Mind Wandering During Everyday Driving

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Abstract

Mind wandering is a common experience but its prevalence and consequences during routine activities such as driving are unclear. This thesis comprises five studies investigating how often drivers' minds wander, and the relationship between mind wandering and crash risk.

The first study was a questionnaire completed by 502 drivers, to explore their experiences of mind wandering including its variation in different driving contexts. All drivers reported mind wandering at least some of the time. Tendency to report mind wandering during driving was positively correlated with trait tendency towards cognitive failure, and negatively correlated with tendency towards mindful attention and awareness. Drivers reported most mind wandering driving their own car on familiar roads.

The second study built on the finding that drivers are most likely to report mind wandering on a familiar trip in their own car through an on-road study of drivers' thoughts. Eleven drivers traveling in their own cars between home and work were periodically asked what they were thinking about, across 110 trips in total, to establish how often drivers report mind wandering on real streets. Drivers reported mind wandering around two thirds of the time, demonstrating that it is a frequent experience on familiar urban roads. Drivers' thoughts shifted frequently, triggered by what they saw in the environment and by internal concerns unrelated to driving.

The first two studies found relatively high likelihood of mind wandering on familiar roads, so the third study investigated links between mind wandering and crash risk by exploring variation in crash patterns on roads close to home and further away. Analysis of crash distance from home, accounting for travel exposure, confirmed a 'Close to Home Effect' for road crashes. New Zealand drivers face increased crash risk on familiar roads within 10km of home, suggesting that higher rates of mind wandering close to home may influence crash risk.

The Close to Home Effect was explored in more depth in the fourth study, which was based on analysis of police Traffic Crash Reports. Crash frequencies at different distances from home were compared in relation with posted speed

limit, crash location (intersection or midblock), and errors (intentional violations or unintentional lapses of attention). Compared with crashes on roads further away, crashes close to home were more commonly reported on urban than on rural roads; more often at midblocks (stretches between intersections) than at intersections; and were more likely to involve a lapse of attention than an intentional violation such as excessive speeding.

The fifth and final study combined an on-road study of drivers' thoughts on a prescribed urban road route with analysis of crash data from the same route. The purpose of the fifth study was to determine how patterns of mind wandering and crashes vary with respect to road environment factors. Results showed that mind wandering is not random, but varies systematically in relation to task demand and crash risk on familiar urban roads.

Overall, results from the five studies showed that mind wandering is ubiquitous during everyday driving. Drivers focus on aspects of the driving task frequently, but typically briefly, in response to momentary actions of other road users, or to situations that are usually demanding, such as roundabouts. Although there is an inverse association between patterns of mind wandering and the places where most crashes happen, there is no evidence that mind wandering causes crashes.

Findings from this research support theories of mind wandering that acknowledge its variation in different contexts. However, while theories imply that mind wandering is an infrequent departure from a norm of task focus, this research found that driving task focus is typically a temporary, intermittent departure from mind wandering. Results are generally consistent with the tandem model of driver behaviour, which suggests that drivers do not pay continual attention to driving but rely on an unconscious monitoring process that governs their behaviour most of the time.

The main implication of this research for road safety practitioners is that roads ought to be designed to account for drivers' unconscious, routine behaviours because their minds are often wandering. Drivers' attention can be captured and directed appropriately where focus on driving is warranted. Overall however, mind wandering is not intrinsically dangerous but is a normal characteristic of safe everyday driving.

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List of Publications from this Thesis

Peer-reviewed journal articles: Reproduced in this thesis with permission from Elsevier.

Burdett, B. R.D., Charlton, S. G., & Starkey, N. J. (2016). Not all minds wander equally: The influence of traits, states and road environment factors on self-reported mind wandering during everyday driving. *Accident Analysis & Prevention*, *95*, 1-7. https://doi.org/10.1016/j.aap.2016.06.012

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Introduction

During routine activities such as washing dishes, riding a bicycle or mowing lawns, a person's thoughts often drift among all manner of topics. Over the last decade there has been increasing interest among cognitive psychologists in the study of mind wandering, and its influence on task performance. Most of this research has investigated mind wandering using laboratory-based tests of attention and memory. Though these studies have been useful to advance understanding of why and how mind wandering happens, its influence on performance of habitual, everyday activities has not been systematically investigated. The focus of this research is mind wandering during the well-practised, everyday task of driving.

Mind wandering, defined as task-unrelated thought, is a shift in focus from some task, toward unrelated topics such as memories or plans (Smallwood, Baracaia, Lowe, and Obonsawin, 2003; Smallwood & Schooler, 2006). The definition of mind wandering combines two necessary components, namely 'thinking' and 'doing': conscious focus is on matters unrelated to a current task, and task performance continues without continuous focused attention.

Studying Mind Wandering

To date most research into mind wandering has used thought sampling (asking people what they are thinking about). Thought content is captured in one of two ways. *Probe-catch* thought sampling involves participants being interrupted and asked what they are thinking about (McKiernan, D'Angelo, Kaufman, & Binder, 2006; McVay & Kane, 2009; Reichle, Reineberg, & Schooler, 2010). During a *self-catch* thought sampling study, participants are briefed about what mind wandering is before they complete an experiment, during which they are asked to alert the researcher (by pressing a button, for example) when they notice that their thoughts are off-task (Reichle et al.,2010).

Research Contexts: Experience Sampling and Laboratory Studies

Thought sampling typically happens in one of two contexts. In the broad context of everyday life thought sampling is known as experience sampling

(Hurlburt, 1979; Killingsworth & Gilbert, 2010). In laboratory studies of mind wandering, researchers typically analyse thought samples as well as measures of task performance (Mooneyham & Schooler, 2013; Smallwood, 2015).

Experience sampling involves participants being interrupted at random and asked both what they were doing, and what they were thinking about when interrupted. Researchers have used pagers, pencil and paper (Hurlburt, 1979) or mobile phone applications (Killingsworth & Gilbert, 2010) to prompt participants to report whether or not their mind was wandering.

Experience sampling studies have provided insight into mind wandering frequency very generally, showing that peoples' minds wander often (Hurlburt, 1975; Killingsworth & Gilbert, 2010). Based on responses to alerts from a mobile phone application, Killingsworth and Gilbert (2010) concluded that thought is off-task for 47% of the average person's day. The high frequency of mind wandering in everyday life is an important reason for further investigation into its prevalence across different tasks, and its relationship with task performance. However, experience sampling has not advanced understanding of the benefits or costs of mind wandering, or whether it varies according to specific task contexts.

Studies of mind wandering in laboratories have been used to explore associations between mind wandering and performance on tests of sustained attention and working memory (e.g. Levinson, Smallwood, & Davidson, 2012; McVay & Kane, 2009, 2012; Rummel & Boywitt, 2014; Unsworth & McMillan, 2013); and in relation to performance of familiar tasks such as reading (e.g. Franklin, Smallwood, & Schooler, 2011; Reichle, Reineberg, & Schooler, 2010; Smilek, Cherriere, & Cheyne, 2010).

In addition to thought sampling, laboratory studies also provide opportunity for researchers to use indirect measures to infer whether or not a person's thoughts are on-task. There are three main groups of indirect measures used to study mind wandering. They are physical measures such as eye movements (Reichle et al., 2010); measurement of cortical activity such as functional Magnetic Resonance Imaging (fMRI) (Binder et al., 1999; Christoff et al., 2009; Gruberger et al., 2011); and task performance measures such as reading comprehension tests (Foulsham, Farley, & Kingstone, 2013; Reichle et al., 2010; Smallwood, McSpadden, & Schooler, 2007). To date researchers have found that there is potential for indirect measures to be used to define periods of mind wandering and task focus, although the associations are not absolute (Foulsham et al., 2013; Schad, Nuthmann, & Engbert, 2012).

Limitations of Thought Sampling Methods

In laboratory studies using probe-catch and self-catch in combination, participants have routinely reported mind wandering when probed, having not come to this conclusion in time to provide a self-caught response (Reichle et al.,2010). That is, periods of task-unrelated thought can often happen without awareness (Gruberger et al., 2011; Mooneyham & Schooler, 2013). Therefore the self-catch method is incomplete and depends on participants' awareness of their thoughts.

The self-catch method requires participants to be briefed in advance of any experiment, which is likely to affect their thoughts (Smallwood & Schooler, 2006). Probe-catch is also intrusive. The notion of ironic processes of mental control suggests that if a person does not want to think about something, an unconscious monitoring procedure is automatically established to scan the contents of the mind for evidence of failure in attaining that goal (Wegner, 1994). As a participant in a probe-catch or self-catch mind wandering experiment, a person's thoughts are likely to be influenced by a desire to stay on-task. This goal generates an unconscious monitor scanning for evidence of task-unrelated thought. Thoughts generated by the monitoring procedure may rise to awareness despite a person's general intention to focus on the task at hand (Wegner, 1994). However, thought sampling studies are typically used to compare mind wandering tendency and its effect on performance between participants, rather than as an absolute measure of mind wandering frequency, because measuring an invisible process such as thinking is very difficult and likely to be experienced differently across participants. The most promising approach to improve understanding of mind wandering may be to use a selection of self-report and indirect methods in combination, and to broaden the range of settings beyond the current dichotomy of experience sampling and laboratory studies (Smallwood, 2013).

Theories of Mind Wandering

Insights from studies of mind wandering have contributed to the development of theories that explain aspects of the why and how mind wandering happens. The theories stem from different views about the cognitive functions that enable and support mind wandering. Although this thesis does not set out to test any theory of mind wandering, they provide context for questions and experimental methods, and for the research implications.

The Theory of Current Concerns

The Theory of Current Concerns was the first to discuss why mind wandering happens (Klinger, 1975, 1987). The Theory discusses mind wandering in terms of goal-directed behaviour, with regard to pursuing reward and avoiding punishment (Klinger, 1975).

People have a wide range of concerns, including many that are unrelated to whatever task they happen to be completing at any given moment (Klinger, 1975; Smallwood & Schooler, 2006). Task focus can be diverted by salient cues, which remind an individual of some current concern. Cues can be external, related to something seen or heard; or internal, in the form of recurring thought. An individual can choose to focus on a particular concern, or it can be brought to mind involuntarily.

While thought can be triggered either intentionally or involuntarily by current concerns, maintenance of any train of thought is linked in this theory to incentives of reward or punishment for committing to, or abandoning the thought. Current conscious focus depends on personal motivation to pursue a particular thought, and the perception of any personal reward that may be gained. That is, the Theory of Current Concerns suggests that mind wandering happens when task-unrelated thought comes with a higher reward (or less punishment) than is likely through continued task focus (Klinger, 1975). In a similar vein, Antrobus (1968) suggested that a person might think about a task, or not, in order to "maximise total pay-off" (p. 423). If the demands of the immediate task become more engaging or the incentive to pay attention becomes higher, a person may then be more likely to return from mind wandering to task focus (Antrobus, 1968).

Although the Theory of Current Concerns describes why peoples' minds might wander, it is not detailed enough to explain what might motivate individuals to direct their thoughts towards or away from any specific task. That is, applications of the theory to any particular task, relating objective measures to subjective motivations for mind wandering or task focus are lacking. Such applications would be useful to understand more about variation of mind wandering within a task, and its relationship with task performance.

Theories of Perceptual Decoupling and Failure of Executive Control

The Theories of Perceptual Decoupling (Smallwood & Schooler, 2006) and Failure of Executive Control (McVay & Kane, 2010) have been proposed as explanations for how mind wandering is enabled in a cognitive sense, beyond subjective motivations for pursuit of reward or avoidance of punishment. The main difference between these theories relates to the role of executive function in mind wandering.

Executive function is a term used to describe 'higher order' mental activity, such as making plans, intentional pursuit of goals, and resisting undesired impulses (Diamond, 2013). An important aspect of executive function related to mind wandering is executive control, which is intentional control of attention and wilful actions (Badgaiyan, 2000). Executive control maintains focus on information either in the external world, or in memory, to pursue some goal (Baddeley & Hitch, 1994). One component of executive control that is central to mind wandering is inhibition of competing thoughts that might distract from the current goal (Diamond, 2013).

The Theory of Perceptual Decoupling states that mind wandering involves goal-directed thought, and therefore draws on executive function. When a person's mind is wandering, conscious focus is 'decoupled' from sensory perception and subsequent motor control related to task performance, enabling a person to think about one thing while doing another (Smallwood & Schooler, 2006). The Theory of Perceptual Decoupling was developed based on findings from research into performance on tasks with varying level of demand. As task demands increase, either mind wandering becomes less frequent, or performance suffers. That is, the Theory of Perceptual Decoupling suggests competition for executive resources between task focus and mind wandering (Smallwood & Schooler, 2006; Teasdale et al., 1995).

Although Smallwood and Schooler (2006) suggest that mind wandering happens when conscious focus is decoupled from sensory perception, the decoupling may not be absolute, but people may experience different levels of both focus, and of disengagement from the environment (Schad, Nuthmann, & Engbert, 2012). The decoupling of thoughts from sensory perception therefore could represent not an elimination but a reduction in the amount of focus applied to the external world during mind wandering (Franklin, Mrazek, Broadway, & Schooler, 2013).

In contrast to the Theory of Perceptual Decoupling, the Theory of Executive Control Failure states that mind wandering results when executive control fails, and it proceeds without executive resource (McVay & Kane, 2010). The Theory of Executive Control Failure suggests that executive control capacity relates directly (and inversely) to mind wandering frequency. It is supported by the finding that reduced executive control capacity, for example, due to drinking alcohol (Sayette et al., 2009) or being tired (Liu & Wu, 2009), results in more mind wandering (McVay & Kane, 2010).

McVay and Kane (2010) argue that inhibition of mind wandering is an executive function allowing task focus to be sustained. An important aspect of the theory is an intentional desire to maintain task focus. Although the Theory of Failure of Executive Control is concerned mostly with the initiation of a mind wandering episode, once initiated, “an individual may choose to exert control over the new train of thought” (McVay & Kane, 2010, p. 190). After the initial failure of control, mind wandering can continue with or without executive resource, depending on an individuals’ intention.

Theories of Perceptual Decoupling and Failure of Executive Control disagree about whether executive resources are necessarily involved in mind wandering. The Theory of Perceptual Decoupling states that executive function is involved in the initial redirection of thoughts away from task focus, and that mind wandering always draws on executive resources (Smallwood & Schooler, 2006). Conversely, the Theory of Failure of Executive Control states that mind wandering begins as failure of executive control, but once initiated, the resources that support mind wandering are different depending on whether or not an individual has decided to exert control (McVay & Kane, 2010).

The Context Regulation Hypothesis

The Context Regulation Hypothesis suggests that while mind wandering might relate to an individual's current concerns, its initiation is more complex than a simple failure of executive control, or departure from sensory input (Smallwood & Andrews-Hanna, 2013). The Hypothesis draws on evidence that some tasks do not require continual focus, so mind wandering is experienced when subjective task demands are low. Task focus is more likely to be applied when demands are high: that is, people regulate their attention according to the momentary task context (Smallwood & Andrews-Hanna, 2013).

The Context Regulation Hypothesis has built on research into mind wandering and working memory capacity. Studies of tasks with varying demand have shown that people tend to report more mind wandering when demands associated with working memory are low, with no adverse effects on performance, and relatively less mind wandering when demands are high (Levinson, Smallwood, & Davidson, 2012; McVay & Kane, 2009). Rather than describing how mind wandering happens in terms of links between sensory processing and conscious focus, the Context Regulation Hypothesis discusses mind wandering in terms of when it is relatively more or less likely to be experienced within a task's varying context.

Summary of Theories of Mind Wandering

The Theory of Current Concerns provides rationale for why people experience mind wandering: they are motivated to pursue thought that provides reward or avoids punishment (Klinger, 1975). Theories of Perceptual Decoupling and Failure of Executive Control discuss the role of executive function in mind wandering, disagreeing about whether the start of any mind wandering episode represents a redirection of executive resources (Perceptual Decoupling; Smallwood & Schooler, 2006) or Failure of Executive Control (McVay & Kane, 2010). The Context Regulation Hypothesis suggests that a person's likelihood to experience mind wandering depends on the changing context of any task (Smallwood & Andrews-Hanna, 2013). Most of the research that has informed theories of mind wandering has been in controlled laboratory conditions, so understanding of how people experience mind wandering and its variation across everyday activities is limited. It would be useful to assess whether findings from research in contexts with more ecological validity support the various theories of mind wandering (Kane et al., 2017; Smallwood & Andrews-Hanna, 2013).

Research Gap

As explained above, there is a gap in understanding how mind wandering is experienced during everyday activities. It is important to understand more about its prevalence and variation both within a task, and between people, to contribute to understanding of attention generally, and so that any negative effects related to mind wandering can be addressed (Kane et al., 2017).

Recently Kane et al. (2017) called for more research into mind wandering in naturalistic contexts. They highlighted the limited range of tasks used to study mind wandering to date, and noted that experimental conditions are likely to engender unnatural thought processes (Kane et al., 2017). Results from laboratory studies may be useful to compare between participants, but give little insight into how mind wandering is experienced in daily life.

In a review of the evidence regarding negative impacts of mind wandering on task performance, Mooneyham and Schooler (2013) listed 30 studies that suggested that mind wandering comes at a cost. Of these, 17 involved laboratory experiments assessing some aspect of cognition such as memory or sustained attention; eight cited studies of reading comprehension; four involved self-assessment of mood or 'life performance' using experience sampling, and one study was of mind wandering during simulated driving.

In summary, the nature and impact of mind wandering during performance of everyday, familiar tasks has not been adequately explored. For everyday tasks where there are known or suspected implications for less than sustained focus, it would be beneficial to understand more about how often mind wandering is experienced, and what personal factors or task contexts affect its variation, so that any negative implications of mind wandering can be mitigated.

Mind Wandering and Driving

Driving is an example of an everyday task that is widely practiced by a large proportion of the adult population. Although crashes are relatively rare, they are often attributed to a driver's 'inattention' (He, Becic, Lee, & McCarley, 2011; Martens & Brouwer, 2013). Understanding the situations that foster both mind wandering, and a return to task focus during driving would be beneficial to mitigate against crash risk for drivers and for other road users.

One of the important differences between everyday activities (such as driving) and laboratory tests is that people tend to complete familiar, well-practiced tasks without sustained focus (James, 1890; Schneider & Shiffrin, 1977; Smallwood & Schooler, 2006). Though learning something new requires effortful focus, it has been acknowledged for over one hundred years that "habit diminishes the conscious attention with which our acts are performed" (James, 1890, p. 1962), and that "our higher-order thought centres know hardly anything about it" (p. 1966). When skills are automatised through repetition, effortful focus is no longer continuously required and physical responses happen implicitly, in response to sensory cues (Schneider & Shiffrin, 1977).

Given that many everyday tasks are habitual, and little is known about mind wandering during performance of habitual, everyday tasks, it would be useful to study mind wandering during an everyday activity such as driving. As well as the benefits to understanding links between task familiarity, mind wandering and task performance, the study of mind wandering during driving could be useful as a standalone contribution toward the understanding of the psychology of driver behaviour. It may also help to improve road safety through mitigation of crash risk.

A small number of researchers have investigated mind wandering during driving. Study contexts have included questionnaires (Berthie et al., 2015; Qu et al., 2015); post-crash interviews (Galéra et al., 2015); and driving simulation (Baldwin et al., 2017; He et al., 2011; Lemercier et al., 2014; Lin et al., 2016; Martens & Brouwer, 2013; Yanko & Spalek, 2013, 2014).

