., 2007). The results revealed that 1.6% of the drivers observed were using a hand-held cell phone while driving. The authors suggest that this slight reduction in phone use may be attributed to the stricter legislation, along with more intensive enforcement of the law in Melbourne. However, a major limitation of the UK and Australian studies is that no observations were conducted in control sites with no cell

phone restrictions. Thus, it is unclear if the observed rates of phone use while driving was attributed to the cell phone law itself or other possible factors.

In a study by the Highway Loss Data Institute (HLDI), the frequency of insurance collision claims was examined before and after the implementation of cell phone bans in New York, D.C., Connecticut, and California (HLDL, 2009). Claim frequency was compared with nearby control states with no such bans. The insurance claims covered first-party physical damage to a vehicle from a collision. The Poisson regression models showed no significant reduction in monthly claim frequency for any of the states in the months before and following the implementation of the bans, relative to control states. The authors concluded that collision claim data showed no evidence that collision risk is reduced when cell phone laws are passed. One limitation of this study is that confounding variables that could have influenced the frequency of insurance claims were not controlled for between the study state and their respective control states. Thus, it is unclear if differences in, for example, highway safety policies, safety education, or road construction during the study period may have biased the results (McCartt et al., 2014). Another limitation is that all collision claim data were examined, rather than claims specific to using cell phones while driving.

Another approach used to evaluate the effectiveness of cell phone laws is to examine the rate of motor vehicle collisions in a single-state (pre-law period vs. post-law period) or across multiple states (states with cell phone bans vs. states without such bans).

In Nikolaev et al. (2010), the number of annual fatal collisions per 100,000 licensed drivers and the number of annual injury collisions per 1,000 licensed drivers were evaluated in all 62 counties in New York from 1997 to 2007. As the statewide ban took effect in November 2001, comparisons were made between the pre-law period of 1997-2001 and the post-law period of 2002-2007. The study found that the mean fatal collision rate declined in 46 counties following the ban (10 of which did so significantly), while the mean injury collision rate declined in all 62 counties (46 did so at a significant level). Counties with higher driver density showed a larger reduction in injury collisions following the ban.

Although these findings seem to indicate that the cell phone ban had an impact on reducing injury collisions, these results should be interpreted with caution as confounding factors, such as safety education or traffic safety laws across counties were not controlled for (for example, the “Safe Streets NYC” program in New York City). Another factor to consider is that, over the study period (1997-2001), the number of cell phone owners had grown substantially, while collision rates had remained flat. Thus, it is unclear whether the decline in collision rates are attributed to the cell phone law itself, or other unexplained factors. Another limitation is that there was no control group used as a comparison (control state with no cell phone restrictions) (McCartt et al. 2014).

Jacobson et al. (2012) evaluated the annual rate of injury collisions in all New York counties before and after the hand-held phone ban took effect. Pennsylvania was used as a control state as it had no phone ban at the time of the study. Injury collision data from 1997-2008 were examined (1997-2001 was considered to be the pre-law period). To control for driver density, counties in both states were placed into three groups based on the number of licensed drivers per roadway mile: (1) urban/suburban, (2) rural, and (3) very rural. Separate regression

models were applied to each group to examine the trend of injury collision rates over time (up to seven years following the ban).

Compared to the results in Pennsylvania, the regression models showed a significant decreasing trend in the collision rate during the post-law period for counties in groups (1) and (2) in New York, relative to the pre-law period. Similar to the findings by Nikolaev et al. (2010), the authors suggest that a cell phone ban may be more effective in reducing the rate injury collisions in areas with higher driver density than areas with lower driver density. However, similar to other collision studies, caution should be exercised when extrapolating these findings to other counties/groups, as factors such as geography, climate, road conditions, education programs, and other driving laws are likely to vary across states.

In a national study, Lim and Chi (2013) examined the impact of cell phone bans on yearly fatality rates across the U.S. State-level collision data obtained from the Fatality Analysis Reporting System (FARS) from 2000 to 2010 were used. The effects of cell phone bans was assessed on fatality rates per 100 million miles traveled, fatality rates per 100,000 population, and number of drivers involved in fatal collisions by age group. Changes in these variables were examined in states before and after the cell phone ban was implemented, and compared with control states without such bans. Factors that might influence the yearly collision rate trend, such as gas prices and unemployment rate, were accounted for in the regression models.

The study found that cell phone bans did not significantly reduce the overall fatal collision rate based on miles traveled and population. However, in states with cell phone bans, the rate of fatal collisions was significantly reduced among drivers under 55 years, particularly drivers in the age group of 18-34 years. However, the authors did not account for the fact that some states had introduced young driver cell phone bans, while other states had secondary enforcement phone bans during the study period (McCartt et al., 2014). Consequently, these confounding factors may have biased the results of the study, which focused only on the effects of primarily enforced cell phone bans by all drivers.

In a 2009 telephone survey conducted in the U.S., the relationship between drivers' patterns of cell phone use in states with and without a ban on hand-held phone use and texting was investigated (Braitman & McCartt, 2010). 1,219 drivers over the age of 18 were sampled in 48 states and D.C. At the time of the survey, the use of hand-held cell phones was prohibited for all drivers in seven states and D.C., while texting was prohibited for all drivers in 16 states and D.C.

The survey found that the frequency of talking on a cell phone while driving was significantly higher in states with all-driver hand-held phone bans than without. In states with such bans, 22% of drivers reported talking on the phone daily, while 13% of drivers reported this in states with no such bans. When asked how often they talk with a hand-held and hands-free phone, 22% of drivers in states with all-driver hand-held bans reported always using hands-free phones, while 19% reported always using hand-held phones. In states without such bans, 13% always talk hands-free, while 40% always talk with a hand-held phone. Overall, the results suggest that laws that make it illegal to use hand-held phones while driving seem to have an impact on self-reported frequency of cell phone use. In states with all-driver hand-held phone

bans, drivers were less likely report talking on cell phones; when they did talk, they were more likely to use hands-free phones than hand-held. The results about texting are discussed in the next section.

4.6.2. Effects of Legislation on Texting While Driving

Given the difficulties associated with observing texting, such as distinguishing it from other phone operations like dialing and drivers hiding their phones from view, few observational studies have focused on drivers' rates of texting before and following the enactment of texting bans.

To evaluate the HVE demonstration programs in Connecticut and New York targeting cell phone use while driving, the NHTSA conducted observations to assess the rate of hand-held phone manipulation (e.g., texting, dialing) by drivers before and after the HVE programs took place, and in control areas without such programs (Cosgrove et al., 2011). The results showed that the rate of phone manipulation while driving was significantly reduced from 3.9% to 1.1% in Hartford (a 72% reduction), while the rate in Syracuse was significantly reduced from 2.8% to 1.9% (a 32% reduction). Similar to the observed rates of talking on hand-held phones, these results suggest that rigorous law enforcement, supported by well-publicized education and awareness campaigns, can be effectively applied to change phone use behaviours, including texting, while driving.