Findings from the range of studies of mind wandering and driving to date include that most drivers report mind wandering (Berthie et al., 2015; Qu et al., 2015). Drivers are more likely to report mind wandering with practice on a simulated route (Yanko & Spalek, 2013, 2014), or on familiar or routine trips such as the daily commute (Berthie et al., 2015). Mind wandering during simulated driving has been associated with changed driving performance relative to driving with sustained focus. Specifically, during periods of mind wandering, drivers' gaze patterns are narrower and variability of speed is lower (He et al., 2011; Martens & Brouwer, 2013).

Drivers who report frequent mind wandering are also more likely to report risky or aggressive driving (Qu et al., 2015). Although mind wandering has not been linked to crash risk directly, it has been described as "threatening safety on the roads" (Galéra et al., 2012, p1). However, there is little understanding of how often drivers' minds wander without causing a crash. Neither is there understanding of whether more crashes happen in the places or situations where drivers are most likely to experience mind wandering.

The covert nature of mind wandering makes it different from other forms of inattention that involve observable distractions such as mobile phones. Crash risk associated with using a mobile phone is known (Caird et al.,2009), because its prevalence during driving can be observed on the roadside (Huisingh, Griffin, & McGwin Jr, 2015; Young, Rudin-Brown, & Lenné, 2010) or in naturalistic studies (Dingus etal., 2016), and crash reports can include information about whether or not a driver was using a mobile phone when the crash happened (Beanland, Fitzharris, Young, & Lenné, 2013; Neyens & Boyle, 2008). Although mind wandering cannot be observed directly, its association with crashes could be investigated through analysis of crash patterns. To date there has been no attempt to explore variation in reported crashes and how it might correspond with variation in mind wandering according to road and traffic characteristics.

Research Aims and Approach

This research aims to address a gap in understanding how mind wandering is experienced during the everyday activity of driving, including its relationship with crash risk. To date, most research into mind wandering has been in the context of laboratory-based tasks that typically require effortful, focused attention. Well-practiced tasks such as driving are different, because they do not always require moment to moment focus (Shiffrin & Schneider, 1977; Charlton & Starkey, 2011, 2013).

Driving provides a useful opportunity to study mind wandering during a well-practiced task. It is a commonly acquired skill that becomes routine for many people, particularly on familiar roads (Charlton & Starkey, 2011, 2013). While mind wandering has been studied in driving simulation (Martens & Brouwer, 2013; Yanko & Spalek, 2013, 2014), its variation and prevalence in peoples' own cars on real streets has not been investigated. Moving outside the laboratory is an important step to improve understanding of mind wandering (McVay et al., 2017).

Studying mind wandering and driving may also help to improve road safety. Although observable distractions while driving, such as mobile phone use, have been studied in considerable depth (e.g. Caird et al., 2009; Klauer et al., 2006), links between mind wandering and crash risk remain unclear.

This research focuses on two main questions:

1) How often do drivers' minds wander?
2) How is mind wandering during driving related to crash risk?

Understanding how often drivers' minds wander is a gap that, if addressed, would help to improve understanding of mind wandering generally, while providing context for evidence about mind wandering from laboratory studies, including simulated driving. Research into mind wandering and driving could also support road safety efforts through improved understanding of any association between mind wandering and crash risk.

Thesis Outline

This research comprises a series of studies of the prevalence of mind wandering during real, everyday driving, and the relationship between mind wandering and crash risk. The research questions and studies that address them are summarised in Figure 1.

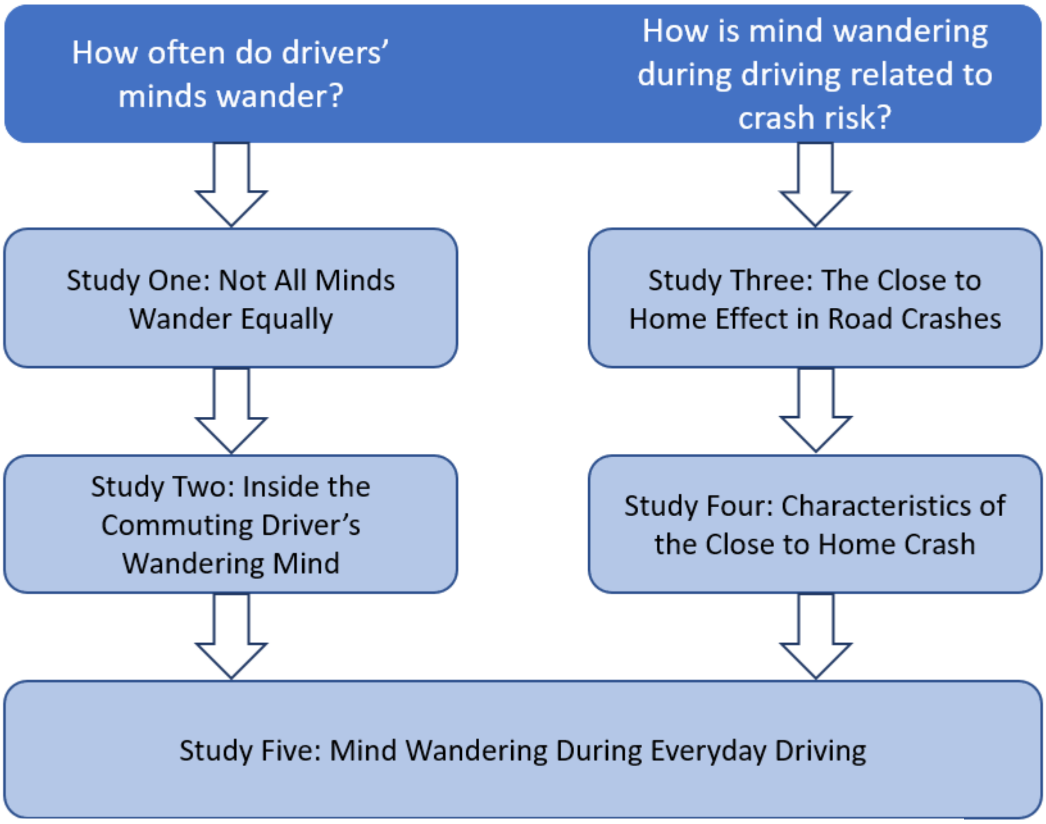

Figure 1 Summary of Studies in this Thesis

The purpose of Study One (Not all Minds Wander Equally) was to understand more about drivers' own perceptions of how often their minds wander. It also asked drivers about frequency of mind wandering in different situations, to better understand its variability, and to provide guidance for on-road studies.

Study Two (Inside the Commuting Driver's Wandering Mind) was an investigation into mind wandering as experienced by drivers in their own cars on familiar roads, because those were the situations that drivers in Study One reported experiencing most mind wandering. The purpose of Study Two was to provide an indication of how often drivers reported mind wandering in undemanding, familiar driving situations.

Study Three (The Close to Home Effect in Road Crashes) built on the finding from Studies One and Two that mind wandering is a frequent experience on familiar streets, by investigating whether crashes are relatively more common on roads close to home. The study was an exploration of crash and travel distance from home for New Zealand drivers, using data from reported crashes and from a nationwide travel survey. By accounting for travel exposure, it demonstrated that mile for mile driven, drivers are more likely to crash on roads close to home than on roads further away.

Study Four (Characteristics of the Close to Home Crash) explored the Close to Home Effect in more depth. Frequencies of reported crashes in different situations were compared, accounting for travel exposure, at different distances from home. Crashes closest to home were found to more frequently involve lapses of attention on urban roads, with more crashes at midblocks and minor intersections than at busy intersections such as traffic signals and roundabouts.

Finally in Study Five (Mind Wandering During Everyday Driving), both mind wandering and crashes were analysed on an urban road route. Drivers familiar with the route were accompanied by the researcher and were periodically asked what they were thinking about. Thought samples and crash patterns on the route were compared to understand how variation in mind wandering corresponds with variation in crash patterns.

Study One: Not All Minds Wander Equally

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Not all minds wander equally: The influence of traits, states and road environment factors on self-reported mind wandering during everyday driving

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ABSTRACT

Inattention is a road safety problem, but few studies have focused specifically on mind wandering during everyday driving. This paper explores differences in self-reported mind wandering according to driver demographic characteristics (including age and gender), cognitive traits (such as tendency toward cognitive failure or mindful attention), states (such as feeling tired or stressed) and road environment factors (such as route familiarity). Five hundred and two participants (113 male, average age 44.4 years, *SD* = 14.0 years) completed a series of questionnaires (Mindful Attention and Awareness Scale (MAAS), Cognitive Failures Questionnaire (CFQ) and Driver Behaviour Questionnaire (DBQ)), as well as study-specific questions about mind wandering during different personal states and across a range of road and traffic situations. All respondents reported mind wandering during driving at least some of the time. Mind wandering was more likely to be reported on familiar roads than on unfamiliar roads and when drivers are tired. Drivers who reported relatively more mind wandering were younger, reported less mindful attention in daily life, more cognitive failures, and more driving violations and lapses. Together, the findings suggest that mind wandering is common in everyday driving, however any link with crash risk remains unclear. Future research using self-report and naturalistic methods could provide more insight into relationships between mind wandering, error and crash risk.

1. Introduction

The effects of many different types of distraction on driving performance have been well documented. For example, several studies have found that mobile phone use while driving is relatively unsafe (Caird et al., 2008; Charlton, 2009; Lamble et al., 1999). Other distractions, such as manipulating a car stereo or eating while driving have been studied naturalistically by analysis of in-car video (Klauer et al., 2014; Sayer et al., 2007). However, inattention where there is no overt external stimulus – the driver is simply not thinking about driving – has not been extensively studied. This is despite the fact that over the last decade there has been an increase in research addressing the nature and influence of task-unrelated thought, or mind wandering (MW) generally, across a range of everyday and laboratory situations (for a review see Smallwood and Schooler, 2015).

MW occurs when conscious focus is on matters unrelated to task-related information perceived by the senses (Smallwood et al., 2003; Smallwood and Schooler, 2006). It is enabled by 'perceptual decoupling' which allows two processes to happen simultaneously (Schooler et al., 2011). First, a task and its ongoing sensory and physical demands can proceed without conscious focus, and second, consciousness can roam among all manner of topics. Research by Charlton and Starkey (2011, 2013) into the effects of extended practice supports this idea and suggests that a high degree of automaticity is often present during everyday driving on familiar routes. While this leaves drivers free to focus on other thoughts, it also appears to result in a degree of inattention blindness and change blindness (Charlton and Starkey, 2011, 2013; Martens and Fox, 2007).

One reason that MW during driving has not been studied extensively may be that it is inherently difficult to measure or observe, compared to overt distractions like mobile phones. To date, the small number of laboratory studies that have examined MW and driving have reproduced findings from other laboratory-based studies; its reported frequency increases with practice (Yanko and Spalek, 2014) and in situations of relatively low task demand (He

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et al., 2011). Although not a study of MW, positive correlation has been found between self-reported cognitive failure in daily life, and driving-related lapses of attention (Pearson's $r = 0.71$) (Roca et al., 2013).

MW has been found to be a common experience across a wide range of everyday tasks. Using an experience sampling procedure in which participants were asked to report their thoughts during their daily lives, Killingsworth and Gilbert (2010) found that people reported MW for 47% of the time on average. Other studies using techniques such as fMRI have found that MW is reported more often during well-practiced tasks that do not require continual focus, such as simple laboratory tests of sustained attention (Kane et al., 2007; McKiernan et al., 2006), and that it increases with task practice (Teasdale et al., 1995).

As well as the relative familiarity of the task, demographic characteristics such as age and cognitive traits such as tendency toward cognitive failure also appear to influence reported MW frequency. For example, older people are less likely to report MW than younger people (Giambra, 1989; Jackson and Balota, 2012; McVay et al., 2013). It has been suggested that this may be due to generally lower incentives for task-unrelated thought in older people, or because MW studies are often carried out on university campuses where there are more opportunities for task-unrelated cues to trigger MW in younger participants (McVay et al., 2013). To date, these findings have not been replicated in relation to MW during driving.

Individual traits associated with executive function and executive control (intentional control of attention and action; Badgaiyan, 2000) also appear to play a role in MW frequency. McVay and Kane (2010) suggested that MW may represent a failure of executive control to inhibit task-unrelated thoughts and therefore, MW may be related to a general propensity toward cognitive failure. Given the putative role of executive function in MW, factors that impair executive control, such as fatigue and stress could also influence MW (Eysenck et al., 2007; McVay and Kane, 2010). More MW has been reported when participants were tired (Kane et al., 2007), or had consumed alcohol (Sayette et al., 2009), however the relative influence of momentary states, cognitive traits and other task factors on reported MW has not been explored in depth during driving, where there can be serious consequences if task performance is compromised.

Like any cognitive process, the way that MW is measured can shape the conclusions drawn about its nature and influence. Methods to measure MW include: asking people to report their thought content (through real time sampling, or retrospectively); infer task focus from performance measures of attention-demanding tasks; and through neuroimaging procedures such as fMRI. Findings from fMRI studies have advanced understanding of the particular brain regions and networks activated when the mind is engaged in some focused task, compared to the restful 'wandering' state involving perceptual decoupling (see for example Gruberger et al., 2011). However, these neuropsychological studies have not yet provided insight into the nature of environmental triggers likely to initiate a change between task focus and MW during performance of a complex task. In part this is because fMRI equipment renders the method impractical for direct study of any aspect of cognition during an everyday activity such as real-world driving (Brookhuis and de Waard, 2010).

The use of thought sampling also has limitations. Interrupting people during performance of any task is intrusive and therefore likely to alter their natural thought patterns. Furthermore, asking a participant to recall their thought content can only capture that component of their attention of which they have been aware (Schooler and Schreiber, 2004). MW can take place without a person's awareness, a so-called 'zone-out', in contrast to task-unrelated thought pursued with intent: a 'tune-out' (Smallwood et al., 2007).

As an alternative to real-time thought sampling, asking people to report their general tendency toward MW retrospectively (for example, with a questionnaire) is not intrusive and can provide insight into differences between individuals, at least in terms of what they recall. Berthié et al. (2015) used a retrospective questionnaire to explore individual and road environment influences on MW frequency during driving. Participants were asked to estimate the proportion of their most recent trip that they spent MW, and how many distinct MW episodes they recalled. Out of 128 participants, 109 (85.2%) reported at least one MW episode. These participants reported MW for an average of 34.7% of the time during their most recent trip, which took place an average of eight hours prior to them completing the questionnaire. Drivers were more likely to report MW if they drove more than 50 km per week on average; and if their most recent trip was a commute to work. There were no noteworthy relationships found between drivers' self-reported proportion of time spent MW during their most recent drive, and age, gender, route familiarity, or prior crash involvement (Berthié et al., 2015).

Berthié et al. (2015) demonstrated the usefulness of a retrospective questionnaire to study MW, and the study supported theoretical predictions that MW is more likely to be reported when driving is well-practiced – that is, by drivers who travel more than 50 km per week or during the commute from home to work (Berthié et al., 2015). They did not, however, provide any insight into the influence of underlying cognitive traits (e.g., executive control) and they were limited to a relatively small sample of drivers' experiences on a single trip. The research could be usefully extended with more information about the incidence of MW during everyday driving, including its variation between individuals and across different road environment situations.

Other studies using questionnaire methods have also explored links between cognitive traits and driving behaviour. Ledesma et al. (2010) developed a questionnaire to study links between error and lapses of attention during driving. The 19-item questionnaire included items indirectly or implicitly related to MW such as "When I head toward a known place, I drive past it for being inattentive" and "For a brief moment, I forget where I am heading to". Ledesma et al. (2010) found that the questionnaire score was not correlated significantly with age or gender, and there was no link between tendency to report lapses of attention and previous injury-crash involvement. Their main finding was that it is possible to study attention-related driving errors using questionnaire methods (Ledesma et al., 2010).

Given that crashes generally and injury crashes in particular are very rare, it is difficult to prove a direct relationship between a subjectively measured phenomenon such as MW and crash risk. However it may be useful to approach the important, broader question of inattention and crash risk through study of self-reported errors and MW. Although previous studies have found no particular link between reported MW tendency and previous crash involvement (Berthié et al., 2015; Ledesma et al., 2010; Qu et al., 2015), its frequency might correlate with driving error.

The notion that drivers are more likely to crash close to where they live also provides some rationale for research into links between attention and driving. A handful of studies have explored crash risk close to home. The main finding to date is that a large proportion of crashes happen within some relatively short distance of a driver's home address (Abdalla et al., 1997; Malek et al., 1990). If crashes are overrepresented relative to travel on roads close to home, it may be that the consequence of reduced conscious focus on familiar roads is that potential hazards are more likely to be overlooked.

In summary, despite gaps in understanding, research suggests that MW is probably common during everyday driving; that it is likely to increase with practice and on familiar roads; and

Table 1
Descriptive statistics for questionnaire responses. MAAS = Mindful Attention and Awareness score; CFQ = Cognitive Failures Questionnaire score; $DBQ_{v,av,l,m}$ = Driver Behaviour Questionnaire (violations, aggressive violations, lapses, mistakes) sub-scale scores.

	N	Mean	SD
MAAS	501	4.20	0.76
CFQ	485	1.54	0.49
DBQ_v	466	4.87	3.32
DBQ_{av}	466	3.70	2.77
DBQ_l	466	7.52	3.96
DBQ_m	466	7.52	2.96

Responses were averaged across 15 items (MAAS: 6-point Likert scale from 1 (almost never) to 6 (almost always)); 25 items (CFQ: 5-point Likert scale from 0 (never) to 4 (always)); or summed across 6 items (DBQ_v, DBQ_{av}) or eight items (DBQ_l; DBQ_m) (6-point Likert scale from 0 (never) to 5 (all the time)).

that reported MW frequency is likely to vary among the driving population. However, to date these suggestions have not been substantiated with data from drivers themselves. The purpose of this study is to determine whether or not theoretical assumptions about MW and driving are supported by the frequency and circumstances of its occurrence according to drivers' self-reports. This study addresses two questions in particular:

1. Whose mind wanders during driving: How do driver demographic characteristics and cognitive traits predict tendency to report MW, generally?
2. In what types of driving situations and personal states is MW most and least likely to be reported?

2. Method

2.1. Participants

Valid questionnaires were returned by 502 participants (113 male). Participants had an average age of 44.4 years (range 18–85 years, SD = 14.0 years), with an average of 23.1 years with a full drivers' licence (range 0–70 years, SD = 15.3 years).

Ethical approval for the study was granted from the School of Psychology Research and Ethics Committee at the University of Waikato. Participants with a full driving licence were recruited to complete an online questionnaire, through advertising on the intranet of large organisations, on social media, through word of mouth and by mail drop. The large organisations were local government and civic offices based in the Waikato Region, New Zealand, which includes the city of Hamilton (population 140,000) and a rural area including smaller towns and countryside. The online questionnaire link was also distributed on social media. It is likely that participants were a mix of employed and unemployed people, students, and retired people from cities, smaller towns and rural areas across New Zealand. A paper version of the questionnaire was also distributed by post to addresses in a residential suburb of Hamilton, New Zealand. The paper version was included to recruit more older participants, and to test for bias in a sample recruited entirely online.