Similar to the study that examined the frequency of insurance collision claims following the implementation of cell phone bans, the HLDI used a similar method to examine collision claim frequency before and after the enactment of all-driver texting bans in California, Louisiana, Minnesota, and Washington (HLDI, 2010). Claim frequency was compared with nearby control states with only young driver texting bans or no texting bans at all. For all four states, the regression models showed no significant change in monthly claim frequency in the months before and after the texting ban, relative to the control states. The authors suggest that, based on collision claim data, there is no significant decrease in collision risk when texting bans are passed. Similar to the prior study, unrelated factors between multiple states may have influenced the trend of collision claim frequency. Caution is also warranted in interpreting these findings as all collision claim data were examined, rather than claims specific to texting while driving.

In the same 2009 telephone survey conducted by Braitman and McCartt (2001) described previously, the results showed no significant effects between texting frequency and presence of a state texting ban. 3% of drivers reported texting daily in states with all-driver texting bans, while 4% reported this in states with no such bans. The authors concluded that while hand-held cell phone bans seemed to have an impact on the frequency of cell phone use while driving, texting bans had little influence on drivers' self-reported frequency of texting. Contrary to these findings in which respondents were all over the age of 18, two very recent survey studies found that texting bans seemed to have an effect on teenage drivers' texting behaviours.

In Rudisill et al. (2015) the relationship between teenage drivers' prevalence of texting was examined in (1) states that imposed no texting bans, (2) states that banned young drivers from using all cell phones (i.e., talking, texting, emailing), (3) states that banned texting only by

young drivers, (4) states that banned texting by all drivers, and (5) states that banned texting by all drivers *and* banned young drivers from using all cell phones. Data on self-reported texting was extracted from the 2013 Youth Risk Behavior Surveillance System survey. The question that was asked among a nationally representative sample of 9th to 12th grade students was “During the past 30 days, on how many days did you text or e-mail while driving a car or other vehicle?” The final sample included 6,216 students after meeting the criteria of driving within 30 days and the minimum driving age in their respective state. All respondents were between 15 to 18 years of age.

The results showed that the prevalence of texting while driving was lowest in states with all-driver bans on texting *and* young driver bans on all cell phone use (36.8%), following by all-driver texting bans (41.5%), no texting bans (43.4%), young driver bans on all cell phone use (49.0%), and young driver texting bans only (49.6%). These findings show that all-driver texting bans seem to be more effective in reducing texting among young drivers than other types of provisions. The authors suggest that all-driver bans may be easier to understand than bans that apply to only certain drivers. This is on par with findings from a prior survey where more drivers reported knowing there was a cell phone ban in their state when they resided in states with all-driver cell phone bans (82%) than states with partial cell phone bans (19%) (Braitman & McCartt, 2010). Another reason that all-driver texting bans may be more effective among teens may be due to the influence of parents. As the law also applies to them, it puts them in a position to “lead by example” and encourage their children to adhere to the law.

Qiao and Bell (2015) used nationally representative data from the 2013 National Youth Risk Behavior Survey to examine the effects of distracted driving laws on texting behaviour among teenage drivers. Specifically, all-driver texting bans and all-driver hand-held phone bans were assessed. Texting frequency was extracted from the survey question: “During the past 30 days, on how many days did you text or e-mail while driving a car or other vehicle?” The final sample consisted of 6,168 high school students that were all above the minimum driving age in their state and drove in the past 30 days. Odds ratios were calculated to assess the association between texting while driving in the past 30 days and presence of state laws against distracted driving.

The results showed that all-driver texting bans significantly reduced the odds of texting while driving among teenage drivers (OR=0.703). However, this was not significant for all-driver hand-held phone bans (OR=0.846). These findings indicate that laws that specifically prohibit all drivers from texting are more effective in deterring high school students from texting and driving than laws that prohibit all drivers from using cell phones. Thus, modifying texting behaviours among teenage drivers may require specific laws that target texting and driving. This has important implications for reducing other distracting behaviours behind the wheel as it may be necessary to specifically prohibit certain activities (e.g., “using social media while driving is illegal”), rather than include it under general legislation (e.g., “using cell phones while driving is illegal”).

In a recent study, Ferdinand et al. (2014) examined the effects of texting bans on the number of fatal collisions across the U.S. Age-specific cohorts were also examined to determine which age groups were most impacted by texting bans. FARS data from 2000 to 2010 were used

to evaluate the number of fatal collisions following the implementation of a state texting ban, and compared with control states without such bans. A total of 48 states were included in the analysis. Several factors were accounted for in each regression model including enforcement of the ban (primary vs. secondary), type of ban (all-driver ban vs. young driver ban only), number of drivers involved in fatal crashes by age group; economic factors such as gas prices, unemployment rate, per capita income; and legal factors such as presence of seatbelt laws, hand-held cell phone bans, blood alcohol concentration limits, speed limits, and GDL programs.

The results showed that states with all-driver texting bans had significantly lower counts of fatalities than states without such bans. Further examination of the analysis revealed that states with primary enforcement of the law reduced fatalities by 3%, but secondary enforcement did not reduce fatalities. The age analysis showed that all-driver and young driver texting bans (primary) were associated with the largest reduction in fatalities among young drivers (15-21 years).

4.6.3. *Summary and Future Direction*

Empirical evidence on the effectiveness of distracted driving legislation, specifically relating to cell phone use (talking and texting) is mixed, indicating a need for further evaluations of these issues. While observational studies show that cell phone bans have immediate and short-term benefits, their impact over time is ambiguous. However, it is promising that regression models have predicted that phone usage in states with cell phone bans is lower five to eight years later than what would have been expected without a ban (McCartt et al., 2010).

Studies using collision and insurance claim data have several limitations, one of which is the inability to control for confounding factors, such as geography, climate, highway safety laws, education programs, road conditions, construction zones, and per capita income at the county or state level. Given that these factors are likely to vary across test and control jurisdictions, this presents challenges in using such data to draw conclusions about the effectiveness of cell phone and texting bans. It is also important that regression models account for any unobserved factors that might have occurred over the study period such as gas prices, recession, or unemployment rate at the state level. As these factors largely impact the number of drivers on the road, and subsequently, the number of fatalities, this can influence the yearly collision trend (Ferdinand et al., 2014; McCartt et al., 2014). From this review, only a few collision studies have attempted to control for these factors, putting their findings in question. Another concern is that the penalties for distracted driving and levels of law enforcement are likely to differ across states, which could lead to different compliance rates; this presents another challenge in multiple-state studies.

Findings from surveys focusing on the effects of texting bans among teen drivers are promising as they indicate that all-driver texting bans may be effective in deterring young drivers from texting and driving. Possible reasons are that complete bans are easier to understand than partial bans, and parents that are impacted by the ban may be able to influence their children to adhere to the law. Similar findings on all-driver texting bans were reported in one collision-based study (Ferdinand et al., 2014); however additional studies and analyses using crash measures are needed to validate these findings. Further research, aside from surveys, is also needed to evaluate the impact of all-driver vs. young driver only texting bans on texting behaviours while driving.

A positive finding is that high-visibility enforcement appears to be effective in reducing the use of cell phones (talking and texting) while driving even after the law had been passed several years before. This suggests that enactment alone may not be sufficient, but with increased publicity and consistent enforcement, it can enhance compliance with distracted driving laws (further discussion in the Strategies to Reduce Distracted Road Use section).