2.2. Materials

The purpose of the questionnaire was to find out how demographic characteristics, cognitive traits, momentary states and road environment characteristics relate to the tendency to report MW during driving. The survey contained three existing questionnaires as well as new questions related to MW in various driving situations. The three existing questionnaires were the Mindful Attention and Awareness Scale (MAAS) (Brown and Ryan, 2003), the Cognitive Failures Questionnaire (CFQ) (Broadbent et al., 1982), and the Manchester Driver Behaviour Questionnaire (DBQ) (Reason et al., 1990). The driving situations questions asked how task factors (such as a familiar rural road or an unfamiliar vehicle) and personal states (such as when driving tired or stressed) affect MW frequency during driving.

2.2.1. Mindful Attention and Awareness Scale (MAAS)

The MAAS was included to describe participants' general tendency toward mindful attention because it assesses natural propensity to focus on the current moment (Brown and Ryan, 2003). It has fifteen items and a six-point Likert response scale ranging from 1 (Almost always) to 6 (Almost never). Higher average scores indicate higher propensity of an individual toward mindful attention and awareness in their daily life. The MAAS is widely used and has good internal consistency (Cronbach's alpha = .87, Brown and Ryan (2003)).

2.2.2. Cognitive Failures Questionnaire (CFQ)

The CFQ assesses an individual's propensity to make lapse-type errors of memory, attention and motor control (Broadbent et al., 1982). Lapses are defined as an error resulting from unintentional action. The CFQ includes 25 questions with a five-point Likert response scale from 0 (Never) to 4 (Very often). A higher average score is indicative of a higher frequency of cognitive failure in everyday life. The CFQ is well-known and has good internal consistency (Cronbach's alpha = .91, Wallace et al. (2002)).

2.2.3. Manchester Driver Behaviour Questionnaire (DBQ)

The DBQ (Reason et al., 1990) asks about subjective experience of driving error, distinguishing between mistakes, violations, aggressive violations and lapses (Özkan et al., 2010; Reason et al., 1990). The 28 items of the DBQ include some questions related to MW, for example "How often do you realise that you have no clear recollection of the road along which you have just been travelling?". The DBQ subscales have six items (violations and aggressive violations) or eight items (lapses and mistakes) each. Each question has a six-point Likert response scale ranging from 0 (Never) to 5 (All the time). The DBQ has been used across a wide range of driving-related research and shows good internal consistency (Cronbach's alpha range.72–.84, Parker et al. (1992)).

2.2.4. Driving situations questions

As well as demographic questions (age, gender, years with a full drivers' licence and average number of kilometres driven per week), participants were asked about MW during driving. MW was defined for participants as "any time you are thinking about something that has nothing to do with driving, for example something you were doing before driving, something you will do later, thinking about people or a particular person, or thinking about what you might have for dinner." To find out about MW in different driving situations, participants were asked to answer the statement "During this situation, my mind wanders..." for fourteen questions, using the same six-point Likert scale as used for the DBQ: 0 (never); 1 (hardly ever); 2 (occasionally); 3 (quite often); 4 (frequently); 5 (all the time). The driving situations included eight road environment settings, two vehicle factors and four personal states. These questions asked about a driver's tendency to experience MW based on road and vehicle factors and personal states that generally prevail for a significant portion of any particular trip. Items were selected to represent a range of typical, everyday road environments and personal states that might reflect different rates of MW during driving.

One of the settings posed in the MW questions ("In the car that I drive most often (e.g. my own car)") was used as the primary indicator of MW during driving. This question was selected because it

Table 2
Descriptive statistics for MW questions ($N = 450$).

	Mean	SD
1 On an *urban* or *city* route that I have driven many times	2.27	1.19
2 On a *rural* or *country* route that I have driven many times	2.31	1.22
3 On a *motorway* that I have driven many times	1.94	1.25
4 On an urban or city route that I have *never* driven on before	0.74	0.82
5 On a country route that I have *never* driven on before	0.80	0.90
6 On a motorway that I have *never* driven on before	0.75	0.87
7 On a long drive (lasting more than an hour) when I am not following any other traffic	2.16	1.18
8 On a long drive (lasting more than an hour) when I am constantly in a line of traffic	1.64	1.27
9 In a car that I don't usually drive (e.g. a rental car)	0.96	1.03
10 In the car that I drive most often (e.g. my own car)	2.27	1.22
11 When I driving while anxious or stressed, for example before an important meeting or appointment	2.06	1.24
12 When I am diving tired, for example at the end of a busy day	2.25	1.17
13 When I am driving under pressure because I am running late	1.75	1.25
14 When I am driving while happy and relaxed	2.05	1.25

The MW responses were to the question 'In this situation, my mind wanders...' on a 6-point Likert scale: 0 (never); 1 (hardly ever); 2 (occasionally); 3 (quite often); 4 (frequently); 5 (all the time).

represents everyday driving, independent of road and traffic characteristics or personal states. This indicator question was used to compare general tendency to report MW to demographic characteristics (age and gender), cognitive traits (MAAS and CFQ scores) and to self-reported rates of driving-related error (DBQ scores).

2.3. Data analyses

One-way ANOVAs comparing responses from those who completed questionnaires on paper ($n = 19$, 7 female, mean age = 60.27, $SD = 21.91$) and a subset of online respondents, matched for age and gender ($n = 19$, 7 female, mean age = 55.92, $SD = 19.46$) showed no significant differences across the MAAS, CFQ or DBQ subscale scores (all $ps > 0.06$; all $\eta_p{}^2 < 0.010$). Therefore, paper and online questionnaire responses were pooled for subsequent analyses.

Descriptive statistics were recorded to summarise responses to the standard questionnaires and the MW questions. Correlations were calculated between the MW indicator question (How often does your mind wander when driving your own vehicle?) and independent variables including age, gender, MAAS and CFQ mean scores, and mean DBQ subscale scores. A multiple linear regression was calculated to predict self-reported MW when driving a familiar vehicle.

To find out when drivers report MW, repeated measures ANOVAs were used to compare means across the MW questions relating to driving tired, stressed, anxious and relaxed. To test road environment influences on reported MW, a 2×3 repeated measures ANOVA was calculated to compare means of reported MW across familiar and unfamiliar roads, and between road types (urban, rural and motorway). Mauchly's tests showed that the repeated-measures data violated assumptions of sphericity, however the departure was not large; adjustments to the degrees of freedom did not change the significance of any main effects or the effect sizes.

3. Results

3.1. Descriptive statistics

Descriptive statistics for the MAAS and CFQ scores and DBQ subscale items are included in Table 1. Cronbach's Alpha results for each scale were 0.88 (MAAS); 0.88 (CFQ) and 0.82 (DBQ). Table 2 lists descriptive statistics for the MW questions. Across 450 respondents who completed the MW questions in whole or part, no participant reported that they 'never' experience MW.

The data in Table 1 show that there was more variation in DBQ scores than there was in MAAS and CFQ scores. Mean MAAS scores were similar to means found previously in normative populations (e.g. Brown and Ryan, 2003). Highest error rates in the DBQ were for lapses and mistakes, however all average subscale scores reflected self-reported error rates of less than 1, where 1 equates to 'hardly ever' on a scale from 0 (never) to 5 (all the time).

Table 2 shows that most MW was reported on familiar urban and rural roads, driving a familiar vehicle, and while tired. The mean score for these items was between 2.25 and 2.31 where 2 equates to 'occasionally' and 3 to 'quite often' on the response scale. Least MW was reported across all types of unfamiliar roads: urban roads, rural roads, and motorways. In these situations participants reported mean scores between 0.72 and 0.80 where 0 equates to 'never' and 1 to 'hardly ever' on the response scale.

Table 3
Correlation matrix. MW = Tendency to report mind wandering when driving a familiar vehicle; MAAS = Mindful Attention and Awareness score; CFQ = Cognitive Failures Questionnaire score; $DBQ_{v,av,l,m}$ = Driver Behaviour Questionnaire (violations, aggressive violations, lapses, mistakes) sub-scale scores. Gender codes were 1 (male) and 2 (female). Correlations > |0.09| were significant at $p < 0.05$ and correlations > |0.12| were significant at $p < 0.01$.

	MW	Age	Gender	MAAS	CFQ	DBQ_v	DBQ_{av}	DBQ_l	DBQ_m
MW	1	−.37	.06	−.46	.40	.30	.14	.37	.20
Age		1	−.04	.28	−.23	−.18	−.20	−.10	−.09
Gender			1	−.18	.13	−.14	−.08	.10	−.03
MAAS				1	−.68	−.32	−.21	−.53	−.34
CFQ					1	.30	.29	.65	.40
DBQ_v						1	.39	.34	.41
DBQ_{av}							1	.26	.31
DBQ_l								1	.51
DBQ_m									1

3.2. Whose mind wanders: predicting self-reported MW tendency based on demographic characteristics, cognitive traits and error

To determine which variables best predicted tendency to report MW during driving, a stepwise multiple linear regression was calculated. Before building the model, correlations were calculated between the MW indicator question, demographic characteristics (age and gender), traits (MAAS and CFQ scores), and DBQ subscale scores. The correlation matrix is shown in Table 3.

The strongest correlations were between MAAS and CFQ (−0.682); and between CFQ and DBQ_l (0.648). Higher MAAS score relate to higher levels of mindful attention in everyday life so its negative correlation with CFQ, where high score relates to high reported rates of cognitive failure is to be expected and aligns with results from previous research (Herndon, 2008). In relation to MW during driving, the strongest correlations were with MAAS (−0.460), DBQ_l (0.370) and Age (−0.365). The direction of the rela-

Table 4
Final regression parameters predicting tendency to report MW during everyday driving. MAAS = Mindful Attention and Awareness Score; DBQl = Driver Behaviour Questionnaire (lapse) sub-scale score; DBQv = Driver Behaviour Questionnaire (violations) sub-scale score.

		b	*SE B*	*β*	*p*
Step 4	Constant	4.391	.465		$p < .001$
$R^2 = 0.524$, $p(\triangle R^2) = 0.010$	Age	−.018	.004	−.210	$p < .001$
	MAAS	−.459	.090	−.269	$p < .001$
	DBQl	.052	.018	.152	$p = .003$
	DBQv	.048	.019	.120	$p = .010$
Final model: $F(4,402) = 38.03$, $p < 0.001$					

tionships between MW, MAAS and lapses of attention suggest that there are links between MW and cognitive failure. The negative correlation between MW and age also replicated findings from previous research into MW (Giambra, 1989; Jackson and Balota, 2012; McVay et al., 2013).

Predictor variables that showed significant correlation with MW above 0.3 were entered in the multiple regression model. To avoid multicollinearity effects, and because there was correlation above 0.6 between CFQ and MAAS, as well as between CFQ and DBQ (lapse), CFQ was not included in the regression model. Age was entered in the first stage (forced entry), followed by stepwise addition of MAAS score, and DBQ violations and lapses. The final regression model is shown in Table 4. These results show that MAAS score and age have similar importance in the model, along with significant contributions from DBQ lapse and DBQ violations subscale scores. Together, the independent variables explain approximately 50% of the variation in tendency to report MW during everyday driving ($R^2 = 0.524$). This analysis suggests that drivers most likely to report MW are aged under 25 years, have low trait rates of mindful attention, and report more driving-related lapses of attention and violations.

3.3. When do minds wander: momentary states and road environment influences on MW during driving

Responses to MW questions (Table 2) show that participants reported similar scores across four personal states (tired, under time pressure, anxious and relaxed). Mean responses across personal states ranged from 1.75 (under time pressure) to 2.25 (tired); the response scale was 0–6 where a score of 2 on the scale indicated "During this situation my mind wanders 'occasionally'". Statistical analysis comparing the four personal states revealed that these differences were significant [$F(3, 1{,}347) = 34.24$, $p < 0.001$, $\eta_p{}^2 = 0.071$]. Post-hoc pairwise comparisons with Bonferroni correction showed that reported MW when drivers were tired was significantly higher than all other states ($ps < 0.001$). MW under time pressure was significantly lower than all other states ($ps < 0.001$). There was no difference in reported MW relating to drivers feeling anxious or relaxed ($p = 1.00$).

Fig. 1 shows the comparison of reported MW for road environment characteristics; road familiarity and road type. Mean scores showed higher rates of MW on familiarthan on unfamiliar roads, with smaller differences between road types. Mean MW score on familiar roads ranged between 1.94 (familiar motorways) and 2.31 (familiar rural roads), where a score of 2 equates to MW "occasionally". Mean MW score on unfamiliar roads ranged between 0.74 (unfamiliar urban roads) and 0.80 (unfamiliar rural roads), where a score of 1 equates to MW "hardly ever". Statistical analysis showed significant main effects of both familiarity [$F(1, 449) = 1{,}140.81$, $p < 0.001$, $\eta_p{}^2 = 0.718$] and road type [$F(2, 898) = 27.66$, $p < 0.001$, $\eta_p{}^2 = 0.058$], and a significant interaction [$F(2, 898) = 34.70$, $p < 0.001$, $\eta_p{}^2 = 0.072$]. The likelihood of MW was highest when the road was familiar, but this effect was lower for motorway driving, which led to the significant interaction.

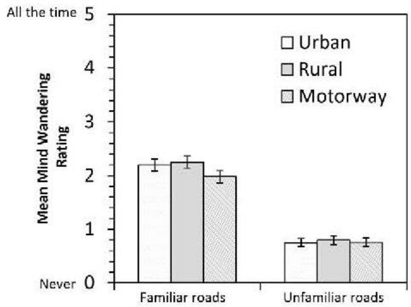

Fig. 1. Average MW ratings for familiar and unfamiliar urban roads, rural roads and motorways. Vertical lines show 95% confidence intervals.

4. Discussion

The aims of this study were to find out whose mind wanders during driving, and to explore differences in its reported frequency according to the effects of personal states and types of road. The results have, for the first time, indicated that MW while driving is a normal rather than an exceptional experience. Further, younger drivers reported more MW than older drivers; MW was reported as most likely on familiar roads and when drivers are tired; and drivers who reported more MW had lower levels of mindful attention and awareness; higher levels of cognitive failure; and reported more driving-related lapses of attention and violations.

Perhaps the most important contribution of this research is the finding that most people report MW occasionally during everyday driving, particularly on familiar roads: it is commonplace in the most common of places. Even though driving is an everyday task carrying considerable risk, people nevertheless admit to driving with less than sustained attention at least some of the time. This extends findings from theories and experience studies that MW is a common experience (Killingsworth and Gilbert, 2010; Smallwood and Schooler, 2006) and provides rationale for more research into MW and driving given the potential adverse consequences of less than sustained task focus.

The results also address the question of who reports MW. First, there was no difference in reported MW between men and women. Although it is a popularly held belief that women are better at multitasking than men, and might perhaps be more likely to experience MW, the limited number of studies in the area suggest there is no noteworthy difference in the tendency to daydream or even in the multitasking abilities of males and females (Lindquist and McLean, 2011; Mäntylä, 2013; Stoet et al., 2013).

Second, younger drivers reported more MW during driving than older drivers. This finding extends predictions from previous studies of MW into the realm of everyday driving. In particular, this study was not carried out on a university campus, so the results go some way to validating claims that older people appear to exhibit lower levels of MW generally, and not only in university laboratories where the environment may be deemed more likely to trigger task-unrelated thoughts in younger participants. As others have noted this result may seem counterintuitive because older people generally have poorer executive function (Krawietz et al., 2012), and might therefore be expected to report more MW. Older people may compensate for reduced levels of executive function by conscious application of attention to tasks such as driving, or at least they tend to report that this is the case.

Although older people are known to be exposed to increased crash risk related to generally reduced levels of cognitive functioning (Stutts et al., 1998), the component of executive control most strongly linked with MW (inhibition) is not associated with reduced driving performance in older people (Adrian et al., 2011). This suggests that older people may compensate for their reduced abilities in some way. Their known tendency to self-regulate their driving environments and hours (Charlton et al., 2006; Kostyniuk and Molnar, 2008) may directly or indirectly result in reduced need for prolonged inhibition of task-unrelated thought, because they rarely drive for very long distances or in environments which they are likely to find particularly demanding.

In terms of cognitive traits, people with lower levels of mindful attention and awareness and higher levels of cognitive failure tend to report more MW during driving. While these results may seem intuitive, further research is needed to establish whether people who exhibit lower mindful attention, for example, also exhibit behavioural changes associated with driving without awareness, and whether they are therefore more likely to be involved in crashes related to attentional failure.

As well as differences related to age and cognitive traits, there was also variation in reported MW tendency according to different momentary states, across different types of road, and according to tendency to report driving-related error. The finding that drivers are least likely to report MW when under time pressure suggests that they perceive some level of control over their attention. Previous research has shown that drivers under time pressure are more likely to report risk-taking (Cœugnet et al., 2013), which may reflect heightened task focus and therefore reduced frequency of MW. It has been suggested that the reason that an individual's mind wanders in the first place is pursuit of current concerns (Klinger, 1975), where the object of attention is whatever is most pressing in terms of momentary motivations. In some situations, such as time pressure, the driving task itself may become the driver's most pressing current concern.

In contrast to more task focus (less MW) reported when under time pressure, drivers reported more MW when they were tired. Some MW researchers suggest that an unintentional zone-out can be the result of a failure of executive control to inhibit task-unrelated thought and that this is more likely when executive resources are low, for example when a person is tired (McVay and Kane, 2010).

Across different types of road situation, most MW was reported on familiar roads. This also raises questions about the underlying role of executive function in MW. More MW might be reported on familiar roads because drivers *allow* their minds to wander intentionally, in pursuit of some pressing current concern, for example (tune-out), or they might experience an unintentional zone-out when driving task demands are low, as is the case on a familiar road. The distinction between tune-out and zone-out is a general challenge of research into MW (Smallwood and Schooler, 2006).

Regulation of MW in different contexts may also explain why drivers report less MW in motorway environments. Relatively high speeds on motorways may affect drivers' perceptions of driving task difficulty, and therefore their estimates of how frequently their minds wander. New Zealand does not have an extensive, intercity motorway network. Many drivers in the sample may encounter motorways only infrequently, so there may be interaction effects (between road type and (un)familiarity, for example) that could not be explored with these data. It would be useful to test this finding by researching MW during driving in countries with more extensive motorway networks.

Drivers who reported more MW also reported more driving-related errors, particularly lapses and violations. Although some researchers have made assumptions about a link between MW and crash risk, (Berthié et al., 2015; Martens and Brouwer, 2013; Galéra et al., 2012; He et al., 2011) the current findings do not support such claims directly. Previous research has found only weak links between error and crash risk (De Winter and Dodou, 2010). It may be that the propensity for cognitive failures leads to both MW and driving error, but there may be some other mediating factor as yet untested. It should be noted that Berthié et al. (2015) asked their respondents some questions regarding their prior crash involvement but were unable to establish any links to MW propensity. Analysis of crash data has found that a high proportion of crashes are reported on roads close to drivers' homes (Abdalla et al., 1997; Malek et al., 1990), however to date these findings have not been matched with information about drivers' exposure on these roads so again, links between familiarity and crash risk remain unclear.

This research has established that MW is a complex and widespread issue during everyday driving. Strengths of this study included its large sample size and age range. One limitation is that it is unclear whether or not drivers' self-reports of their state of mind during driving are accurate. If MW can happen without drivers' awareness, retrospective self-reports might not be reliable. This is also a limitation of the Berthié et al. (2015) study of MW and driving, where drivers were asked to estimate how many distinct task-unrelated thoughts they experienced in their most recent drive. However, with currently available methods we are limited to study of what drivers can report. Understanding could be progressed through a combination of simulation and naturalistic studies of driving, in which not only the influence of MW is investigated, but its overall frequency using some form of thought sampling during the drive.