Based on this review, future assessments are needed to better understand the efficacy of cell phone and texting bans on drivers. This is important as many countries have allocated significant time and resources to implementing, publicizing, and enforcing these laws, however direct evidence of their benefits is unproven (McCartt et al., 2014). To address the limitations of current research, below is a list of recommended directions for future study:

1. There is a need to conduct more adequate and well-controlled observational and collision-based studies, particularly outside the U.S., so that more general conclusions about the effectiveness of distracted driving laws can be made.
2. As changing behaviour largely depends on changing traffic safety culture, there is a need to conduct more periodic surveys to assess changes in driver behaviour, attitudes, and perceptions following the enactment of distracted driving laws and over time.
3. There is a need to examine the varying levels of enforcement and penalties of current distracted driving legislations to determine which approaches are most effective and efficient in curbing distracted driving.
4. More research is needed on the long-term efficacy of cell phone bans, and in particular, texting bans. Given the recent passing of texting laws in many countries/areas, this has not been evaluated yet.
5. Research is needed to investigate the effects of distracted driving restrictions beyond cell phone use, such as entering information into navigation systems, watching TV/video players, operating music players, reading, writing, and personal grooming in order to determine if they have the desired effects on driver behaviour, and whether resources should continue to be directed towards these countermeasures.
6. Further studies following a methodology similar to the HVE demonstration programs initiated by the NHTSA are needed to examine the effectiveness of distracted driving legislation in combination with other strategies, such as tougher enforcement and increased education and awareness initiatives, particularly in other countries.

5. Strategies to Reduce Distracted Road Use

The enactment of laws prohibiting the use of cell phones and other electronic devices while driving is a policy tool that is commonly used to change driver behaviour, in order to prevent and reduce collisions where distraction is a factor. However, as reviewed above, enactment alone is insufficient to maintain and sustain compliance with the law. In this section, strategies to reduce distracted road use will be discussed within the context of the five E's of traffic safety: education, enforcement, engineering, engagement, and evaluation.

5.1. Education

The epidemic of distracted road use is believed to be more than just a traffic issue. Rather, it is a societal issue that is governed by culture (WHO, 2011). Traffic safety culture refers to the social factors that guide a community to engage in safe or risky behaviours in traffic (Ward et al., 2015). These social factors include general attitudes towards distracted road use, perceptions of risk and social acceptability of engaging in distracting behaviours, knowledge of distracted road use issues, and support for countermeasures. If the public response is indifference towards the problem of distraction, changing this cultural norm will be essential. Thus, the goal of education is to develop a more positive culture towards distracted road use in order to change road user behaviour (e.g., increasing the risk perception of distracted driving, increasing the knowledge of distracted driving laws, increasing public support for countermeasures to reduce distracted walking, cycling, and riding).

To assess the traffic safety culture within the Edmonton region, the Edmonton and Area Traffic Safety Culture Survey is conducted biennially to determine the behaviours, attitudes, and perceptions of road users towards various traffic safety-related issues, including distracted driving. In the 2014 telephone survey, 89% of respondents perceived distracted drivers to be a very serious threat to their personal safety (Thue & Grekul, 2015). 64% perceived drivers talking on hand-held cell phones to be a very serious threat, while 88% thought the same about drivers who were texting, emailing, or using social media while driving. When asked about the acceptability of talking on a hand-held cell phone while driving, 72% of respondents viewed it as completely unacceptable. 22% viewed the same about talking on hands-free cell phones and an overwhelming majority (92%) viewed texting, emailing, or using social media while driving as completely unacceptable. However, 20% of respondents said they talked on a hand-held cell phone while driving in the past 30 days. 42% said they talked on a hands-free cell phone and 11% said they sent a text message or email while driving in the past 30 days. Thus, while the majority of road users perceived distracted driving to be a threat to their safety and found it completely unacceptable, many drivers still willingly engaged in such behaviours. This indicates a need for further efforts to reduce the gap between attitudes of road users and their behaviours.

One approach to changing the culture of traffic safety is through education and training programs. This begins with ensuring that road users understand what distraction is, how it arises, and how it negatively affects traffic performance. Given that new drivers are often not aware of the dangers of engaging in distracting activities behind the wheel, it is critical that they understand the basics of attention as a limited resource and the consequences of multi-tasking

while driving, such as inattentive blindness. In Texas, all young and new drivers are required to take a distracted driving module in the classroom (Texas Department of Public Safety, 2016). On top of that, drivers must view a 2 hr informational video, as part of the Impact Texas Teen Drivers (ITTD) program, before taking the road test. The ITTD program was developed by the state Department of Public Safety to raise awareness and educate drivers about the issue of reckless and distracted driving. The Canadian Automobile Association (CAA) also offers an online distracted driving course that focuses on how driving ability is affected by limited attentional capacity, the effects of distracted driving, and strategies to deal with distractions. While this is a voluntary course, similar courses should be part of the curriculum in driver education and motorcycle training programs. Pedestrian and cycling education focusing on safe road use and reducing distractions should also be taught in schools so that safe traffic habits are developed at an early age (Elvik et al., 2009).

Aside from providing road users with knowledge about distracted road use, training is needed to ensure that road users are self-aware of their skills and ability to manage distractions (Regan et al., 2009). This includes teaching road users to recognize their own strengths and limitations in traffic performance, be self-aware of the effects of distraction imposed by certain secondary tasks, and be able to self-regulate their use of secondary tasks based on current traffic task demands (such as avoiding the need to use a cell phone when driving on busy roads). Strategies to avoid distractions while driving should also be taught, such as entering information on a GPS unit before starting to drive, limiting the number of passengers, storing away loose objects so they do not move around in the vehicle, ensuring that personal grooming is finished before driving, and pulling over to a safe location if it is necessary to use a cell phone.

A school-based program called “You Hold the Key” was developed and tested in Ohio for students aged 15-19 years old (King et al., 2008). The program aimed to promote safe driving knowledge, attitudes, and behaviours towards distracted driving, seatbelt use, impaired driving, and peer influence. The 10-week program consisted of student discussions, group work, role-playing, educational videos, presentations by experts (e.g., law enforcement officers, judicial prosecutors), and panel discussions with young adults in the community whose lives had been impacted by reckless driving. To evaluate the program, a survey was administered to students before the program started, after the program was completed, and 6 months later (King et al., 2008). The results showed that students involved in the program reported significantly more positive driving behaviours following the program and 6 months after, compared to those not in the program. For instance, drivers in the program were less likely to report distracted driving and knew more strategies to reduce distractions.

In Lenné et al. (2011), a simulator-based training program was developed and piloted to promote safe communication between young drivers and peer passengers. Over a 2-hr training session, pairs of 18-21 year olds (one acting as the driver, the other as the passenger) were taught about teamwork, effective communication skills, and being a positive influence as a passenger. The program consisted of group discussions, role-playing, and driving simulations. Evaluation of the program 1-2 weeks later showed that drivers who received the training exhibited safer driving behaviours during the simulated driving test and passengers made more safe-related comments (such as urging drivers to not speed or engage in distractions) than driver-passenger pairs that did not receive the training. The findings of these two studies indicate that such

programs can be effective and should be offered in schools and driver education to promote safe road user behaviours.