Although the age range for the sample was broad (18–85 years) there were not enough data in the very young and very old age groups to enable meaningful analysis of these sub-groups. It would be useful to replicate this study with extensions to explore particular interactions such as age, gender and road type, or to ask different questions such as MW at different times of the day, for example, to work towards findings that can inform road safety interventions more directly.

Young drivers report the most MW, so more research is recommended into whether or in what situations drivers regulate their attention. Although drivers report more MW on familiar roads, the issue of what constitutes 'familiar' is difficult to quantify. There are clear poles at either end: roads can be very familiar (such as the daily commute) or completely unfamiliar (a road that a driver has never driven on). Between these extremes, however, there remains work to be done to establish a clear operational definition or measure of familiarity in driving. The increasing availability of more and better data about drivers' travel behaviour may support this kind of enquiry in future (e.g. Schönfelder and Antille, 2002).

It would also be worthwhile to explore regulation of attention further, given potential interactions between independent factors such as time pressure, tiredness, route familiarity and cognitive traits, as well as other unexplored variables such as trip purpose, time of day or the number of passengers in the vehicle. Simply encouraging drivers to 'pay attention' does not seem practical given current findings about the widespread occurrence of MW during everyday driving. A logical next step would be to find out when MW combines with other personal, vehicle and road factors to result in heightened crash risk.

Given the lack of studies linking MW and driving as a whole, it would be helpful to pursue the issue using a wide range of methods to find out which approaches are most promising. These findings could be validated using real driving situations and self-report during or immediately after a drive, for example. Although it is difficult to study, continued research into MW and driving using self-report, and where practical, naturalistic methods can only help as the transportation industry looks to further reduce the social costs of road trauma.

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Study Two: Inside the Commuting Driver's Wandering Mind

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Inside the commuting driver's wandering mind

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ABSTRACT

The aim of this study was to explore how frequently drivers report mind wandering during their daily commute, and to learn more about how conscious and unconscious processes combine during everyday driving. We recorded 587 thought samples across 110 drives by eleven female participants aged between 28 and 48 years who regularly drive between home and work. Using a probe-catch descriptive experience sampling procedure, thought samples were captured and categorised according to whether they were driving-related or not, and according to their trigger (sensory vs internal). We found that drivers on the daily commute reported mind wandering on 63% of reports, and were actively focused on the driving task for between 15% and 20% of samples. For the remaining one fifth of thought samples, drivers were not actively thinking about anything in particular. Over half of drivers' mind wandering reports were related to things they saw or heard, suggesting that although they are not directly focused on driving all of the time, they frequently and habitually scan the road and roadside environment. When momentary driving task demands do not command attention, drivers' minds wander towards personal current concerns. Mind wandering is often triggered by what drivers see or hear. These findings suggest that in familiar, undemanding situations, drivers are more likely to be found mind wandering than focusing on driving, however mind wandering is swiftly interrupted when driving task demands command effortful attention. The results have implications for research into mind wandering, implying that a baseline of sustained task focus is not the norm when driving the daily commute. Researchers and policy-makers ought to consider how to design road and traffic systems that align with drivers' unconscious expectations.

1. Introduction

Mind wandering is a common experience during everyday life, particularly during routine, familiar activities. Allowing our minds to wander to task-unrelated thoughts is relatively harmless during most of these everyday activities, such as while reading a book (Smallwood, McSpadden, & Schooler, 2008). Somewhat more surprisingly, mind wandering (MW) is also relatively common during everyday driving, according to drivers themselves (Burdett, Charlton, & Starkey, 2016). The suggestion that it is normal for drivers to experience MW during an everyday drive seems counter-intuitive, because driving, unlike reading a book, is inherently risky. Nevertheless, although drivers may routinely engage in MW while driving to and from home and work, they do not routinely crash. It may be that because crashes are rare events, drivers allow their minds to wander. Alternatively, it may be that everyday driving by its nature does not always require sustained attention.

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In contrast to MW, engaging in some types of task-unrelated thought while driving appears to be unambiguously hazardous. For example, drivers' use of mobile phones for conversations or texting significantly increases the risk of a crash (Beanland, Fitzharris, Young, & Lenné, 2013; Caird, Willness, Steel, & Scialfa, 2008). If we are to make sense of this apparent paradox and understand how and when drivers' minds can safely wander, we need to learn more about what drivers think about during everyday driving, and how their focus shifts between driving and other, unrelated thoughts during a routine, familiar drive. As a starting point, it would appear to be important to simply determine the extent of MW in driving: that is, how often drivers report mind wandering, and what captures their attention during an everyday drive.

The fact that there are few published studies of MW frequency in everyday driving reflects both the difficulties in observing and measuring MW, as well as a longstanding problem in driver behaviour psychology, namely that the interaction of conscious and unconscious processes during everyday driving is poorly understood (Charlton & Starkey, 2011; Martens & Brouwer, 2013). To date, what little we know about when and how often drivers' minds wander has come from retrospective questionnaires (Berthié et al., 2015; Burdett et al., 2016; Galéra et al., 2012). Although questionnaires give some indication of drivers' reported tendency to experience MW, they may not be reliable indicators of MW frequency during everyday driving because of limitations associated with retrospective accounts generally, and our lack of insight into the experience of MW specifically.

Although they have not established the frequency of MW, driving simulation studies have explored the effect of MW on aspects of behaviour such as eye fixation duration, driving speed and headway to a lead vehicle (He, Becic, Lee, & McCarley, 2011; Yanko & Spalek, 2013). He et al. (2011) asked drivers to report when they noticed that their minds were wandering during a simulated car-following task. They found a positive correlation between MW and narrowed gaze patterns during the 12 s preceding a self-caught MW episode (He et al., 2011). Yanko and Spalek (2013) periodically asked participants completing a simulated driving task whether or not they were thinking about the task (a probe-catch procedure). They found that participants drove faster, with shorter headways and slower response times when they reported MW than when they reported driving task focus (Yanko & Spalek, 2013).

One potential problem with these laboratory studies is that attention and driving performance are known to change with repeated practice in driving simulation. This was revealed by Charlton and Starkey (2013) who studied the effects of practice on conscious and unconscious processes during simulated driving. They found that driving performance including lane position and mean speed differed between a group that drove the simulated route repeatedly across twenty sessions, and a group who drove the same simulated route just once. The one-off group reported higher task difficulty, while difficulty ratings among the repeated-sessions group reduced over time, with several participants volunteering that they drove on "autopilot" or were "thinking about food" after the first three to five sessions. Thus, although laboratory simulation can be used to investigate aspects of driving as a proceduralised activity if repeated often enough, baseline results from a single simulation session are not likely to reflect baseline performance during normal, everyday driving in the real world (Charlton & Starkey, 2013).

The laboratory environment is particularly limited in its ability to give any insight into the frequency or nature of MW in normal, everyday driving. Driving a simulated journey as a research participant is likely to foster a different kind of conscious experience than driving in the real world, not least because theories suggest that MW may be triggered by an individual's underlying momentary goals, or current concerns (Klinger, 1975). Driving between home and work on an everyday journey is conceivably likely to trigger different concerns than may manifest in a university driving simulator or during an experimental drive with no explicit purpose from the participant driver's perspective. Participants in the He et al. (2011) study, for example, were instructed to "keep their attention on the driving task as much as possible" (p. 15). There is no evidence to suggest that drivers in the real world actually operate with this level of diligence.

To find out how often drivers' minds wander, it may be useful to study them on a familiar trip such as the daily commute between home and work. Berthié et al. (2015) found that drivers were more likely to report MW during their most recent trip if it was their daily commute, and in general drivers report more MW driving their own cars on familiar roads (Burdett et al., 2016). Research involving qualitative analysis of interviews has also suggested that drivers readily report driving on "autopilot" during familiar drives such as the daily commute (Handy, Weston, & Mokhtarian, 2005; Papp et al., 2004; Steinberger, Moeller, & Schroeter, 2016).

MW during the daily commute can perhaps best be studied using experience sampling, which has long been used to investigate natural conscious experience during everyday life. Klinger (1975) pioneered experience sampling by equipping participants with a pager, notebook and pencil so that they could record their thoughts when paged at random as they went about their lives. The procedure was found to be a useful and unobtrusive method to capture insights into the content of everyday thought outside of the laboratory (Klinger, 1975). More recently, experience sampling research has revealed that attention fluctuates between MW and task focus during all manner of everyday activities (Killingsworth & Gilbert, 2010).

In experience sampling studies, thoughts are often categorised in some way by the participant, according to mood, for example (Killingsworth & Gilbert, 2010) or the temporal focus of the thought as past, present or future (Baird, Smallwood, & Schooler, 2011). Descriptive experience sampling is a specific version of the method where participants describe what they are thinking about when probed, without being confined to specific categories (Hurlburt & Akhter, 2006). Although not widely used in traffic psychology to date, it has potential to provide insight into complexities associated with the content and flow of conscious experience that cannot be captured by analysis of categorised thought samples in isolation from their context (Engelbert & Carruthers, 2011). Descriptive experience sampling is a form of ambulatory assessment, which is increasingly recognised as a reliable and authentic way to explore conscious experience, because it is defined by data capture during a participant's everyday life (Trull & Ebner-Priemer, 2014).

The ecological validity of descriptive experience sampling makes it a potentially useful method for studying attention during everyday driving. It allows for data capture "in the life of participants as they choose to live it, filled with the intricacies of the human experience that are difficult to capture in laboratory settings" (Bryant, Coffey, Povinelli, & Pruett, 2013, p3). This is important when investigating the intimate and fleeting contents of consciousness, because faithful reports are most likely when sampled as close to the event as possible (Heavey & Hurlburt, 2008).

Along with finding out how often drivers report MW, exploring the nature of their thoughts with descriptive experience sampling could provide insight into the processes that afford driving without awareness. Driving without awareness is believed to involve a mental model, framework or schema (Koustanaï, Boloix, Van Elslande, & Bastien, 2008; Ranney, 1994). While it is suspected that schemata are initiated, used and developed without a driver's explicit knowledge (Bellet, Bailly-Asuni, Mayenobe, & Banet, 2009), the way that they are formed and adapted in everyday driving remains largely unknown.

To our knowledge there have been no published studies to date which have used experience sampling to study MW during driving, but accompanying drivers on real roads is not an entirely novel research method. For example, Mårdh (2016) studied interactions between older drivers and their spouse as passenger, with a total of four participant pairs, on familiar roads in their home town. Variations on the 'ride-along' method have also involved researchers accompanying people as they drive, as a means to explore genuine interactions between participants and the environments through which they move (Harada & Waitt, 2013).

Given that experience sampling has proven to be a useful way to study everyday conscious experience, and the method of accompanying a driver also has precedents, we merged these approaches and used direct, descriptive experience sampling with a researcher as passenger to learn more about the nature of attention during everyday driving. This method is the most ecologically valid way to study driving. Compared to simulation or an experimental journey, it involves relatively naturalistic observation and questioning of a driver in their own vehicle on a trip that has a genuine purpose for them as they go about their day.

In summary, there is a gap in understanding the nature of driver attention during the daily commute, which we aimed to address by studying drivers in their own cars on their regular drives between their homes and workplaces. Specifically, we were interested in measuring how often drivers reported task-unrelated thoughts when queried with experience sampling probes. Secondary goals were to determine whether descriptive experience sampling was a useful and non-intrusive method to study drivers' thoughts during everyday driving, and to provide some qualitative insights into the ways that drivers regulate their attention.

2. Method

2.1. Participants

The study methods were approved by the School of Psychology Research and Ethics committee of the University of Waikato. Eleven participants (all female; age range 28–48; $M = 40.6$ years, $SD = 5.9$ years) were recruited to drive their normal commute between home and work and back again, up to ten trips in total, per participant, with a researcher traveling with them in their car. Participants worked in a variety of roles across six different workplaces, that is, they did not all work in the same place or in the same type of job. Each of the eleven participants reported that they had not been involved in any injury accidents during their previous five years of driving.

Participants were recruited through social media and advertising on the intranet of a local council office. In order to provide a relatively homogeneous sample by age and gender and limit the degree of intrusiveness caused by the presence of the observer, the selection criteria were that participants were female (as was the observer) and aged between 25 and 50 years. Further criteria were that participants lived in the northeast of the city and typically drove alone to work and back each day, with a minimum average commute time of fifteen minutes. Participants were given a ten dollar petrol voucher at the conclusion of each drive to thank them for their commitment to the study.

2.2. Materials

Materials included a study-specific questionnaire; pre-drive questions; experience sampling during the drive; and post-drive questions. The questionnaire was included to record each participant's age, aspects of their driving and commute experience (including average kilometres driven per week, length of time driving their current commute, previous injury and non-injury crash involvement), and their normal sleep pattern (sleep and wake times). It also included the Mindful Attention and Awareness Scale (MAAS), which assesses natural propensity to focus on the current moment (Brown & Ryan, 2003). The MAAS was included because the score has significant negative correlation with retrospectively reported MW frequency during driving (Burdett et al., 2016). It has fifteen items and a six-point Likert response scale ranging from 1 (Almost always) to 6 (Almost never). Higher average scores indicate higher propensity of an individual toward mindful attention and awareness in their daily life. The MAAS is widely used and has good internal consistency (Cronbach's alpha = 0.87, Brown and Ryan (2003)). After completing the questionnaire, participants were asked to draw their normal commute on a map.

The pre-drive questions asked participants to describe their current state: how tired, relaxed, under time pressure and happy they felt at that moment, each on a seven-point Likert scale from zero (very tired/very anxious/under a lot of time pressure/very sad) to six (very alert/very relaxed/under no time pressure/very happy). Before morning drives, participants were also asked what time they went to sleep the previous night, and woke that morning. Before evening drives, participants were asked to rate the working day they had just experienced, as easy, normal or stressful compared to a 'normal' working day.

During each drive, participants were asked between four and six times what they were thinking about at that moment ("What are you thinking now?" i.e., the descriptive experience sampling part of the study). Open-ended responses were recorded on paper and audio.

There were three post-drive questions. Participants were asked first, to estimate what proportion of the drive they estimated that their mind was wandering, described for participants as "not thinking about driving"; second, whether they had noticed anything interesting, unusual or hazardous during the drive, recorded verbatim; and third, to rate the drive difficulty on a seven-point Likert scale from 0 (easy) to 6 (very difficult).

2.3. Procedure

Participants were recruited through advertising on social media. Those who expressed interest were emailed an information sheet and if they wished to continue, a researcher met them at their home or workplace to talk through the study procedure. After signing a consent form, participants completed the study-specific questionnaire and arranged drive times with the researcher.

A researcher met each participant ten times at their home or workplace a few minutes before they were due to leave for work (AM) or home (PM). Before each drive, participants were asked the pre-drive questions.

The researcher sat in the back seat of the participant's car for each drive. The probe for descriptive experience sampling, "What are you thinking now?", was asked between four and six times on each drive depending on trip length, with probes a minimum of one minute apart. Other than the one minute separation criterion, probes were spread evenly through each drive, but at different locations for each of the ten drives per participant, to avoid probes being anticipated. Probes were withheld at locations where it was not deemed safe to interrupt the driver, such as in the middle of an intersection manoeuvre. Participants were informed at the start of the study that they did not have to provide an answer to a thought probe if they did not want to reveal what they were thinking about. Participants' open-ended responses to the probe were written down during the drive, as well as audio-recorded for later analysis.

At the end of each drive participants were asked the post-drive questions. They were given a ten dollar petrol voucher after each of ten drives to thank them for their participation.

3. Analysis

Thought samples were coded into one of five categories (Fig. 1) adapted from Smallwood and Schooler's (2015) taxonomy. The first two categories included all thought samples with no evidence of a driving task focus ("Focus: Not driving"); that is, the participant's mind was engaged in task-unrelated thought (MW). Thought samples could also be coded according to whether they directly concerned sensory information from the driving environment (e.g., "Those people out walking might get wet, they don't have an umbrella"), or whether they appeared to be internally triggered (e.g., "I'm hungry, I'm wondering what's for dinner").

Similarly, the third and fourth categories were either sensory triggered or internally triggered, but in both cases the focus of the thoughts was related to the driving task. For example, "I'm just overtaking this truck" would have been classified as driving-related and sensory triggered. A probe response of "I wonder whether there will be a car park at work" would have been classified as driving-related and internally triggered.

The fifth category was included to account for samples that reflected no particular thought at all. We named this category "passive stand-by" mode, to account for samples where no specific driving task could be assigned (for example, "Nothing, I'm just watching the traffic"), and where no task-unrelated thought was engaged with, pursued or actively inhibited (for example, "Honestly, nothing......can be processing stuff but not really thinking about it" (Participant 1, Drive 5). The passive category represents a kind of down-time with no active thought at all, defined by comedian Bill Bailey as "power-saving mode" (O'Driscoll, 2015). The resulting five-way categorisation is summarised in Fig. 1.

All samples in the MW categories (MW: internal and MW: sensory) were collectively defined as MW so that overall proportion of MW responses could be calculated, per participant (across all of their drives), and collectively at different stages of the morning and evening commutes (with participants' responses grouped). Samples in the 'passive stand-by' category were not included as part of the MW proportion because they did not present evidence of task-unrelated thought; the participant's mind had not 'wandered' anywhere.

A subset of thought samples were categorised separately by three researchers with good agreement (Kappa = 0.74), with any discrepancies agreed by consensus. Samples with more than one potential category were coded according to the first

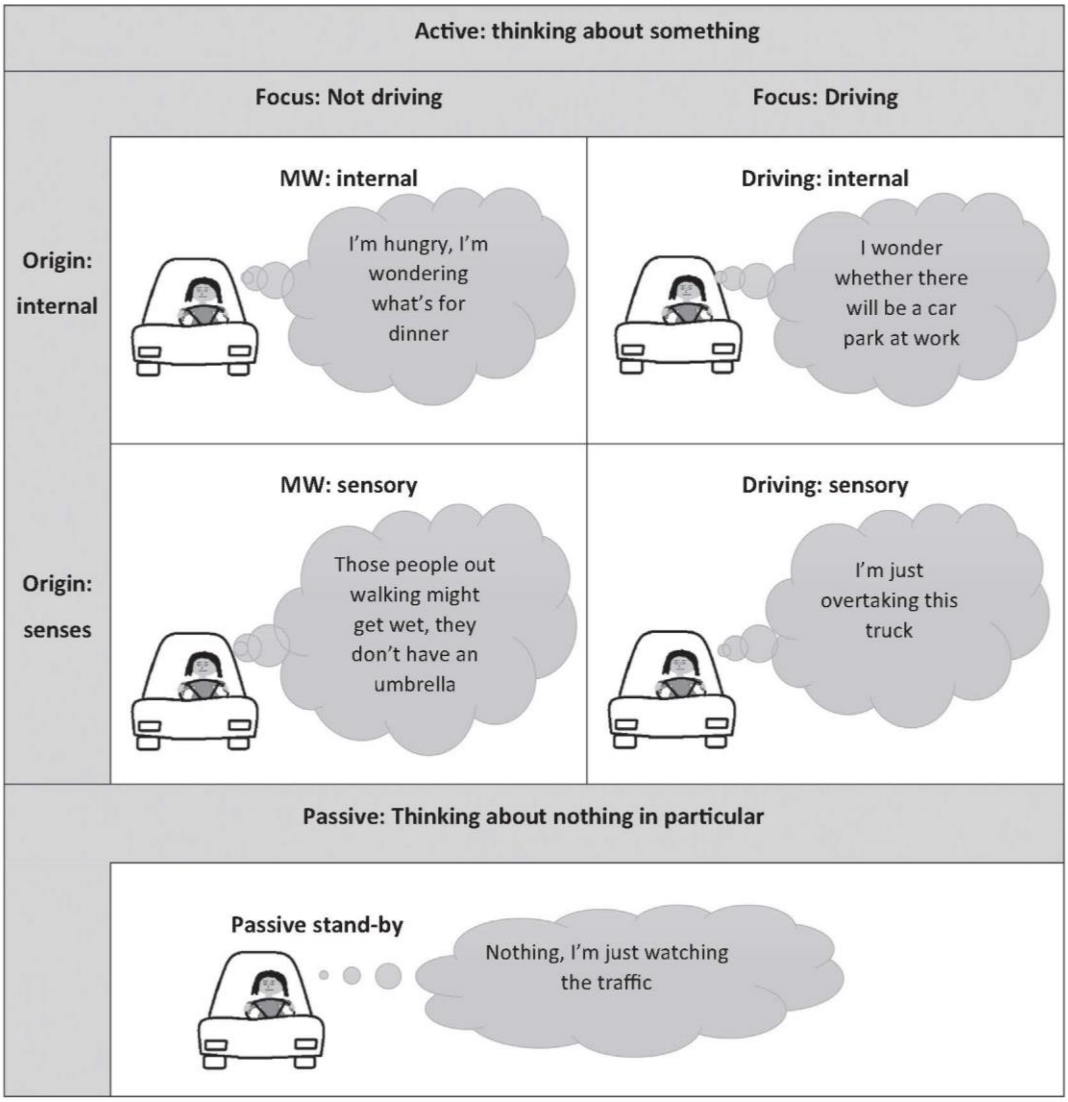


Fig. 1. Five-way categorisation of thoughts, adapted from Smallwood and Schooler (2015).

component of the response. For example, "Jacob Dillon's got a much better voice than his father [singer on CD] and watching that car pull out" was coded as MW: sensory because the first response reflected thought related to what the participant was listening to, and it was not related to the driving task.