Education should also be directed at commercial truck drivers, shift workers, and experienced drivers who often drive with low driving task demands (e.g., driving along the same route every day or for long hours on the highway) (Craft & Preslopsky, 2009). It has been suggested that when drivers are “under-aroused” (e.g., bored), they are more likely to be affected by unpredictable changes in road conditions, weather, and behaviour of other road users, as well as the appearance of extraneous stimuli, such as roadside billboards (Bunn et al., 2005; Wallace, 2003). These drivers are also more likely to be involved in distracting activities, such as using a cell phone, to increase arousal levels. Simple, low-key strategies such as engaging in mental trivia tasks, consuming caffeine, taking frequent breaks, and cooling the temperature inside the vehicle by 5-10 degrees have been shown to effectively maintain vigilance in drivers without compromising road safety (McKernon, 2008). Such strategies should be taught in driver education and truck driver training programs so drivers are aware of safe alternatives that may be used to stay alert behind the wheel.

Another strategy to inform and educate the public about distracted road use is through targeted campaigns. Information about the impact and risks of distraction may be delivered through mass media channels, such as the radio, television, print (newspapers, magazines, billboards), or online. For road safety campaigns to be effective, the target audience should be considered and messages should be tailored to appeal to them. For example, research has shown that teen drivers and drivers between the ages of 18 to 35 years are overrepresented in collisions involving distraction (NHTSA, 2012a). Drivers in these age groups are also more likely to use electronic devices and/or engage in other activities while driving than older drivers. Other targeted groups are commercial truck drivers and shift workers who often drive for long distances on monotonous roads, and thus have an increased tendency to engage in distracting activities to maintain alertness (Craft & Preslopsky, 2009). Accordingly, media coverage about the dangers of distracted driving and information on safe alternatives to increase driver alertness should be aimed at these targeted groups. Pedestrian and cycling safety campaigns should also target teens and young adults given their high ownership of cell phones and other electronic devices.

Once the target audience is identified, it will be essential to learn the demographics’ needs and interests in order to increase the likelihood that they are exposed to the messages – for example, determining what radio stations and television programs the audience prefers so that advertisements about distracted road use are effectively placed. Popular websites (e.g., blogs, online forums) and social media networks of the target audience should also be identified so that messages are delivered to the relevant groups.

Information and awareness about distracted road use can also be disseminated more personally through face-to-face interaction, such as presentations and workshops in schools, work settings, or community organizations. A meta-analysis of studies on the effects of road safety campaigns on collisions suggests that information delivered by means of personal communication may be associated with greater reductions in collisions than mass media campaigns (Phillips et al., 2011).

Several initiatives have been made by the U.S. Department of Transportation (DOT) to raise awareness about the issue of distracted driving. This includes developing an official website (<http://www.distracted.gov/>) that specifically advocates against distracted driving. The dedicated website provides tools and suggestions for teens, parents, educators, and employers; facts and statistics about distracted driving; and awareness campaigns and pledges.

The following are some national anti-distracted driving campaigns that have been launched by the DOT:

1. [“Faces of Distracted Driving”](#) is an online video series that started in 2010 to raise awareness about the tragic consequences of distracted driving. The video series features the true stories of victims involved in collisions caused by a distracted driver as told by their family and friends.
2. Released in 2012, the [“Blueprint for Ending Distracted Driving”](#) was developed to lay out a plan to end distracted driving. Strategies in the blueprint included: (1) stricter enforcement on cell phone and texting laws and encouragement of states without such laws to enact them, (2) addressing in-vehicle technologies by encouraging automakers to develop guidelines to minimize their potential for distraction, (3) updating the driver education curriculum to better educate young drivers about the risks of distracted driving, and (4) working with employers to enact employee policies against distracted driving.
3. The “Put It Down” and “Phone in One Hand, Ticket in Another” campaigns were launched in April 2010 to raise awareness about the risks of distracted driving and convey the message of increased enforcement (Cosgrove et al., 2011). The campaigns were part of the high-visibility enforcement demonstration programs in Connecticut and New York (discussed in a following section). Information and messages were spread through the radio, television, in newspapers, and online.
4. In April 2014, advertisements ran the slogan “U Drive. U Text. U Pay” nation-wide on the radio, television, and online to discourage drivers from texting and driving. The campaign was coupled with high-visibility enforcement in many states (NHTSA Press Release, 2015).
5. To educate cyclists and drivers about safe behaviours on the road, the NHTSA and AAA launched the [“Be A Roll Model”](#) campaign in 2011, which included the tagline “Riding and Driving Focused -- never distracted.” The campaign included safety tips and pledges for adults and youth.

In February 2013, Alberta Transportation launched the campaign [“Crotches Kill”](#) to dissuade drivers from looking down at their phone (or similar device), which is often held in their lap. Awareness was generated through billboards, washroom posters, and online and radio advertisements, targeting those between 25 to 34 years old (CBC News, February 19th, 2013). In February 2016, the Calgary Police Service promoted the campaign on Twitter using the hashtag #crotcheskill (Metro Calgary, February 2nd, 2016).

[“Heads Up!”](#) was a safety campaign launched by the Edmonton Police Service and the City of Edmonton’s Office of Traffic Safety in November 2010 to inform and educate pedestrians and drivers about the importance of safety and courtesy at crosswalks and intersections. Information was distributed through print ads, posters, brochures, and street signs. Short animation videos with safety tips for pedestrians and drivers were also created, including one on avoiding distractions. The taglines "Unplug. Don't be a distracted walker" and "Hang up and drive. Don't text or use your phone" were used to encourage pedestrians and drivers to put away their cell phones and electronics while on the road.

In October 2013, Quebec launched the pedestrians campaign [“Distraction, Carelessness and Impatience Can Leave Marks”](#) to raise awareness about being vigilant on the road. Posters were displayed in metro stations and bus shelters, urging pedestrians to avoid distractions, obey traffic signs and signals, and be aware of vehicle blind spots.

Conferences and summits are other educational tools that can bring together students, educators, researchers, health professionals, engineers, law enforcement, community partners, government representatives, and experts from around the world to share and discuss new information, developments, and strategies for road safety, including practices for reducing distracted road use. For example, the International Urban Traffic Safety Conference held annually in Edmonton, Alberta provides an educational platform to increase awareness and understanding of traffic safety issues, expand the knowledge base of urban traffic safety strategies, and facilitate exchange of information through networking opportunities.

Two Distracted Driving Summits, organized by the U.S. DOT, have been held in 2009 and 2010. The summits were attended by students, academics, policy-makers, law enforcement agencies, industry representatives, and government officials. During the two-day events, experts shared their insights on distracted driving, and the U.S. Transportation Secretary announced new regulations to curb distracted driving, such as the enactment of anti-distracted driving policies for commercial motor vehicle drivers and train operators in 2010 (NHTSA Press Release, 2010). The summits were broadcast live online to over 30,000 viewers from the U.S. and around the world (Leone, 2010).

5.2. Enforcement

Past research has shown that education and awareness on their own is not enough to bring about long-term changes in road user behaviour (Catherine Chase, 2014; IIHS, 2001). Increased efforts towards stricter law enforcement are also needed, in combination with education and road safety campaigns. In a 2004 report, the World Health Organization stated that “when used in support of legislation and law enforcement, publicity and information can create shared social norms for safety. However, when used in isolation, education, information and publicity do not generally deliver tangible and sustained reductions in deaths and serious injuries” (Peden et al., 2004, p. 137).

Elvik et al. (2009) conducted a meta-analysis of studies on the effectiveness of road safety campaigns (e.g., impaired driving campaigns, speeding campaigns) on reducing collisions. As shown in Table 5.1, road safety campaigns alone have little effect on the number of

collisions. However, when combined with targeted enforcement and education, the results show an overall injury reduction of 14%.

Table 5.1. Influence of road safety campaigns on motor vehicle collisions.

	Percentage change in number of injuries	
	Best estimate	95% confidence interval
General effect	-9%	(-13; -5)
Campaign only	+1%	(-9; +12)
Campaign + enforcement	-13%	(-19; -6)
Campaign + enforcement + education	-14%	(-22; -5)

Sources: Elvik et al. (2009); Hoekstra & Wegman (2011).

Large-scale studies provide evidence that intensive enforcement, coupled with public education and awareness on the dangers of distracted driving and the enforcement effort, can effectively change driver behaviour and reduce the rate of cell phone use. Initiated by the NHTSA, two high-visibility enforcement (HVE) demonstration programs targeting the use of cell phones (talking and texting) while driving were tested in Hartford, Connecticut and Syracuse, New York (Cosgrove et al., 2011).

From April 2010 to April 2011, four waves of HVE demonstrations took place in both communities. During the demonstrations, mass media coverage about the dangers of distracted driving and the HVE program were generated in newspapers, on the radio, television, and online. Rigorous enforcement strategies involved the use of stationary patrols, spotters, and roving patrols to actively monitor and ticket drivers who were using cell phones. The total number of enforcement hours over the four waves was 2,707 hours in Hartford and 3,201 hours in Syracuse. 4,956 tickets for distracted driving were issued in Hartford, and 4,446 tickets were issued in Syracuse. To evaluate the HVE programs, roadside observations were conducted in Hartford and Syracuse before and after the four waves of HVE, and in control areas (without HVE programs), to assess the rate of cell phone use by drivers. Additionally, individuals who visited driver licensing offices in the study and control areas completed a survey on their use of cell phones and their awareness of the distracted driving campaigns and HVE program.

The results showed that, from baseline (before the first wave) to after the fourth wave, the observed rates of phone use while driving was significantly lower in both communities, relative to the control areas. In Hartford, hand-held phone use while driving was reduced by 57% (from 6.8% to 2.9%). The rate of phone manipulation (e.g., texting, dialing) while driving was reduced by 72% (from 3.9% to 1.1%). In Syracuse, hand-held phone use while driving decreased by 32% (from 3.7% to 2.5%). The observed rate of drivers manipulating their phones decreased by 32% (from 2.8% to 1.9%). The survey results showed that, in both Hartford and Syracuse, more respondents reported hearing about distracted driving and targeted enforcement over the course of the program. 60% reported hearing such information during the initial phase of the program. By the end of the program, 80% reported hearing this. Thus, awareness about both distracted driving in general and the enforcement effort was extremely high.

To follow-up on these positive findings, the NHTSA examined the effectiveness of HVE demonstrations in larger jurisdictions, namely the entire state of Delaware and multiple counties in California (nine counties in the Sacramento Valley Region, which made up nearly 10% of the population in California) (Schick et al., 2014). Over the course of three waves, campaigns about distracted driving and the HVE effort were promoted through mass media and law enforcement targeting cell phone use was stepped up.

The observational data showed that, from baseline to after the final wave, hand-held phone use while driving (talking and manipulating a phone in any way) was significantly reduced in both states. In California, the use rate dropped from 4.1% to 2.7%. In Delaware, the use rate declined from 4.5% to 3.0%. Surveys also revealed that awareness of the media campaigns and enhanced enforcement was significantly higher in both states from baseline to the end of the final wave, but not in the control locations. In California, the percentage of respondents who reported hearing about such information increased from 56% to 73%. In Delaware, awareness of such information increased from 28% to 38%.

Collectively, these findings show that targeted enforcement, generating awareness, and educating drivers about the dangers of distracted driving can effectively reduce drivers' use of cell phones while driving in a single community and over more widespread jurisdictions. Accordingly, future strategies should consider using such an integrative approach on an ongoing basis to enhance compliance with distracted driving laws.

In Canada, throughout the month of February, in support of Distracted Driving Awareness Month, many police services across the country step up their enforcement of distracted driving legislation. In Toronto, Ontario, the campaign called "That Text or Call Could End It All" ran for one week in February 2016 as police officers specifically targeted distracted drivers (CBC News, February 16th, 2016). In Edmonton, Alberta, a 24-hour enforcement period was launched in February 2016 as police officers sought out various traffic offenses, including distracted driving, impaired driving, speeding, red light violations, and not wearing a seatbelt (Global News, March 3rd, 2016). In a one-day intensive enforcement period as part of the "Hang Up and Drive" campaign in August 2015, Edmonton police issued 480 tickets for distracted driving. 96% of these citations went to drivers who were using a cell phone while driving (Edmonton Sun, August 7th, 2015).

5.3. Engineering

The latest advances in technology have made it possible for automakers to develop safety systems in vehicles to mitigate the potential for distraction from cell phones and other electronic devices. Known as advanced driver assistance systems (ADAS), these technologies can monitor surrounding vehicles and pedestrians, warn drivers about potential forward collisions, and intervene with emergency braking if necessary. Other systems can alert drivers if the vehicle is drifting out of its lane or when unobserved vehicles, pedestrians, or objects enter the blind spot (Lee, 2008).

Recently, driver support systems that operate in real-time have been implemented to prevent or reduce the risk of distracted driving. One technological solution is *workload*

management systems, which seek to prevent driver workload and distraction from occurring in the first place (Engström & Victor, 2008). These systems work by controlling the functionality of in-vehicle information systems and portable devices based on driving task demands. For example, when in a busy traffic area, an incoming call/text message alert may be delayed or the use of a GPS system may be locked until the area is passed. Two workload management systems in market are the Saab Dialogue Manager and the Volvo Car Intelligent Driver Information System (Engström & Victor, 2008). These systems monitor the demands of driving conditions (e.g., speed, road curvature, traffic density), and control when secondary task information is presented. [Keeping Roads Safe Technologies](#), a start-up company in Halifax, Nova Scotia is currently developing a similar device to delay all alerts from cell phones until the vehicle is turned off (Global News, August 14th, 2015).