The proportions of thoughts in each of the five categories were summed overall, and for the morning and evening commutes separately. The purpose of these summations were to reveal any differences in the relative frequency of different types of thoughts overall, and during the morning and evening drives.

To explore whether driving-related thoughts were more frequent at different stages of the drive, all responses were grouped according to their focus (driving or not driving), for the beginning, middle and end of the drives to work, and drives home. The beginning and end segments were defined as the first four minutes and last four minutes respectively, with the remaining drive time assigned as the "middle" segment which had a mean duration of 7 min and a range of 4–22 min.

To explore whether thoughts triggered by the senses were more frequent at different stages of the drive, responses were grouped according to their origin (sensory/internal). These groups were also separated by stage of the drive in the same way as for the driving/not driving analysis.

To explore the nature of commuting drivers' thoughts in more depth, the temporal distribution of three participants' thought samples were mapped. Two participants' thought samples across five drives between home and work (AM) were mapped, and one participant's samples between work and home (PM) were mapped. The reason for mapping these thought samples was to explore what drivers were thinking about on the daily commute in more depth than was possible with categorised data alone. These participants in particular were selected because they provided a range different amounts of MW, and illustrated the range of the types of thoughts sampled as a whole.

4. Results

4.1. Thought samples: Incidence of MW

The data summarised in Table 1 show the results from eleven participants' ten drives, comprising a total of 578 thought samples across 110 drives. Drivers were asked what they were thinking about 5.25 times on average, per drive. Drivers reported actively thinking about something unrelated to driving on 63% of probes; reported active driving-task focus on 19% of probes; and reported thinking about nothing in particular on 18% of probes. Proportion of MW per participant, per drive ranged from 0% to 100% across the 110 drives. Individually across ten drives each, the participants' mean proportion of MW responses to probes ranged from 36% (Participant 10) to 84% (Participants 5 and 9). Drivers reported feeling relatively relaxed, happy and under no time pressure at the beginning of their drives. Their reported alertness was the most variable of states.

The average proportion of MW across all participants became stable after the eleventh participant had completed the study. When asked to report how much their mind was wandering on the preceding drive, drivers reported not thinking about driving for 53% of the time on average (range 1% to 100% across 110 drives).

4.2. Categorised thought samples

The proportions of thought samples in the five categories are shown in Fig. 2. As a whole, drivers' minds were more likely to be wandering when probed, than to be focused on some aspect of the driving task. Around half of MW thought samples had a trigger in the sensory environment (including what was seen on the road and broader roadside, or heard, for example on the radio) and half had no obvious sensory trigger. Around two thirds of driving-related thoughts reflected momentary focus on current driving task demands. The least frequent type of driving-related thought was internal, which included thoughts unrelated to the current moment, such as route choice or thinking about where to park.

The proportions of thought samples in the five categories, separated by morning and evening commutes, are shown in Fig. 3. The main difference in thought samples between drives to work in the morning, and evening drives home, was that drivers were more likely to report non-driving, senses-related thoughts, and fewer momentary driving task-related thoughts in the morning. Drivers also reported slightly fewer MW: internal thoughts during their morning commute. The differences between proportions of thought in each category during morning and evening commutes were not significant ($t(9) = 110.9$; $p = 1.00$).

4.3. Thought variation through the drive

To examine variation in thought categories through the morning and evening commute, data were combined to show the proportion of thoughts in different categories at the start, middle and end of both morning and evening drives. The purpose

Table 1
Descriptive statistics: Number of probes, MW proportion by probe and estimated, pre-and post-drive question responses concerning momentary state and drive difficulty.

	N	Mean	SD	Range
Probes per drive	–	5.25	0.48	4–6
Proportion MW by probe, per drive	110	63%	23%	0–100%
Proportion MW: internal, per drive	110	30%	24%	0–100%
Proportion MW: sensory, per drive	110	33%	27%	0–100%
Proportion driving, per drive	110	19%	18%	0–75%
Proportion driving: internal, per drive	110	6%	10%	0–40%
Proportion driving: sensory, per drive	110	13%	16%	0–75%
Proportion passive stand-by, per drive	110	18%	18%	0–80%
MAAS score	11	4.13	0.53	3.27–4.93
Pre-drive measures				
Alert (0 = very tired, 7 = very alert)	110	4.70	1.50	0–7
Relaxed (0 = very anxious, 7 = very relaxed)	110	5.57	1.15	2–7
Happy (0 = very tired, 7 = very alert)	110	5.82	1.19	2–7
Under no time pressure (0 = a lot, 7 = no time pressure)	110	5.96	1.27	2–7
Hours of sleep previous night (AM drives only)	55	6.93	0.98	4–9
Working day stress (PM drives only: 1 = Easy; 2 = Normal; 3 = Stressful)	55	2.06	0.71	1–3
Post-drive question				
Estimated MW by participant	110	53%	27%	1–100%
Drive difficulty (0 = very easy, 7 = very difficult)	110	0.75	1.23	0–5

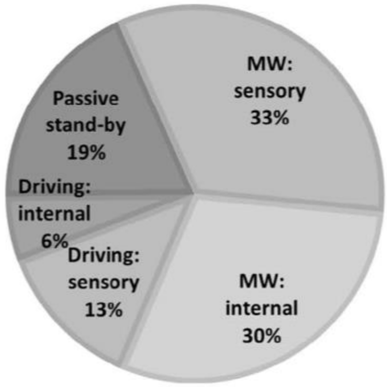


Fig. 2. Proportion of probes in different categories: all probes (n = 578).

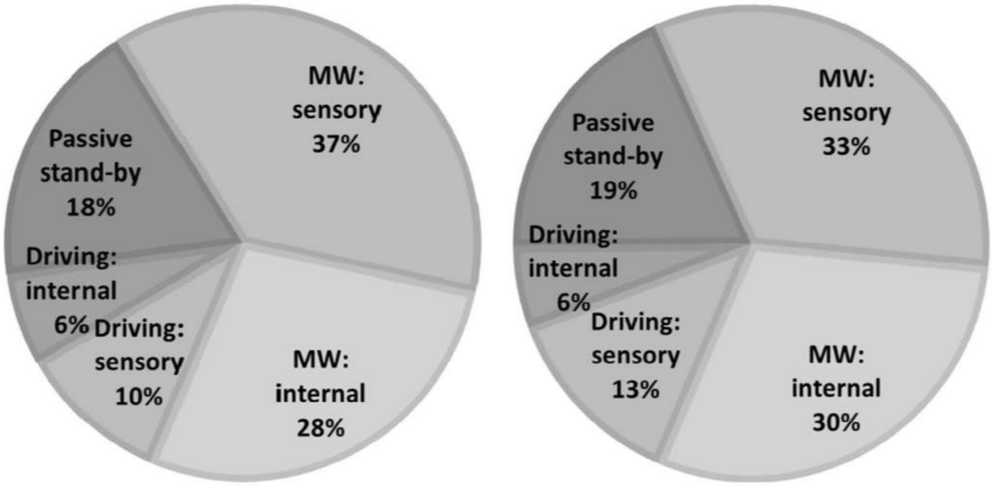


Fig. 3. Proportion of probes in different categories: AM drives (n = 289; left) and PM drives (n = 289; right).

of this analysis was to determine whether different types of thoughts were more likely to be reported at different stages of the drive. These data were not analysed statistically due to the small sample size and because the samples for evening and morning drives were not independent; each participant provided between four and six thought samples across five morning and five evening drives. They are therefore provided as an initial description of how MW might vary across a drive, and between morning and evening.

Data were collapsed from five categories to three in Fig. 4, which shows passive stand-by mode as well as driving (combination of driving: sensory and driving: internal) and MW (combination of MW: sensory and MW: internal) thought categories. These data show that driving task focus was more likely to be reported on the commute from work to home in the evening than it was in the morning, repeating the finding from the analysis presented in Fig. 3, although MW was commonly reported throughout both morning and evening drives. There was no portion of any drive where MW featured on fewer than 56% of thought samples. Driving task focus generally increased through each drive, and through the day, with the lowest proportion of driving task focus (12% of thought samples) recorded at the start of the morning commute, and the highest proportion (25% of thought samples) towards the end of the evening commute. These data also reveal that passive stand-by mode (thinking about nothing in particular) occupied a persistent 15% to 23% of thought samples across all stages of morning and evening commutes.

Data were also collapsed from five categories to three in Fig. 5, which shows passive stand-by mode as well as sensory (combination of driving: sensory and MW: sensory) and internal (combination of driving: internal and MW: internal) thought categories. These data show that internally triggered thoughts were least likely to be reported at the end of each drive. The highest proportion of internally triggered thoughts was observed at the start of the evening commute (41% of thought samples) whereas the highest proportion of thoughts with sensory origin was observed at the end of the morning commute (57% of thought samples).

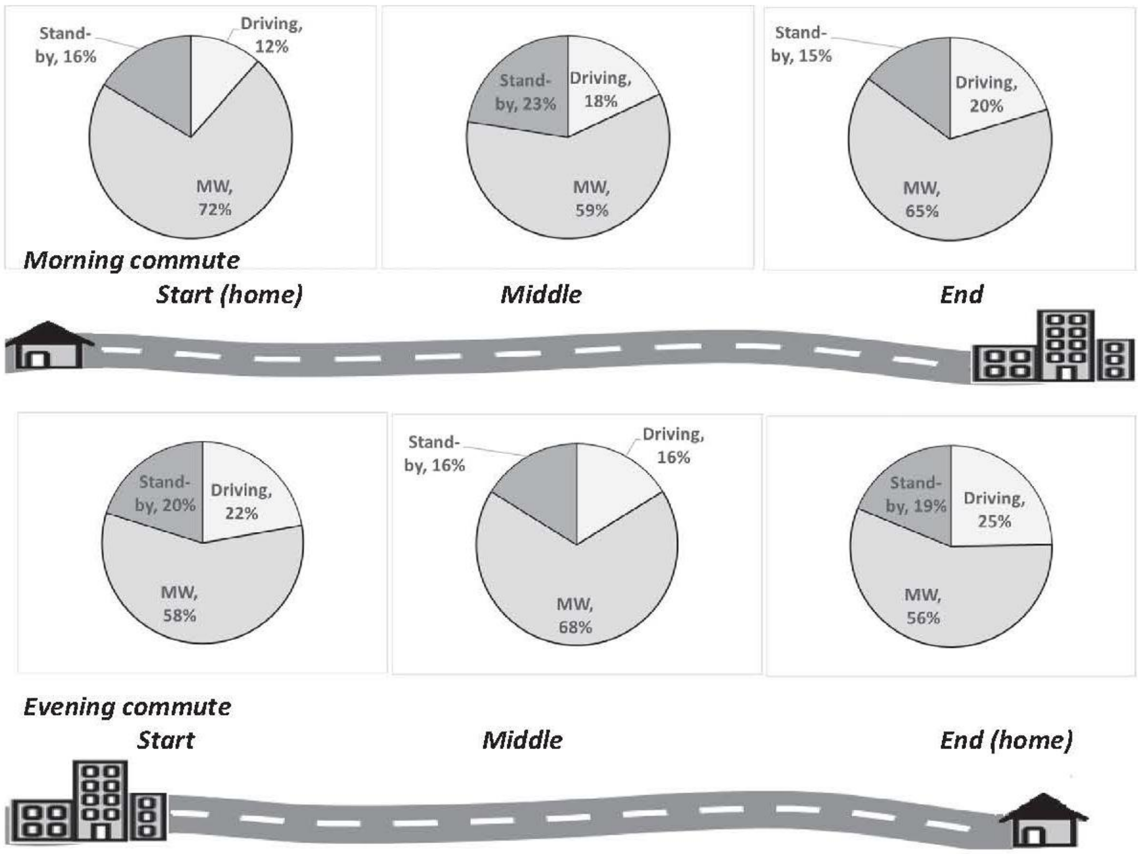


Fig. 4. Thought variation as MW, driving focus on stand-by on the drive from home to work (AM commute; top) and work to home (PM commute). Thoughts are grouped as either driving-related (sum of driving: sensory and driving: internal); MW (sum of MW: sensory and MW: internal), or stand-by.

4.4. Thought variation through the drive: Three case studies

Data from three participants were mapped as case studies, which provide examples of thought samples in each of the five categories, and enable examination of some of the complexity inherent in commuting drivers' thoughts. The thought samples mapped were from Participant 6 across five drives from work to home, and from Participants 10 and 5 across five drives from home to work. As mentioned earlier, these three participants' data were selected to illustrate the range of the types of thoughts sampled. To protect participant confidentiality, the maps shown in the results were not the actual routes taken by any participants, but are generic routes reflecting the kinds of roads driven on and the typical lengths of participants' commutes.

As stated earlier, across all participants, reported MW proportion from probes ranged from 36% to 84%. Mapped data were from Participant 6 (74% MW overall); Participant 10 (36% MW overall); and Participant 5 (84% MW overall). Thought samples across five drives for each of these case study participants were listed and grouped according to whether they were recorded at the start, middle or end of the drive. Within each case study, the first probe responses across five drives were grouped as the 'start'; the last probe responses from five drives were grouped as the 'end', and a representative selection of the remaining responses to probes was grouped as the 'middle'. Thought sample maps are shown in Figs. 6–8.

The thought samples in Fig. 6 show that for Participant 6, thoughts unrelated to driving were more frequent than specific driving-related thoughts. Many of these thoughts were about the participant's work or her life at home. Participant 6 was more likely to think about work as she left the workplace (for example, "Issue at work, try to do the right thing but there's always someone who doesn't like what you do"), although these thoughts were replaced by thoughts about home life as she neared her home (for example, "That was a quick drive, nearly home, looking forward to a really relaxing evening."). Rather than driving being the 'default' topic, this driver appeared to use the drive to think about aspects of life at work and home, and momentary driving-related situations commanded her attention momentarily and infrequently (for example "Keeping my distance [laughs] from the police car. Might go into this lane.").

The thought samples in Fig. 7 show that in contrast to Participant 6, Participant 10 spent more time thinking about driving, although many of these were passive, such as "nothing, just watching the traffic". Several of Participant 10's thought

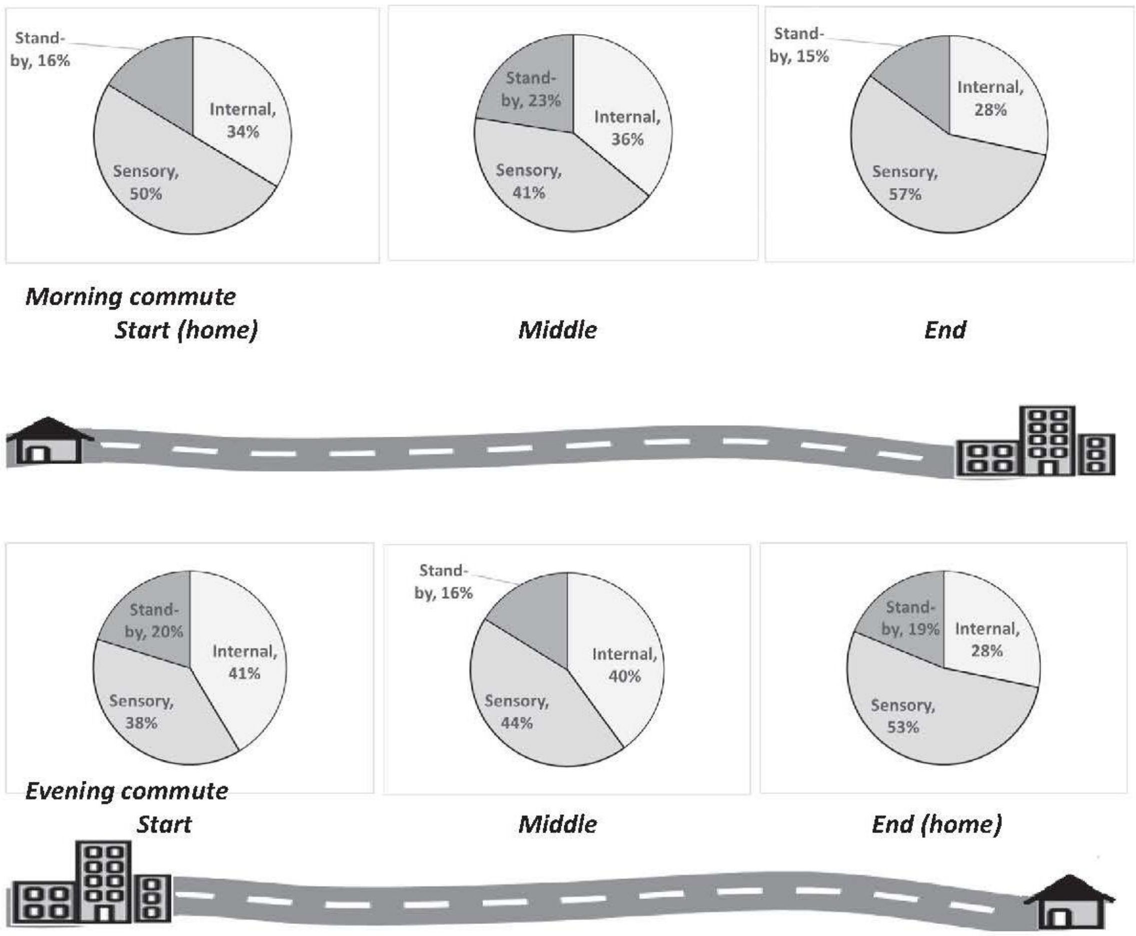


Fig. 5. Thought variation as internal, sensory or stand-by on the drive from home to work (AM commute; top) and from work to home (PM commute). Thoughts are grouped as either internal (sum of driving: internal, and MW: internal), sensory (sum of driving: sensory, and MW: sensory), or stand-by.

samples suggested that she was scanning the environment as part of the driving task, but internal concerns were triggered by what she saw. For example, "If we send the kids to that College there's a nice cycle lane" was categorised as MW: sensory, even though the driver was at that moment specifically aware of the marked cycle lane which is an aspect of the road environment.

Data in Fig. 7 show an example of a driver with a higher proportion of driving focus towards the end of the morning commute, as indicated by aggregated data in Fig. 4. Passive stand-by thoughts were spread throughout the commute, while thoughts unrelated to driving (in this case, typically triggered by the senses) were most likely during the start and middle sections of the drive, for example "What was going on site where the home show was, they've started building something else" and "Since I'm going past the school where the kids have their swimming lesson, it's their last lesson tomorrow".

One of Participant 10's responses (Fig. 7) demonstrated some of the complexity within the commuting drivers' thought patterns. This example was categorised as "MW: Sensory": "Jacob Dillon's got a much better voice than his father…and watching this car pull out" (Fig. 7). The first topic of thought mentioned in response to the probe was related to what the participant heard on her car stereo, but this was quickly interrupted by a driving-related thought, triggered by the manoeuvre of another driver.

The responses listed in Fig. 8 show that Participant 8 also thought about topics triggered by what she saw, although these thoughts were not often driving-related. The links between sensory perception and thought processes were well demonstrated by the following thought sample, coded as MW: sensory: "About this guy at work and what a dickhead he is… Name on the radio triggered it. Association. Then I looked up and there was a girl in a red jacket who reminded me of someone else associated with him too". This thought sample shows how quickly thoughts switch between the immediate sensory environment and internal reflections.

Closer to work:

"My mind's quite busy, I'm still in work mode.. Good I can switch off and get out, kids aren't home, it will be a relaxing evening."

"Nothing much at the moment, just in a bit of a whiz cause I rushed out of the office. I'm between work and home."

"Issue at work, try to do the right thing but there's always someone who doesn't like what you do"

"Just the traffic, so much cars on the road, I have to really concentrate, and it's raining, all the silly people are on the road, people get silly when it's raining "

"That guy can talk .. Just had a meeting with a contractor."

Middle:

"Just listening to the radio, not particularly anything on my mind."
"I have another crazy night ahead, bbq at friends and gym"

"Having a look at the weather, thinking I haven't been outside much today. My mind is quite wandering, it's flicking all over, maybe because I rushed out of the office.."

"Keeping my distance [laughs] from the police car. Might go into this lane."

"Wondering what's for dinner tonight, how the evening will play out, just observing all the cars and people around me."

"Thinking a lot of cars on the road, just been thinking traffic's busy, every light's red, annoys me a little bit I just want to get home. "

"Just looking at this old truck wondering whether I'll pass it or not, this person in front of me is really going slow"

Closer to home:

"Nothing much at the moment. Daydreaming a little bit, thinking about kids, surroundings. I think as I drive [farther from work] my mind starts to clear."

"That was a quick drive, nearly home, looking forward to a really relaxing evening."

"Someone told me they are building another dentist on this side as well."

"Just really tired, would really like to just kick my shoes off and do nothing, sit back and relax tonight."

"Not anything specific, just concentrating on driving more than I normally do."

Fig. 6. Participant 6, Evening commute (work to home): collated thought samples across five drives.

5. Discussion

5.1. Frequency of MW

The aims of this study were to find out how often drivers report MW during the daily commute, to determine whether descriptive experience sampling was practical and non-intrusive during everyday driving, and to provide some qualitative

Closer to home:

"What was going on site where the home show was, they've started building something else"

"Nothing"

"Just about the traffic at 7:37, there's not usually so much"

"They've started work [on that site], I don't know whether they're doing another show home or a more permanent thing"

"I was thinking it was very quiet and then this [queue] is very unusual for 7:38"

Middle:

"Nothing, Just watching the traffic"

"How much one of those new Audi A6s that just went past us might cost"

"Since I'm going past the school where the kids have their swimming lesson, it's their last lesson tomorrow"

"If we send the kids to [that particular] College there's a nice cycle lane"

"That person in a giraffe onesie crossing the road.. She'll be going to the shop... [laughs]"

"Nothing really. Just... traffic. That's how quick you can forget about a giraffe."

"Nothing, just driving"

"A mish-mash of things, just told myself not to think about work cause I was thinking about work"

"Got a text today saying 10 cents off per litre of fuel if you spend $40, just wondering if I'd get to $40 in my tank, probably not"

Closer to work:

"Just wondering what that bus is going to do"

"Looking for that car [that passed us earlier], wondering which way is faster"

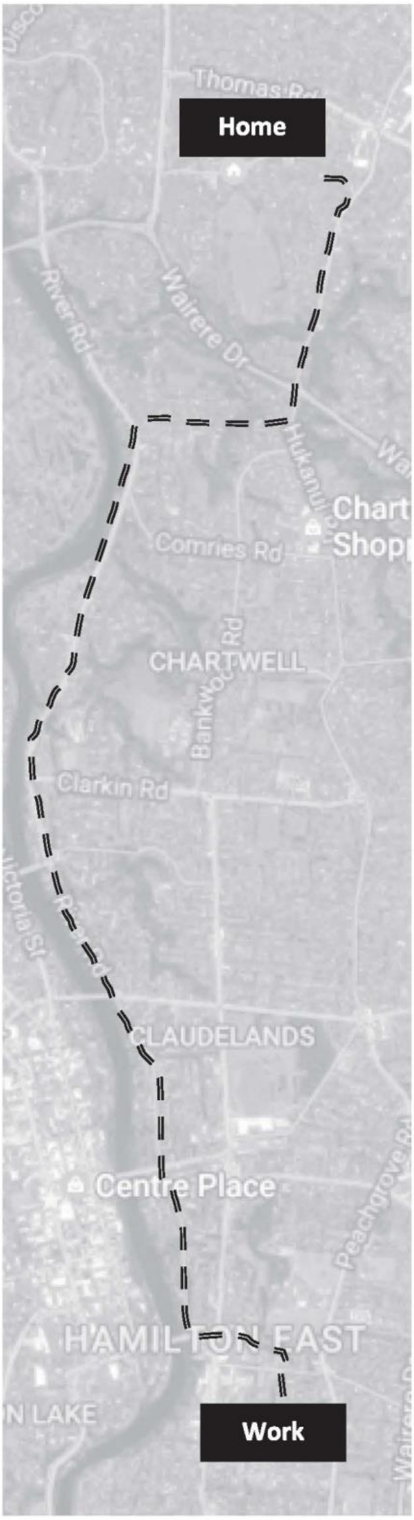
"Looking for the car [that passed us earlier]..there he is!"

"Was thinking there was potential for disaster at those lights, how do they know? [signals out]"

"Jacob Dillon's got a much better voice than his father [singer on CD] and watching that car pull out"

Fig. 7. Participant 10, Morning commute (home to work): collated thought samples.

insights into the ways that drivers regulate their attention during everyday driving. Regarding the first of these aims, the thought samples we collected were indicative of a very high rate of MW during the commuting trips we sampled. All of the participants reported MW, with an average of 63% of probe responses reflecting driving-unrelated thought of some kind. A further 19% of responses reflected a passive stand-by mode, with no immediate concerns commanding attention. Of the remaining 18% of samples that were coded as driving-related, around one third were not related to momentary driving tasks



Closer to home:

"Thinking that I feel good, that might be why I whistled"

"Was just thinking what a mismatch her outfit was, that girl standing by the bus stop there"

"My neighbour, issues with a new fence she's put up"

"More traffic out this morning"

"What a funny thing to have on the radio: New Zealand's worst place for STIs"

Middle:

"That I have a really busy day [ahead]"

"How quiet the roads are, everyone must still be on holiday"

"Dammit my boss is back. He's ghastly, we're all dreading it."

"Cute boy up there with spiky hair"

"About this guy at work and what a dickhead he is.. Name on the radio triggered it. Association. Then I looked up and there was a girl in a red jacket who reminded me of someone else associated with him too."

"Literally looking around thinking, my god this is a picture, it's just beautiful"

"I was kinda blank, was thinking about that girl [pedestrian] how she should've waited cause there were only two cars and not get stuck in the middle of the road like that"

"My girlfriend who works at work, if she's having a nice holiday, drove past her street"

Closer to work:

"Did you know this [street] is called Anzac Parade? I only just noticed"

"We're almost there, I'm not excited about today"

"After [restaurant] burning down they talked about Russia burning and I wondered if it's coincidence or journalism"

"I'm hungry. Did I remember to bring my lunch?"

"This whole thing about Miley Cyrus (radio)"

Fig. 8. Participant 5, Morning commute (home to work): collated thought samples.

but to abstract considerations such as where to park. Therefore on average, drivers were thinking about driving for less than one fifth of reports; and were found to be thinking about current driving task demands on only 12% of reports.

Drivers in the current study themselves estimated that their minds were wandering an average of 53% of the time. This proportion, and the overall proportion of MW by probe (63%) are both higher than estimated by participants in the Berthié et al. (2015) study, who reported MW for an average of 35% of the time during their most recent drive. However, their data covered all manner of drives and not just the daily commute, which is among the most familiar of driving situations. Correlations were not calculated in this study due to the small sample size, but nevertheless this finding provides some support for the use of retrospective, subjective judgments concerning attention during everyday driving, such as the subjective attention score adopted by Martens and Brouwer (2013). Retrospective estimates may be most useful to provide an indication of relative MW proportion in settings where experience sampling is impractical.

In terms of temporal variation in MW through morning and evening commutes, results suggest that driving task focus is highest at the end of the drive, regardless of direction. Drivers were no more likely to report task focus near their workplace per se, except during the drive to work. It may be that work-related thoughts at the start of the evening drive home resulted in fewer driving-related thoughts in these locations, however it is also possible that differences in the street environments along participants' different routes affected their likelihood to report MW at different places. Future research using the same route may help to determine the influence of road and traffic variables on the likelihood of drivers to report MW.

5.2. Why do drivers' minds wander so much?

It seems that drivers report frequent MW on the daily commute because driving task demands are low. It is 30 years since Hughes and Cole (1986) suggested that driving a familiar route leaves drivers with spare capacity, which is unlikely to be channelled towards driving when there is nothing particularly novel in the road and roadside environment that may capture their attention. The relatively high proportion of MW reported by participants in this study is not in itself surprising, given recent research suggesting that it is most likely on familiar roads and in drivers' own cars (Burdett et al., 2016).

This spare capacity sometimes results in a passive stand-by mode of thought, with drivers thinking about nothing in particular even though driving is still 'going on'. This was highlighted by many thought samples such as "Nothing really, just watching the car in front of me" (Participant 2, Drive 8); "Kinda thinking about those cars but nothing specific" (Participant 3, Drive 10); "Nothing at the moment. Just observing the cars and the environment" (Participant 6, Drive 3); "Nothing really, just looking to see how much traffic is backed up" (Participant 9, Drive 1); and "Nothing, just driving" (Participant 10, Drive 3). These samples suggest that drivers are ready to apply active focus to the driving task when necessary. Conversely, this mode may itself be a precursor to more MW. The possibility that drivers, or anyone, can be thinking about 'nothing in particular' is contentious, and worthy of continued investigation.

As alluded to in the Introduction, it is a possibility that drivers may be more likely to let their minds wander on familiar routes because based on their daily experience there is no reason to believe the routes pose a hazard. Had we chosen to test drivers on unfamiliar roads (or for that matter in unfamiliar vehicles) we might have found lower rates of MW answers to the probes. Indeed, we have previously reported that the daily commute is one of the situations when drivers are most likely to experience MW (Burdett et al., 2016). We chose the daily commute as the setting for the present research, however, because it constitutes such an overwhelming proportion of our driving experience. Future research might try to quantify how route familiarity and risk perception alter the likelihood of drivers reporting MW.

Even though drivers frequently reported thoughts unrelated to driving, they appeared engaged in the 'drive' as a whole and regulated their attention according to momentary demands. This was apparent in the complexity of drivers' thoughts, for example from Participant 10: "Jacob Dillon's got a much better voice than his father [singer on CD] and watching that car pull out" (Drive 9). This sample demonstrates how swiftly the mind can be brought back to the driving task when necessary.

The complexity of drivers' thoughts is also exemplified in this sample from Participant 2: "Numberplate of this motorbike, watching him for a while, he tends to speed up and slow down, and that's the last colour helmet I'd have.. But I suppose he wants to be seen, which makes sense." (Drive 6). This sample reveals a complex trains of thought, with leaps from sensory observations through to reflections and perceptions about the behaviour of others, all repeated within a thought sample voiced in a matter of seconds. Thus drivers do indeed appear to have spare capacity, which they use to think about a broad range of topics related to the road environment and their everyday life. Despite frequent MW, the fact that so many of the drivers' thoughts were triggered by the sensory environment suggests that they are ready to react to driving task demands when momentary situations warrant active focus.

5.3. How do conscious and unconscious processes interact in everyday driving?

As well as suggesting that MW is commonplace during everyday driving, the results also give clues as to how driving comes to be largely governed by unconscious processes. The results support the tandem model of driver behaviour presented in Charlton and Starkey (2011), which proposes that there are two modes of cognition underlying behaviour during driving: a continuously engaged, unconscious monitoring process and an active, operating mode is engaged in unfamiliar or inherently complex situations.

In the current study, the monitoring process governed behaviour when drivers' minds were wandering or when they were thinking about 'nothing in particular'. Drivers reported active focus only when necessary, or because they were exercising explicit diligence. Participants reported effortful focus in response to the actions of other road users, for example "That car overtaking the cyclist - coming into my lane" (Participant 3, Drive 6); and "Just watching this reversing car" (Participant

11, Drive 3). These actions are less likely to be proceduralised because road users react in different ways each day and in different locations along the commute.

Participants also reported effortful focus during situations that were complex or unpredictable, including specific locations and types of traffic. For example, "Just the traffic, so much cars on the road, I have to really concentrate, and it's raining, all the silly people are on the road, people get silly when it's raining." (Participant 6, Drive 8), and "At the moment - nothing – [this intersection] is so busy, I usually don't think of anything" (Participant 1, Drive 7). These responses suggested that participants actively inhibited MW when they had learned that the situation warranted focus, even if there was no specific momentary action required. It may be that they had experienced near-misses in their driving experience in heavy traffic or rain, or at particular intersections, which meant that they had learned to inhibit MW in these momentary situations.

Alongside momentary traffic demands and situations known to be demanding, the final trigger for active focus was when drivers simply thought they ought to pay attention, for example "Checking speed, reminding myself to concentrate on what I was doing: telling myself not to wander" (Participant 1, Drive 3). However, this trigger was relatively rare. It seemed that for most participants, when their attention was not commanded by unfamiliar road or traffic situations, they either thought about nothing (stand-by) or their mind quickly wandered to driving-unrelated concerns.

One particularly helpful insight into the way that conscious and unconscious processes interact was revealed by three participants who commented on the *absence* of characters that they were used to seeing during their commute. These thought samples were "I haven't seen my friend Bevan out running for a while, normally pass him driving to work" (Participant 3, Drive 7); "Thinking about another Mum I see from school driving at this time, I haven't seen her today" (Participant 4, Drive 4); and "I was just thinking that lady that always has the ducks, there's no ducks. Where's the ducks?" (Participant 7, Drive 1). These responses suggest that the entire road and roadside environment is part of the commuting driver's unconscious schema. Unconscious processes appear to be governed by a range of what can normally be expected to be present or absent on the commute. Changes to the normal range manifest as conscious experience, whether or not the change warrants some kind of driving-related action. If the change is repeated often enough (for example, if the ducks never came back), the new situation is likely to itself become the status quo and not be explicitly noticed again.

The results suggest that drivers' schemata are indeed sophisticated and dynamic. Even when thought samples imply MW, drivers are frequently building and adapting their expectation of what is 'normal'. Expectation is informed by changes in the road and roadside environment as it appears on the daily commute; by the actions of other drivers; and by the behaviour of specific non-driver characters that inhabit an individual driver's commute in time and space. Whether or not changes in the driver's broad schema manifest as conscious thought seem to be affected by interaction of their novelty value or conspicuousness compared to 'normal', and the depth or strength of a driver's ongoing driving-unrelated train of thought.

5.4. What do drivers' thought samples suggest about direction for future research into MW?

Regarding the second of the goals of this study, it would appear that using experience sampling to study MW during everyday driving is not only possible, but highly fruitful in terms of exploring the ways that people regulate their attention. There are, however, several unanswered questions about the implications of the findings for driver performance. The more ecological approach adopted by the present study meant that driver performance was not rigorously assessed as it might have been in an instrumented vehicle or driving simulator. As a consequence, although we have a good indication of how often task-unrelated thought occurs during a commute, we do not yet know how it affects driver performance in these circumstances. Although future research would do well to examine the implications on MW for driver performance and safety, care will be required to measure performance without changing the driving experience and find a way to increase the rate of thought sampling without intruding into the natural ebb and flow of task focus. For example, we withheld probes at situations where driving safety could have been compromised. Future studies, either on-road or in simulation, might examine how to overcome this bias in collecting thought samples across the full range of driving situations.

Further, thought samples recorded in this study were complex, which makes a dichotomous "MW-or-not" categorisation potentially misleading in terms of its relationship with risk. The definition of MW as task-unrelated thought (Smallwood & Schooler, 2006) belies the ability of people to regulate their attention according to task demands and the nature of current concerns. Rather than exploring MW and performance using strict categorisation, away from the context of natural behaviour, exploring the way that people shift their focus between task-related and unrelated concerns may be more meaningful.

6. Limitations and conclusion

On the whole, this study has provided rich and novel insights into the mind of a commuting driver. However, the results must be interpreted in the context of the study's limitations. Most obviously, the sample size was small and homogenous, albeit across a relatively large number of trips (110). The results reflect samples of thoughts from women aged 28–48 who live and work in a medium-sized city in New Zealand and who drive alone. The commute is an example of everyday driving, but it is only one trip purpose. It may be that other examples of everyday driving, or drives with passengers, may result in different proportions of thought in each category.

Another limitation in the present study was that with the experience sampling technique it was not possible to determine the proportion of time spent engaged in thoughts from each of the categories. A particular instance of task-unrelated sensory triggered thought may have lasted only a very short time, whereas a driver may have dwelt on a task-related internally triggered thought for a much longer period, yet these two very different durations could not be discriminated by the probe responses we collected. We think that our periodic sampling would reflect this difference simply by having a higher probability of capturing thoughts that were present over longer periods and have a lower chance of capturing fleeting thoughts. Future research could modify the method to ask participants for an indication of how long they had been engaged in thinking about a particular topic. However, the complexity of the thoughts captured in the present study suggests that this endeavour will be very challenging indeed. Furthermore, probes were withheld in potentially safety-critical situations, which is why we reported frequencies of samples, and have not necessarily assumed that they equate to the proportion of time driving as a whole.

Related to the issue of the duration of individual thoughts is participant verbosity. While it did not appear from our data that the proportion of samples reflecting MW was related to how much the participants had to say, it may be that there are individual differences in the ability to access and articulate their thoughts. Future research using these methods might benefit from more analysis of these differences and how they affect likelihood to report MW.

Although the drivers were on their regular drive between work and home, they do not usually drive to work and back with a researcher present in the back seat of their car. It is likely that the researcher's presence affected the driver's conscious experience in some way, although they all volunteered that their thought samples were probably a reasonably accurate reflection of the kinds of things they usually think about while driving. When asked to estimate the proportion of time spent MW on the previous drive, one participant volunteered that "honestly, I've no idea how I got here from home" (Participant 6, Drive 5), which suggests that the researcher's presence was certainly not grounding her thoughts towards the driving task.