Evaluation studies of workload management systems show that driving performance is improved when in-vehicle tasks are rescheduled or locked out in demanding driving situations compared to driving without in-vehicle task interruption (Donmez et al., 2006; Rimini-Doering & Dambier, 2007). In Donmez et al. (2006), the impact of locking out drivers' interaction with an auditory or visual task was examined. Driving performance in response to a lead vehicle suddenly braking and during curve entry was evaluated. The results showed that when the auditory task was locked out, drivers exhibited longer minimum times to collision and more controlled braking responses to lead vehicles than without secondary task interruption. When the visual task was locked out, drivers exhibited less erratic steering on curves compared to when task interaction was not interrupted. These findings indicate that workload management systems have different safety effects on driving performance depending on the type of secondary task that is controlled (Engström & Victor, 2008).

Another technological solution is *distraction mitigation systems*, which seek to minimize the effects of distraction once it has occurred (Engström & Victor, 2008). These systems provide an alert when the driver is estimated to be distracted (based on a threshold level) to try to redirect attention back to the driving task. For example, prior research has shown that cognitive distraction is associated with gaze concentration toward the center of the driving scene, thereby reducing visual scanning. A project by Volvo (VISREC) developed an algorithm to detect drivers' gaze using a percent road center (PRC) metric (Victor, 2005). PRC is a measure of the time that gaze is focused in the central field of vision. When a certain PRC threshold is reached, LED lights positioned along the dashboard are reflected on the windshield. The LEDs are reflected in the center, left, and right side of the windshield to induce visual scanning (Victor, 2005). Other mitigation systems monitor how long the driver is looking away from the road. In a project that was part of the SAVE-IT program, off-road glance durations in the last three seconds were calculated to estimate visual distraction (Donmez et al., 2007). When a certain threshold was reached, an alert was triggered, in the form of LED lights attached along the top of the dashboard near the steering wheel. Studies show that distraction mitigation systems do not improve driving performance per se, however they do increase the frequency and duration of on-road glances (Donmez et al., 2007; Engström & Victor, 2008). Thus, these systems can redirect drivers' visual attention from secondary tasks to the forward road.

Although these technologies seem promising, it must be stressed that no system is error-free, therefore "overtrust" and "overreliance" in their capabilities can be extremely hazardous

(Inagaki & Itoh, 2013; Lee, 2008). A related concern is that these systems may actually encourage drivers to engage in more distracting activities as they can create a false sense of security. Thus, while these technologies may help reduce the potential for distraction, it is critical that they not be used as a sole countermeasure to address driver distraction, but rather complement other strategies, including education and targeted enforcement.

Another engineering approach is ensuring that safety regulations and guidelines are put in place for the design of in-vehicle technologies to minimize their levels of distraction from driver interaction. The following standards are recommended for designers and engineers (Burns, 2009; Young & Zhang, 2015):

- Text and graphics on visual displays are legible, organized, and simple.
- Visual and auditory messages are short and concise, such as consisting of a single word or a short phrase.
- The location of the system does not obstruct the driver's field of vision.
- Performing the task requires little to no manual interaction (the driver must be able to keep at least one hand on the steering wheel).
- Driver interaction with a device can be interrupted at any time.

In 2013, the NHTSA released their Phase 1 driver distraction guidelines for the design of visual-manual devices that are factory-installed in vehicles. One recommended guideline is that tasks/devices do not take the driver's eyes off the road for more than two seconds at a time or twelve seconds in total (NHTSA, 2012b). Another recommendation is disabling manual text entry, video content (such as video phoning or conferencing), and display of text information, such as text messages, social media content, and websites until the vehicle is stopped or in park. Still in development, Phase 2's driver distraction guidelines will focus on portable and after-market devices brought into the vehicle, while Phase 3 will focus on voice-based auditory interfaces in vehicles (NHTSA, 2012b).

Finally, roadway design can be important in limiting external sources of distraction. Naturalistic driving studies have shown that the relative risk of a collision is increased when drivers are focused on external roadside objects, such as signs and advertisements (Klauer et al., 2006; Stutts et al., 2003). Traffic safety could be improved with a careful consideration for where on the road certain advertising billboards are installed. For example, the placement of billboards should be avoided in areas that demand a high level of attention, such as traffic circles, merge zones, or intersections with high pedestrian and cyclist traffic. The content of billboards should also be considered. Research has shown that information that is salient, unexpected, or conspicuous can capture attention at the expense of the driving task (Chan & Singhal, 2013, 2015; Chan, Madan, & Singhal, 2016). This is particularly important with the recent rise of electronic billboards featuring dynamic messages/images and bright lights. In 2007, guidance on the design of electronic billboards was issued by the U.S. Federal Highway Administration (FHWA). The following standards are recommended in the memorandum (Shepherd, 2007):

- The duration of each message is between 4 to 10 seconds.
- The transition time between messages is between 1 to 4 seconds.
- The brightness is adjusted according to light levels so that it is not so unreasonably bright that it interferes with public safety.

Traffic signs should also be regulated by road authorities to minimize their potential for distraction. For example, signs should not be placed near distracting or attractive objects (such as a particular billboard) as this may cause confusion and reduce the effectiveness of the traffic sign. Warning signs should also not be placed in the middle of road sections that require high concentration (such as a sharp curve or high-risk intersection), but be placed well in advance so that drivers who see the sign have adequate time to disengage from a secondary task and divert full attention back to the driving task.

5.4. Engagement

For road safety strategies to be effective, it is critical that the community understands that all road users have a social responsibility in improving road safety. Thus, the community is encouraged to become involved in distracted road use discussions and activities. This includes youth, parents, educators, researchers, enforcement agencies, policy-makers, community partners, and other key stakeholders from public, private, and non-governmental organizations. Engagement can foster confidence in finding the right solutions to reduce distracted road use, encourage other people to become involved so that new knowledge and strategies are shared, build positive relationship between groups (such as the local police service), and motivate other road users to change their traffic safety culture.

One approach to increasing engagement is through the development of community-based initiatives that target distracted road use. The following initiatives should be implemented and promoted on an ongoing basis:

- Youth events/activities aimed at increasing knowledge, positive attitudes, and awareness towards distracted road use.
- Targeted presentations, panel discussions, and workshops held within schools, work places, churches, and other community organizations focused on what distracted road use is, the effects of distraction, and the laws of distracted road use.
- Grant and scholarship opportunities to encourage the community to become involved in developing local projects aimed at reducing distracted road use in Alberta. An example of this is the [Alberta Traffic Safety Fund \(ATFS\)](#). Implemented by the Alberta Government and its traffic safety partners, the ATSF was developed to fund local traffic safety projects addressing one of the topics in the 2015 Alberta Traffic Safety Plan, including impaired/distracted driving, occupant restraints, speeding, and intersections. The projects may relate to awareness raising, education/training, or engagement at the community level (Government of Alberta, 2016b).
- Use of local and social media to encourage participation and increase communication between road users and stakeholders. In February 2016, Calgary police used the hashtag #crotcheskill on Twitter to spread the word and encourage drivers to stop looking down at their devices while driving. A number of Canadian celebrities – including Mayor Naheed Nenshi, Jann Arden, and Terri Clark – took the pledge and challenged others to do the same (Metro Calgary, February 2nd, 2016).