While it is convenient to reduce thoughts to discrete samples, thinking is complex and continuous, as described over one hundred years ago by William James: "Consciousness, then, does not appear to itself chopped up in bits. Such words as "chain" or "train" do not describe it fitly......It is nothing jointed: it flows" (James, 1890, p239). This notion of a stream of consciousness was reflected in the current study by the swiftly changing nature of topics in drivers' minds, and their active inhibition of MW when driving commanded their attention. MW is frequently reported, but an off-task thought is swiftly aborted when driving becomes task-critical.

It is important for future research into MW and attention during driving to acknowledge that many drivers are not actively thinking about driving a lot of the time. This study has demonstrated the value of exploring this seemingly ubiquitous state by combining quantitative and qualitative analyses. It is recommended that more researchers look beyond the laboratory to explore relationships between MW, active driving task focus and road safety in the real world of everyday driving.

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Study Three: The Close to Home Effect in Road Crashes

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The close to home effect in road crashes

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ABSTRACT

The notion that most crashes happen close to home has been repeated so often it has come to be an accepted truth. Despite this, to our knowledge there have not been any studies to date which have adequately accounted for rates of exposure in drawing conclusions concerning relative crash risk and distance from home. We addressed this gap by using data representative of all travel (from the New Zealand Household Travel Survey) and crashes in New Zealand, by New Zealand drivers, from 1 July 2013 to 30 June 2014. Trip origins, destinations and driver home address were used to convert 31,102 trips into travel exposure on roads at increasing distance from home. Travel data were compared with crash distance from home for 6,295 injury crashes involving 9,315 drivers. Analysis showed that on average, drivers were indeed more likely to crash close to home. Roads within 11 km (6.8 miles) of home accounted for half of all travel and 62% of all crashes. The 'close to home' effect held for male and female drivers. Novice (learner) drivers were the only demographic subgroup to not exhibit the close to home effect. Compared with crashes further away, crashes close to home were more likely to involve alcohol and diverted attention, and less likely to involve driver fatigue. These findings provide a mandate for continued investigation into the science of typical, everyday driving. We contend that behavioural effects associated with driving on familiar roads may be a factor in injury crash risk for experienced drivers.

1. Introduction

It is a widely accepted truism that drivers are more likely to crash on roads close to home. Insurance industry reports have stated that 99% of crashes occur within 50 miles (approx. 80 km) of home (CalculateMe, 2015); 77% of crashes take place within 15 miles (24 km) of home (Driving Today, 2015); and that one third of crashes happen within one mile (1.6 km) of home (Telegraph, 2015). One interpretation of the increased crash risk associated with roads close to home is drivers' familiarity and overconfidence on these roads. For example, studies have shown that drivers are more likely to experience mind wandering, or driving without awareness on familiar roads (Burdett et al., 2016; Charlton and Starkey, 2013; He et al., 2011; Martens and Fox, 2007; Yanko and Spalek, 2013) leading to an increase in unsafe driving behaviours including altered visual search (He et al., 2011; Martens and Fox, 2007) and inattentional blindness (Charlton and Starkey, 2013).

The insurance industry reports of the 'close to home' effect have been used to encourage drivers to remain vigilant on familiar roads (Driving Today, 2015), but the data collection and analysis methods that lie behind the reports are not typically reported in any detail except to state that they are from insurance records that link crash location with an insured driver's home address. In fact, there have been very few systematic analyses of the crash risk associated with familiar roads (Brown et al., 2016). Given the possible road safety implications of a close to home effect (elevated crash risk on roads close to a drivers' home), more rigorous analyses are needed to investigate this phenomenon.

More robust analyses of the spatial distribution of crashes have shown that crash risk varies for reasons as diverse as policy environments (Andrey, 2010) and fuel prices (Chi et al., 2013). Regarding proximity to one's home, Steinbach et al. (2013) analysed crash distances (from home) for different modes of transport, studying social and geographic differences. A 'crow flies' distance between geocoded crash locations, and the centroid of the crash victim's home postcode was calculated for each crash. The median crash distance from home for car occupants was 8.3 km (5.2 miles) for injuries in rural areas and 2.8 km (1.7 miles) in urban areas. Overall, 53% of injured car occupants were in crashes within a 5 km (3.1 mile) radius of their home, with male drivers somewhat further from home than females. Steinbach et al. (2013) concluded that people from "more deprived and urban areas" (p6) were relatively more likely to be involved in crashes close to their home.

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McGwin and Brown (1999) studied the relationships between driver age and a range of crash characteristics including distance from home. Their analysis of all police-reported crashes in Alabama in 1996 (n = 136,465) revealed differences in crash type by driver age. For example, younger drivers (aged 16–34 years) showed higher proportions of crashes involving fatigue; middle-aged drivers (aged 35–54 years) were relatively more likely to crash at night; and older drivers (aged 55 years and over) were more likely than other age groups to have 'illness' listed as a crash causal factor. Pertinent to the present topic, most crashes happened within 25 miles (40 km) of the driver's home, a finding that was most prevalent for younger drivers (87.2% of crashes), followed by older (83.2%) and middle-aged (82.0%) drivers (McGwin and Brown, 1999). Similarly, a study of child injuries found that 95% of trips in which children were injured happened within one hour's drive of home (Chen et al., 2005). Although the distribution of trip length for incident-free trips was not provided for this study, crashes were associated with "usual driving circumstances rather than unusual circumstances" (Chen et al., 2005, p222).

While these studies have analysed where crashes happen relative to drivers' homes, they have fallen short of providing strong empirical support for the close to home effect because they did not account for the higher exposure drivers have to roads close to their homes. This limitation was acknowledged by the authors of these studies with Steinbach et al. (2013) stating that "exposure is a likely mechanism" (p5) to explain the high proportion of crashes close to drivers' homes, and McGwin and Brown (1999) acknowledging that having "no other information on driving patterns and exposure" (p195) was a limitation of their research. Thus, the high proportion of crashes occurring close to home may simply be because this is where we drive most frequently.

One important component of exposure to risk is the proportion of travel on urban and rural roads. Analysis of crash rates (per vehicle-kilometre travelled) shows that for highly motorised countries, injury crashes are far more likely on urban than on rural roads (Elvik et al., 2009). For example, the crash rate on urban access roads is 2.4–7.1 times higher than the rate on rural main roads (excluding motorways, which have the lowest crash rate of all types) in countries such as the Netherlands, United Kingdom and the USA (Elvik et al., 2009). Similarly, in New Zealand crashes on urban roads are more likely. Data from 2011 to 2015 inclusive show that urban roads carry 44% of vehicle kilometres travelled (VKT) in New Zealand, but have 49% of fatal and serious crashes, and 61% of all injury crashes. In other words, the overall odds ratio is approximately 2.0, that is, an injury crash is twice as likely per 100 M VKT on urban compared to rural NZ roads and fatal and serious injury crash risk is 1.25 higher on urban roads.

Elvik et al. (2009) suggested that reasons for this increased risk on urban roads may include factors such as higher numbers of pedestrians and a higher proportion of intersections. It must be pointed out, however, that most trips are close to home in their entirety as drivers travel to and from work, school, shopping and other routine trips. If a close to home effect can be seen within the range of everyday travel such as this, then another explanation (beyond the increased risk posed by urban access roads) must be considered. For example, it may be that factors associated with driver inattention also contribute to the increased risk on urban roads.

A suitable measure of exposure is needed to investigate whether a close to home effect exists, whether or not such an effect is wholly related to urban and rural differences in risk. Vehicle-kilometres travelled is often considered the most appropriate measure of exposure (Eksler, 2010; Newstead and D'Elia, 2010), but these data are not often available so proxy measures or alternative analyses (such as comparisons within certain crash types) have been used instead (Cercarelli et al., 1992; Jiang and Lyles, 2011). Recently, Brown et al. (2016) attempted to account for exposure by comparing crash distance from home to trip length for home based and non-home based travel. Their analysis of crashes (from 2007 to 2012) and travel (from the 2009 National Household Travel Survey) in South Carolina revealed that approximately 35% of crashes were reported within five miles (eight kilometres) of home, but over 45% of trips were five miles or less. They concluded that "the probability of being involved in a fatal or injury crash is lower for trips closer to home" (p13).

Whilst the conclusions the authors reach reflect the findings of their analyses, there are two potential flaws in their approach that raise questions. First, the dichotomous classification of trips as home based or non-home based does not provide an accurate indication of distance from home. By way of example; a trip commencing as little as 0.2 km from home would be classed as a non-home based trip, as would a trip commencing 200 km from home, yet in the first example drivers would actually be travelling on roads close to home. To address this the origin and destination of each trip is required in the calculation of distance from home for all trips. Second, using the total trip length for the analyses does not correctly account for exposure. To accurately derive the overall distribution of drivers' travel on roads at increasing distance from home, the distance from home for each kilometre travelled must be calculated (regardless of the trip origin or trip destination). For example, a three kilometre journey from home to the shops includes travel at zero, one and two kilometres from home. A two kilometre trip commencing one kilometre from home includes travel at one and two kilometres from home. Thus trip length, as used by Brown et al. (2016) does not accurately represent a drivers' exposure to roads close to home and cannot inform us about the existence of a close to home effect.

As well as the challenges associated with accurately accounting for exposure, limitations from previous studies of crash distance from home also need to be addressed. These include pinpointing drivers' home addresses and crash location with reasonable precision. There are also issues with the method of calculating crash distance from home which has typically been based on distance as the 'crow flies' rather than distance by road (e.g. Steinbach et al., 2013).

To address the methodological challenges of earlier studies, we used national household travel survey data to derive the distribution of travel distances from home. We compared these travel data to a comprehensive record of crash distances from home for New Zealand drivers to determine whether a close to home effect was present for New Zealand drivers. By carefully calculating travel distances from home for each kilometre of a trip (rather than trip length alone) and comparing the distributions of both travel and crash distances we hoped to present a relatively unbiased accounting of crash likelihood controlling for exposure at increasing distance from home.

Our exploration of a close to home effect is considered in the knowledge that New Zealand drivers are likely to face increased risk of involvement in an injury crash on urban roads. Given that most New Zealanders live in urban areas, heightened risk on roads close to home seems likely. The following research questions were addressed:

(1) Is there a 'close to home' effect in road crashes: are injury crashes over-represented on roads close to home relative to drivers' amount of travel on those roads?
(2) Does the relationship between crash and travel distance from home vary by driver age, gender or driving experience?
(3) Do the causal factors of crashes differ by distance from home?
(4) If there is a close to home effect, is it likely to be explained by a higher proportion of travel on higher risk urban roads close to home?

2. Methods

The study rationale and methods were reviewed by the Research and Ethics Committee of the School of Psychology, University of Waikato. Using travel and injury crash data, the study aim was to find out whether drivers are relatively more likely to crash closer to home than further away, even if a large proportion of their travel is on roads near where they live. Travel data were extracted from the New Zealand Household Travel Survey (NZHTS) for the survey year 2014 (1 July 2013 – 30 June 2014 inclusive). The NZHTS employed a representative sampling technique to estimate the entirety of household travel behaviour throughout New Zealand for the entire year. The survey data included all trip origins and destinations for New Zealand drivers of cars, vans and SUVs, and included driver age, gender, licence status and home address. Household Travel Surveys are routinely used for road safety research to estimate exposure (Beck et al., 2007; Christie et al., 2007; Lee et al., 2014; Moeinaddini et al., 2015; Trowbridge and Kent, 2009).

The crash data were all reported injury crashes involving drivers (of cars, vans or SUVs) with a known home address in New Zealand, from 1 July 2013 to 30 June 2014. As well as crash location the data included driver age, gender, licence status, home address, and information about crash causal factors (such as alcohol, inattention or fatigue).

Travel and crash data from a six-month period in 2008 were also analysed to verify whether the travel distribution for crash-involved drivers was different from drivers not involved in crashes. This analysis could not be conducted on the 2014 dataset because questions about previous crash involvement were excluded from the NZHTS after 2009.

2.1. Travel data

The travel data were derived from all trips made by drivers as part of the NZHTS from 1 July 2013 to 30 June 2014 (n = 31,102 trips). Data for this study included every unique trip made by a driver of a car, van or SUV. Each driver in the survey recorded all of their travel for a 24-h timeframe within the study period. Across the entire sample, all days of the calendar year were included. A unique trip was one where there was no change of purpose. For example, a journey from home to a shop to a workplace was coded as two separate trips. For each trip, the driver's home address, trip length in kilometres, trip origin and destination were recorded. NZHTS data includes weightings to account for both non-response and variability in response rates around New Zealand. These weightings were used to convert the sample data to an estimate of all travel by New Zealand drivers over the survey period.

To derive travel data, each trip was divided into kilometre distances from home driven. Where a trip origin or destination was the driver's home (70% of trips; n = 21,717) the trip length as stated in the survey data was used as the trip distance from home. For example, a three kilometre trip starting at the driver's home comprised one kilometre of travel at each of zero, one and two kilometres from home.

For cases where a trip did not start or end at the driver's home (30% of trips; n = 9,385), the shortest distances by road from the trip origin and destination to the driver's home were calculated using an algorithm based on Google Maps®. The difference between these two locations was used to calculate the amount of travel at different distances from home. For example, a trip from a driver's workplace at three kilometres from home to a shop at five kilometres from home was assumed to comprise one kilometre of travel at three kilometres from home, and one kilometre of travel at four kilometres from home.

To calculate proportions of travel at each kilometre from home, outliers (travel on roads farther than 400 km from home; 6.1% of all travel) were excluded. The independent variables associated with travel data that were included in this analysis were driver gender, age (<25 years, 25–50 years, >50 years), and licence status (learner, restricted or full licence).

2.2. Crash data

The crash data included all reported injury crashes that happened in New Zealand from 1 July 2013 to 30 June 2014, by drivers of cars, vans or SUVs (excluding taxis), where at least one driver involved had a known home address in New Zealand. The crash data were extracted from New Zealand's Crash Analysis System, which includes details of all crashes reported to the police. Drivers' home address, gender, licence status and age at the time of the crash were extracted along with crash location.

The focus of the analysis was restricted to injury crashes as non-injury crashes are known to be greatly under-reported. Although police-reported crashes are rarely a complete dataset of all crashes, this is particularly the case for non-injury crashes in New Zealand, where no form of vehicle insurance is mandatory.

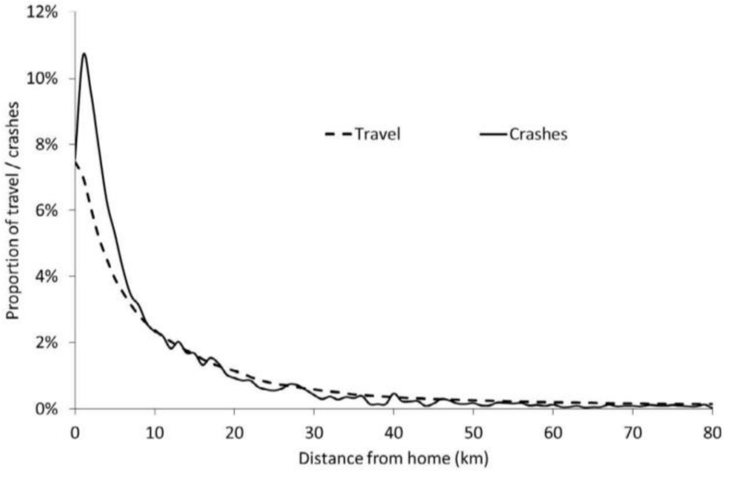

Fig. 1. Proportions of travel and crashes at increasing distance from home.

Outliers (crashes on roads farther than 400 km from home; 1.6% of all crashes) were excluded. A total of 6,295 injury crashes involving 9,315 drivers were analysed. For each driver involved, the crash distance from home by road was calculated.

3. Analysis

To determine whether crashes were over-represented on roads close to home, frequency distributions of travel and crashes on roads at increasing distance from home were plotted. Differences between mean travel and crash distance from home were analysed with Welch's *t*-test and verified with a non-parametric Mann-Whitney *U* test. There was no noteworthy difference in the conclusion from parametric and non-parametric test results for analysis of travel and crash distance from home, therefore only Welch's t-tests were reported for the remaining analyses.

Frequency distributions and differences between means were also compared by gender, age (<25 years, 25–50 years, >50 years) and driver licence status (learner, restricted or full licence). For New Zealand drivers, a learner licence requires supervision during all driving, whereas a restricted licence allows solo driving between 5 am and 10 pm. Travel distances from home were also compared to crash distance from home separately for two crash outcome severity groups (minor vs fatal and serious injury).

Crash causal factors were analysed to determine whether some crash types are relatively more prevalent on roads close to home. Differences in the proportions of crashes involving diverted attention; alcohol; fatigue and inattention, for solo-vehicle crashes within 5 km of home and beyond 30 km from home, were compared with chi-squared tests of independence. Only solo-vehicle crashes were compared, due to difficulties assigning causal factors to a specific driver involved in a multiple-vehicle collision.

To determine whether or not drivers involved in crashes had different travel behaviour to drivers not involved in crashes, travel distributions for these groups (using data from the 2008 NZHTS, as explained earlier) were plotted and means compared with *t*-tests. All *t*-tests were Welch's two-tailed tests for independent samples.

4. Results

The proportions of travel and crashes at increasing distance from home are presented in Fig. 1. As the figure shows, compared to where drivers travelled, crashes were over-represented on roads close to home with half of all injury crashes occurring within 7 km of home while half of all travel occurred on roads within 11 km of home. Descriptive data for crash and travel distance from home and for trip distances are shown in Table 1. As can be seen in the table the mean for each group is larger than the median, reflecting the positive skew of the data and the proportion of travel that happens on roads that are a considerable distance from drivers' homes. As shown in the table, the mean crash distance from home (25.3 km) is lower than mean travel distance from home (38.7 km). A Welch's *t*-test comparing mean travel and crash distance from home revealed that this difference was significant ($t(9{,}314.01) = 24.11$, $p < .001$, $d = .22$); this finding was replicated with the non-parametric test ($U = 1.3 \times 10^{14}$, $p < .001$, $r = .13$). Therefore, drivers are more likely to crash close to home when exposure is accounted for.

4.1. Age, gender and driving experience

The travel and crash distance from home for males and females are shown in Fig. 2 (as well as Table 1). Analyses showed that males drove significantly farther from home than females ($t(3.01 \times 10^{10}) = 17{,}580.66$, $p < .001$, $d = .20$) and crashed farther from home than females ($t(8{,}657.27) = 2.64$, $p = .008$, $d = .06$). For males the mean crash distance from home was significantly lower than the mean travel distance ($t(5{,}293.00) = 23.09$, $p < .001$, $d = .27$); a similar significant difference between crash and travel distance from home was also observed for females ($t(4{,}005.00) = 8.52$, $p < .001$, $d = .13$).