Community engagement can also be enhanced by holding public consultations on a more periodic basis to encourage discussions about distracted road use issues and possible strategies. For example, in British Columbia, a four-week public consultation was held in the summer of 2015 to discuss whether penalties for distracted driving should be increased. The consultation website received over 24,000 visits, more than 10,000 emails/comments, and 9,400 individuals contributed to the online poll (BC Gov News, July 24th, 2015). An overwhelming majority of respondents stated they were very concerned about distracted driving (90%), wanted to increase the fine for distracted driving (90%), and stiffen the penalties for repeat violations (96%). Feedback from the consultation was used by the provincial government to review its distracted driving legislation, with the final decision expected to be made in spring 2016.

Finally, collaboration and coordination among key stakeholders is encouraged to ensure that the most effective practices for addressing distracted road use will be developed and implemented. Partnerships will facilitate the exchange of new knowledge, methodologies, and expertise, which will be key to achieving the goal of reduced fatalities and collisions involving distraction.

5.5. Evaluation

To determine the effectiveness of a program or initiative (education, awareness campaign, enforcement effort, or in-vehicle system) in changing road user behaviour, it must be formally evaluated using an evidence-based approach. This is a crucial component of all road safety strategic plans as evaluation provides insight into the costs and benefits of an initiative, what concepts of an initiative are appropriate and useful, and if the initiative is ineffective, how to refine and improve it. Thus, evaluation is essential for the development of distracted road use strategies that are *effective*, *efficient*, and *impactful* on road user behaviour over the long-term.

One approach used to evaluate the effects of an initiative is to conduct a pre-test/post-test experiment (Hoeksstra & Wegman, 2011). As shown in Figure 5.1, participants are randomly assigned to an experimental group that is exposed to an initiative (e.g., an education program) or a control group that is not exposed to the initiative.

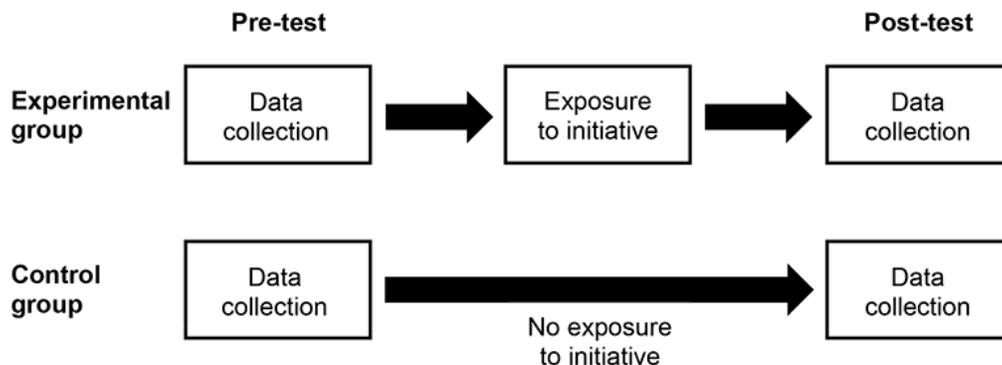


Figure 5.1. A pre-test/post-test design used to evaluate a program or initiative.

Behavioural measures are conducted before and after the initiative for both groups and compared. If the results for the experimental group are more promising than those for the control group, then the effect can be attributed to the initiative (assuming all other factors are controlled for). If people's behaviours are influenced by the initiative in a controlled setting, testing it in the real world would be warranted (Hoeskstra & Wegman, 2011). If the initiative is shown to be unsuccessful, the results from the pre-test/post-test can be used to determine what modifications are needed to improve it (e.g., changing the entire concept of a program or certain aspects of it).

When random assignment of participants is not feasible, a quasi-experimental design is conducted (similar to an observational study). As with a true experiment, measures are collected before and after exposure to the initiative in an experimental group and compared with measures from the same time points in a control group (no exposure to the initiative). However, caution is warranted when interpreting the findings from quasi-experiments as the lack of randomization may introduce confounding variables (such as differences in demographics) and weaken conclusions about cause and effect. Despite these limitations, this type of design is useful for examining the behavioural effects of a road safety campaign or law enforcement effort in a test area and control area (with no exposure to the campaign or enforcement effort). This method was used by the NHTSA to evaluate their distracted driving HVE demonstrations.

For both evaluation designs, general ideas about the effectiveness of a new or pre-existing initiative or program can be uncovered. Behavioural measures may be collected through the use of a driving simulator (for example, to assess the effects of an in-vehicle distraction mitigation system), survey (to assess the behaviour, attitudes, and perceptions of road users), or observational approach (to assess the prevalence of distracting activities engaged by road users).

Another important component of evaluation is conducting follow-up assessments of an initiative that has been implemented. This is essential for determining whether behavioural changes can be sustained over time, and whether any unintended consequences might have occurred from the initiative. For example, McCart et al. (2010) conducted observations of drivers' use of cell phones in New York and D.C. from a few months to several years after their cell phone legislation was enacted. The data showed that the long-term impact of the law was more effective in D.C. than New York, which may, in part, be due to D.C.'s more publicized and stricter enforcement of the law.

5.6. Summary

Laws that prohibit the use of cell phones and other electronic devices while driving are intended to change driver behaviour and improve road safety, however research has shown that enactment of a law is insufficient to achieve long-term changes in behaviour. An example of this is the use of seat belts by motorists. The enactment of mandatory seat belt laws in the mid 1970's in Canada led to immediate increases in the use of seat belts, however the impact of the law declined over time as use rates dropped (Solomon et al., 2002). In the early 1980's, the implementation of a seat belt program that consisted of high-visibility enforcement and public education through mass media achieved a large increase in the rate of seat belt use (Jonah et al., 1982). Canada was the first country to apply such an integrative approach to encourage motorists to wear seat belts. By the 1990's, ongoing efforts using such programs increased seat belt usage

to 87% (Jonah et al., 1982). The history of seat belt laws suggest that initiatives beyond enactment of the law are needed to produce long-term changes in road user behaviour. Likewise, research indicates that an integrated effort is needed to successfully address distracted road use. As reviewed in this report, an integration of strategies spanning the five E's of traffic safety is recommended: education, enforcement, engineering, engagement, and evaluation.

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Additional Links and Resources

AAA Foundation for Traffic Safety

<https://www.aaafoundation.org/distracted-driving>

Alberta Transportation

<http://www.transportation.alberta.ca>

Canadian Automobile Association (CAA)

<http://distracteddriving.caa.ca/education>

City of Edmonton's Office of Traffic Safety

<http://www.edmonton.ca/transportation/traffic-safety.aspx>

Crotches Kill | Government of Alberta

<http://crotcheskill.com/>

Drop It And Drive

<http://dropitanddrive.com>

Edmonton International Conference on Urban Traffic Safety

<http://www.trafficsafetyconference.com>

Governors Highway Safety Association (GHSA)

<http://ghsa.org/html/issues/distraction/index.html>

Insurance Institute for Highway Safety, Highway Loss Data Institute (IIHS-HLDI)

<http://www.iihs.org/iihs/topics/t/distracted-driving/topicoverview>

National Electronic Injury Surveillance System (NEISS)

<http://www.cpsc.gov/en/Research--Statistics/NEISS-Injury-Data>

National Highway Traffic Safety Administration (NHTSA)

<http://www.nhtsa.gov>

Official U.S. Government website for distracted driving

<http://www.distraction.gov>

Road Safety in Canada | Transport Canada

<http://www.tc.gc.ca/eng/motorvehiclesafety/tp-tp15145-1201.htm>

Traffic Injury Research Foundation: Young and New Driver Resource Centre

<http://yndrc.tirf.ca/issues/distraction.php>

Appendix A. Distracted Driving Legislation in Canada.

Jurisdiction	Fine(s)	Demerits	Restrictions while driving	Last amended
British Columbia ¹	\$167	3	<ul style="list-style-type: none"> • Use of hand-held cell phones and other specified electronic devices • Drivers in GDL program – use of any hand-held or hands-free devices 	Oct. 2014
Alberta ²	\$287	3	<ul style="list-style-type: none"> • Use of hand-held cell phones and other specified electronic devices • Entering information on GPS units • Reading and writing • Personal grooming 	Jan. 2016
Saskatchewan ³	\$280	4	<ul style="list-style-type: none"> • Use of hand-held electronic communication devices • Drivers in GDL program – use of any hand-held or hands-free devices 	June 2014
Manitoba ⁴	\$200	5	<ul style="list-style-type: none"> • Use of hand-held mobile devices 	July 2015
Ontario ⁵	\$490 - \$1000	3	<ul style="list-style-type: none"> • Use of hand-held communication and electronic entertainment devices • Viewing display screens unrelated to driving 	Sept. 2015
Quebec ⁶	\$115 - \$154	4	<ul style="list-style-type: none"> • Use of hand-held devices with a telephone function 	April 2015
New Brunswick ⁷	\$172.50	3	<ul style="list-style-type: none"> • Use of hand-held cell phones and other specified electronic devices • Programming a GPS • Viewing non-built in display screens unrelated to driving 	June 2011
Nova Scotia ⁸	\$233.95 1st offence \$348.95 2 nd offence \$578.95 subsequent offences	4	<ul style="list-style-type: none"> • Use of hand-held cell phones and any text messaging devices 	Feb. 2015
Prince Edward Island ⁹	\$500 - \$1200	5	<ul style="list-style-type: none"> • Use of hand-held wireless communication devices 	Aug. 2015
Newfoundland and Labrador ¹⁰	\$100 - \$400	4	<ul style="list-style-type: none"> • Use of hand-held cell phones and electronic devices 	Sept. 2010
Yukon ¹¹	\$250	3	<ul style="list-style-type: none"> • Use of hand-held electronic devices with the capability of talking, texting or emailing • Drivers in GDL program – use of any hand-held or hands-free devices 	April 2011
Northwest Territories ¹²	\$322	3	<ul style="list-style-type: none"> • Use of hand-held cell phones and other specified electronic devices 	June 2014
Nunavut	N/A	N/A	No law	

Sources: Canadian Automobile Association; Robertson et al. (2015).

¹Road Safety BC, ²Government of Alberta, ³Saskatchewan Government Insurance, ⁴Manitoba Public Insurance, ⁵Ontario Ministry of Transportation, ⁶Quebec Highway Safety Code, ⁷New Brunswick Public Safety, ⁸Nova Scotia Transportation and Infrastructure Renewal, ⁹PEI Highway Safety Division, ¹⁰Government of Newfoundland and Labrador, ¹¹Yukon Government, ¹²Government of NWT

Appendix B. United States Legislation on Cell Phone Use While Driving.

State	Hand-Held Phone Ban	Hand-Held and Hands-Free Phone Ban		Texting Ban All Drivers
		School Bus Drivers	Novice Drivers	
Alabama			16, or 17 w/ Intermediate License <6 months	Yes
Alaska				Yes
Arizona		Yes		
Arkansas	18 - 20 years	Yes	<18 (Secondary)	Yes
California	Yes	Yes	<18 (Secondary)	Yes
Colorado			<18	Yes
Connecticut	Yes	Yes	<18	Yes
Delaware	Yes	Yes	Learner or Intermediate License	Yes
D.C.	Yes	Yes	Learners Permit	Yes
Florida				Yes (Secondary)
Georgia		Yes	<18	Yes
Hawaii	Yes		<18	Yes
Idaho				Yes
Illinois	Yes	Yes	<19	Yes
Indiana			<21	Yes
Iowa			Restricted or Intermediate License	Yes (Secondary)
Kansas			Learner or Intermediate License	Yes
Kentucky		Yes	<18	Yes
Louisiana	Learner or Intermediate License	Yes	1st year of License	Yes
Maine			Learner or Intermediate License	Yes
Maryland	Yes		<18	Yes
Massachusetts		Yes	<18	Yes
Michigan		Yes	Level 1 or 2 License	Yes
Minnesota		Yes	<18 w/ Learner or Provisional License	Yes
Mississippi		Yes		Yes
Missouri				<18
Montana				
Nebraska			<18 w/ Learner or Intermediate License (Secondary)	Yes (Secondary)
Nevada	Yes			Yes
New Hampshire	Yes		<18	Yes
New Jersey	Yes	Yes	Permit or Provisional License	Yes
New Mexico	Yes		Learner or Provisional License	Yes
New York	Yes			Yes
North Carolina		Yes	<18	Yes
North Dakota			<18	Yes
Ohio			<18	Yes (Secondary)
Oklahoma	Learner or Intermediate License			Yes

Oregon	Yes		<18	Yes
Pennsylvania				Yes
Rhode Island		Yes	<18	Yes
South Carolina				Yes
South Dakota			Learner or Intermediate License (Secondary)	Yes (Secondary)
Tennessee		Yes	Learner or Intermediate License	Yes
Texas		Yes	<18	<18
Utah		Yes	<18	Yes
Vermont	Yes		<18	Yes
Virginia		Yes	<18 (Secondary)	Yes
Washington	Yes		Learner or Intermediate License	Yes
West Virginia	Yes		<18 w/ Learner or Intermediate License	Yes
Wisconsin			Learner or Intermediate License	Yes
Wyoming				Yes

Source: Governors Highway Safety Association (GHSA) (2016)

Appendix C. Scope of Distracted Driving Legislation in European Union (EU) Countries.

Country	Hand-held phone ban	Navigation device ban	Music player ban	TV/video player ban
Austria	Specific			General
Belgium	Specific			
Bulgaria	Specific			
Cyprus	Specific	Specific		Specific
Czech Republic	Specific	General		
Germany	Specific	General	General	General
Denmark	Specific	General		General
Estonia	Specific		General	General
Greece	Specific	General	Specific	Specific
Spain	Specific	Specific	Specific	Specific
Finland	Specific	Specific	Specific	Specific
France	Specific	General	General	Specific
Hungary	Specific			
Ireland	Specific			
Italy	Specific	General	General	General
Lithuania	Specific			
Luxembourg	Specific	Specific	Specific	
Latvia	Specific			
Malta	Specific	General	Specific	
Netherlands	Specific	General		General
Poland	Specific			
Portugal	Specific	General	Specific	General
Romania	Specific			
Sweden	Specific			
Slovenia	Specific	General	General	General
Slovakia	Specific	General	General	General
United Kingdom	Specific	General		Specific

Source: Avenoso (2012).