Table 1
Descriptive statistics for crash and travel distance from home by driver group, and overall trip distance.

	n	Mean (km)	Standard deviation (km)	Median (km)
Crash distance from home	9315 crashes	25.3	53.8	7
Males	5294	26.5	54.0	8
Females	4006	23.6	53.6	6
<25 years	2678	26.3	54.0	8
25–50 years	3990	23.0	49.5	7
>50 years	2647	27.6	59.5	7
Full licence	6557	25.6	54.3	7
Restricted licence	1334	23.6	49.0	7
Learner licence	559	20.2	47.2	6
Travel distance from home	3.2×10^{10} vehicle-kilometres/year	38.7	67.5	11
Males	2.0×10^{10}	43.7	71.8	13
Females	1.3×10^{10}	30.8	59.1	8
<25 years	3.3×10^{10}	41.3	75.9	10
25–50 years	1.7×10^{10}	41.1	72.6	11
>50 years	1.2×10^{10}	34.5	56.3	12
Full licence	3.1×10^{10}	39.0	67.2	11
Restricted licence	1.4×10^{9}	39.7	77.9	9
Learner licence	1.8×10^{8}	9.1	14.4	4
Trip distance	31,102 trips	9.8	20.1	4

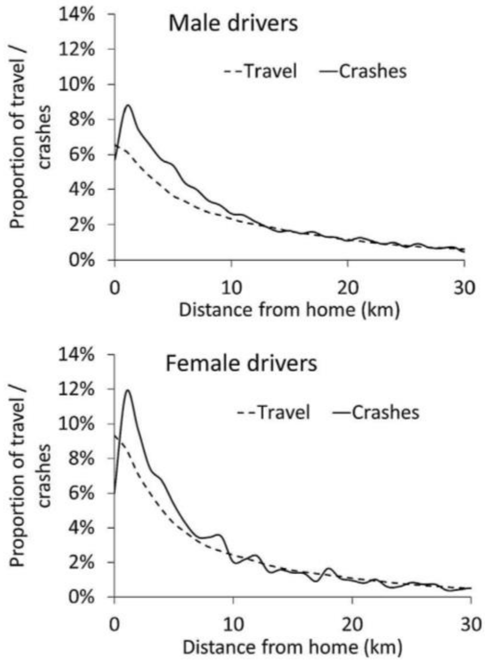

Fig. 2. Proportions of travel and crashes at increasing distance from home for male (top) and female drivers.

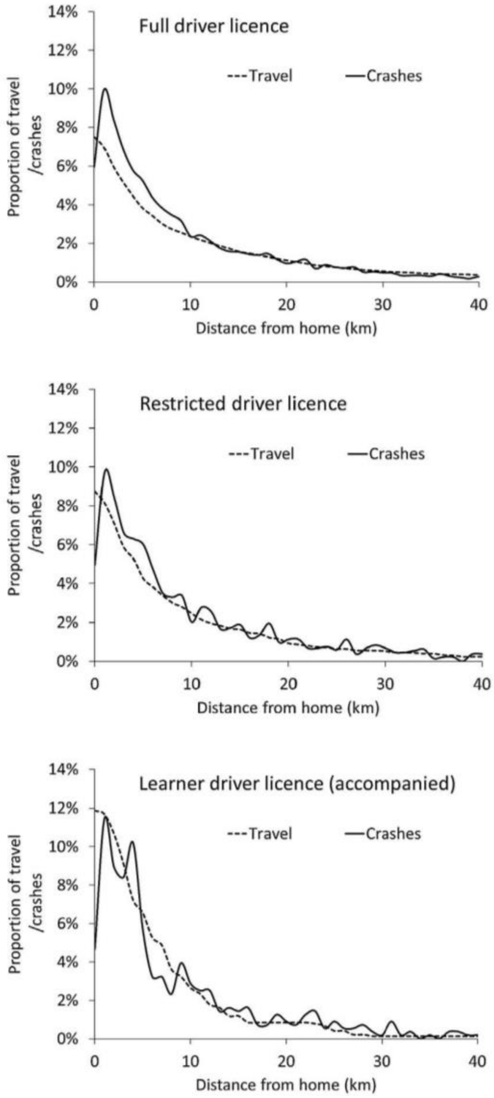

Fig. 3. Proportions of travel and crashes at increasing distance from home for drivers with different graduated licences: Full (top), Restricted (middle) and Learner (bottom).

In other words, the close to home effect holds regardless of driver gender. Males and females are both relatively more likely to crash on roads close to home.

Comparison of travel and crash distances from home for different age groups (see Table 1) showed that the close to home effect holds regardless of driver age. Mean crash distance from home for drivers aged under 25 years (26.3 km) was significantly lower than mean travel distance (41.3 km; $t(2,677.01) = 14.39$; $p < .001$; $d = .23$). Drivers aged 25–50 years also crashed significantly closer to home (23.0 km) than they travelled (41.1 km; $t(3,989.00) = 23.09$; $p < .001$; $d = .29$). The close to home effect also held for drivers aged over 50 years, whose mean crash distance from home (27.6 km) was significantly lower than mean travel distance (34.5 km; $t(2,646.00) = 6.01$; $p < .001$; $d = .12$).

Fig. 3 shows travel and crash distances from home for three groups of drivers, using graduated driver licence status as a proxy for experience. Drivers with a full licence showed a close to home effect similar to the effect for all drivers as their mean crash distance from home (25.6 km) was lower than their mean travel distance from home (39.0 km). This difference was significant ($t(6,556.00) = 19.96$, $p < .001$; $d = .22$). The close to home effect also held for drivers with a restricted licence (who are permitted to drive solo within certain restrictions concerning time of day and number of passengers). On average, restricted drivers crashed significantly closer to home (23.6 km) compared to how far they travelled (39.7 km) ($t(1,333.01) = 11.94$; $p < .001$; $d = .25$). However, drivers with a learner licence did not show a close to home effect. Learner drivers' mean crash distance (20.2 km) was significantly further than mean travel distance from home (9.1 km) ($t(558.00) = 5.55$; $p < .001$; $d = .32$).

4.2. Crash severity and causal factors

Fig. 4 shows travel distance from home compared to crashes of different severity (minor injury vs fatal or serious injury crashes). The average distance from home for minor injury crashes was 24.1 km, somewhat lower than the average distance from home for fatal and serious injury crashes (30.7 km) ($t(2,202.01) = 4.12$, $p < .001$, $d = .12$). Regardless of crash severity, however, injury crash distance from home was significantly lower than the average overall travel distance (38.7 km) [minor crashes $t(7,678.01) = 24.41$, $p < .001$, $d = .24$; fatal and serious crashes $t(1,635.00) = 5.44$, $p < .001$, $d = .13$)].

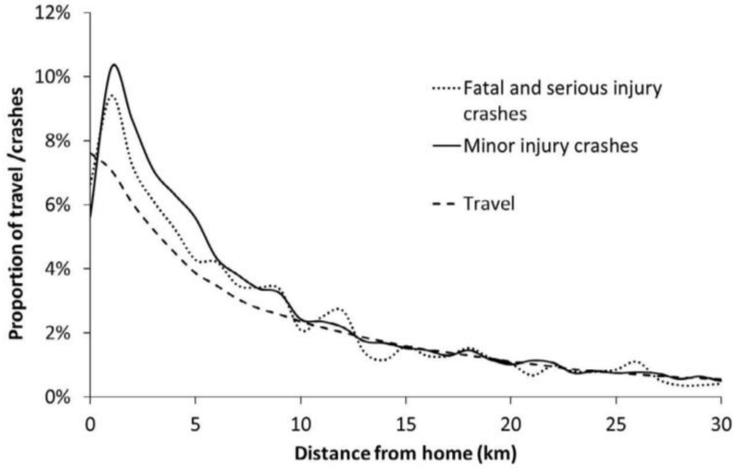

Fig. 4. Proportions of travel and crashes at increasing distance with crashes separated by severity of outcome (minor injury vs fatal or serious injury).

Fig. 5 shows the proportion of solo vehicle crashes with different causal factors within 5 km of home, and beyond 30 km from home. A significantly higher proportion of crashes involved alcohol ($\chi^2(2, 2835) = 51.81$, $p < .001$) and distraction ($\chi^2(2, 2,835) = 25.15$, $p < .001$) within 5 km of home compared to beyond 30 km of home. "Distraction" is assigned at the scene of a crash in New Zealand when attention is likely to have been diverted by some overt distraction such as a mobile phone, food or the actions of a passenger in the vehicle. There are significantly lower proportions of crashes involving fatigue on roads within 5 km of home ($\chi^2(2, 2,835) = 27.93$, $p < .001$) as compared to over 30 km from home. Crashes involving driver inattention show no significant difference on roads within 5 km from home compared to further away ($\chi^2(2, 2,835) = 1.73$, $p = .188$).

4.3. Travel of drivers reporting crash involvement

A comparison of travel behaviour for drivers reporting crash involvement was compared to drivers reporting no crashes in the previous two years. Drivers reporting crash involvement drove, on average, significantly closer to home (mean = 35.3 km) than drivers reporting no crash involvement (mean = 37.9 km; $t(3.27 \times 10^9) = 2,163.33$, $p < .001$, $d = .04$). However, the difference in travel distance from home between these groups was not large (2.6 km) compared to the difference in crash distance from home (mean = 21.9 km for 2008 crash data). The distributions of travel distance from home for drivers involved and not involved in crashes, alongside crash distance from home, is shown in Fig. 6.

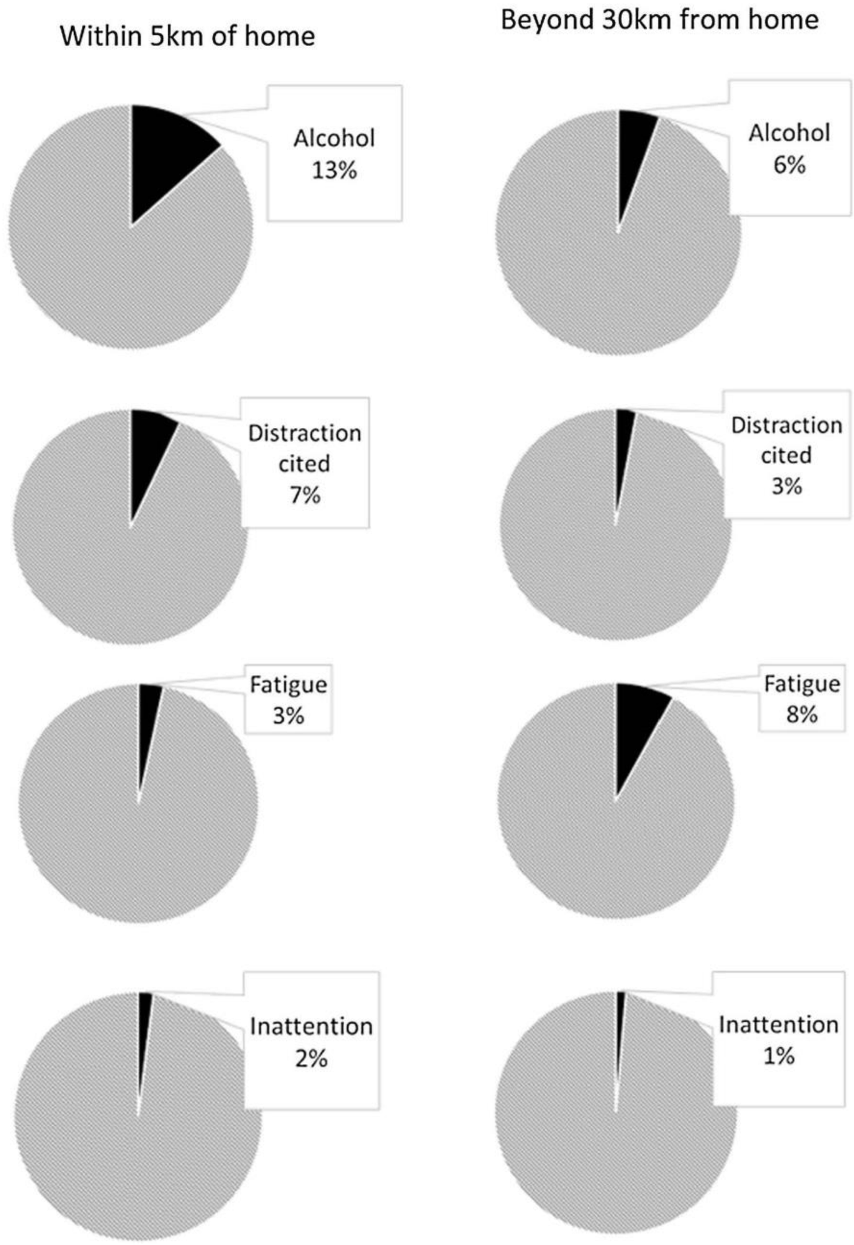

Fig. 5. Proportions of solo-vehicle crashes with different causal factors, within 5 km of home (left) and beyond 30 km from home (right).

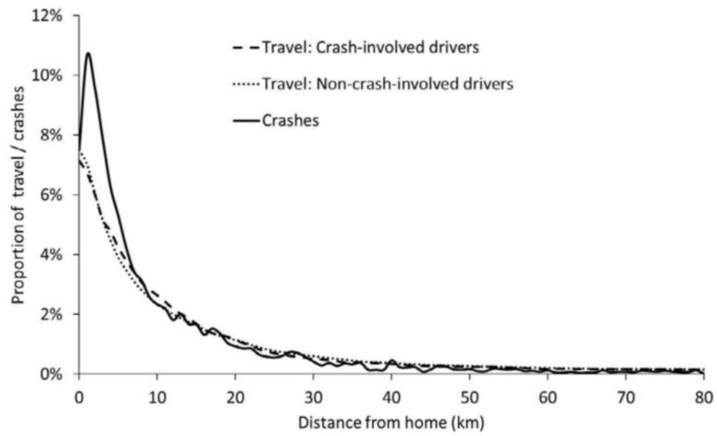

Fig. 6. Travel distance from home for drivers reporting crash involvement and no crash involvement, compared to overall crash distances from home.

5. Discussion

At the outset of this investigation we posed the question of whether the anecdotal reports of an increased crash risk on roads close to home (the close to home effect) were true once drivers' travel exposure on these roads was carefully accounted for. The short answer to this question is yes, there is indeed a significantly higher crash risk when driving on roads close to home. The study addressed limitations of previous analyses of crashes and drivers' home locations due to the availability of large, comprehensive crash and travel datasets for representative samples of drivers. These data included precise home, trip origin, trip destination and crash locations as well as driver age, gender and licence status. The ability to compute exposure at increasing distance from home, accounting for travel including for trips that did not start or finish at home, was also an important component of this study.

The close to home effect (higher crash likelihoods closer to home) was obtained across all levels of injury crash severity. Further, the relationship held for both male and female drivers, although men drove somewhat further and crashed somewhat further away from home. For New Zealand drivers as a whole, 50% of reported injury crashes happened within 6 km of home, a similar distance from home as reported previously. Steinbach et al. (2013), for example, found a median crash distance from home of between 2.8 km (urban areas) and 8.6 km (rural areas).

The most obvious reason for the existence of the close to home effect appears to be exposure to risk on urban vs rural roads. Although we could not calculate an absolute difference in risk at different distances from home or on different types of roads, the results do suggest that like other highly motorised countries, New Zealand drivers face higher risk on urban roads. This is because crashes are over-represented relative to travel on roads close to home; and most drivers live within a network of urban roads.

As well as confirming a close to home effect that is probably linked to urban/rural differences, the fact that the effect was apparent for all demographic subgroups except novice drivers supports the idea that urban crash risk close to home may be related to behavioural effects associated with driving without awareness and inattention blindness, which are more likely on well-practiced routes (Charlton and Starkey, 2013; He et al., 2011; Martens and Fox, 2007; Yanko and Spalek, 2013). This adds to knowledge about risk on urban roads, suggesting that as well as increased exposure to inherently risky environments (such as an abundance of intersections and roving pedestrians), part of the risk associated with driving in familiar but complex urban environments may be a higher prevalence of inattention blindness.

Analyses of different factors related to solo-vehicle injury crashes revealed that diverted attention and alcohol both feature more prominently in crashes close to home, whereas fatigue is more likely to be cited in crashes further than 30 km from home. It may be that on everyday journeys close to home, drivers are more likely to extend their daily habits into their drive; as famously observed by Tillmann and Hobbs (1949): "a man drives as he lives" (p329). It is conceivable, for example, that drivers are more likely to use a mobile phone, or eat their lunch on roads close to home without actively considering the potential impact of their behaviour on their crash risk. Conversely, on a long drive or in a less familiar environment, drivers may be more likely to prepare for their journey by ensuring that their mobile phone is out of reach, or that they stop for a meal instead of eating 'on the run'.

In a similar vein, those who consume alcohol may be less likely to drive if they are far from home in relatively unfamiliar circumstances; their sense of 'knowing the road' or the fact that they are not far from home may result in relatively unsafe driving behaviour. While it may be the case that urban roads are inherently more risky than rural roads (Elvik et al., 2009), and thus contribute to the close to home effect, the crash risk close to home in our data was observed to increase so quickly so as to suggest that the risk increases even before the driving environment changes. In other words, many of our daily trips are short and entirely within the urban area, and the elevated crash risk was found to occur within the likely bounds of these short trips. This means that other factors (in addition to driving environment) may contribute to the increased crash risk; factors such as the increased likelihood of unsafe driving behaviour. Looked at another way, it may even be the case that these unsafe behaviours close to home contribute to the elevated risk associated with urban access roads.

The higher prevalence of fatigue on roads further from home may be related to the effect of longer trips. Although not all driving on roads close to home is on short trips (it may be at the end of long trips, for example) it is nevertheless the case that a high proportion of any long trip will take place on roads relatively far from home. For example, a journey between home and a destination 100 km away involves only five percent on roads within 5 km of home. Therefore, if fatigue is more likely on long trips, then it is unsurprising that fatigue is more often a causal factor in crashes some distance from where drivers live.

The lack of significant difference in crashes involving inattention on roads close to and far from home is probably due to the inherent difficulties in 'diagnosing' inattention at the roadside (Beanland et al., 2013). Measurable factors such as blood-alcohol, and observable behaviours such as mobile phone use are much easier to code in a traffic crash report than the covert nature of a driver's attentional focus in the instant preceding a crash. Although it is generally suspected that inattention plays a role in crash outcomes, difficulty pinpointing its occurrence is strong rationale in itself to explore the nature of attention during driving using methods other than simple analysis of crash causal factors.

Perhaps the main unanswered question remaining from this study is the issue of absolute risk for an individual relative to their home, which could not be calculated because of the diverse nature of New Zealand's road network and the myriad of factors known to affect crash risk. One important factor known to affect injury crash risk in particular is travel speed (Elvik, 2013). While the analysis demonstrates a generally increased risk close to home (which is likely explained to some extent by increased exposure on urban roads), no attempt to calculate absolute risk on specific segments of the network was possible with these data. Future analyses using road-specific exposure data could go some way to addressing the issue of where the close to home effect manifests, and why.

Non-injury crashes were excluded from the present analysis. It is possible that there are different relationships between crash risk and distance from home for non-injury crashes. However, these crashes are known to be significantly under-reported, particularly in New Zealand. Current crash data collection methods do not allow for any meaningful analysis of non-injury crashes in terms of their geospatial distribution.

As well as differences between urban and rural areas, there were other limitations due to the nature of the crash and travel data. There was no analysis of trip purpose; of drivers at fault; of crash types such as single vs multiple-vehicle crashes, or crashes on different types of roads such as single or multi-lane roads. It was also impossible to tell from these crash data whether crashes close to home are more likely on short trips (from home to the local shops, for example) or at the start or end of longer trips. As noted by Hauer (1995), over-representation of crashes by itself "has no discernible logical link to funding, programming, decision or action" (p138). The relationship between exposure and risk at increasing distance from home is complex, and worthy of further investigation.

6. Conclusion

To our knowledge this is the first study to confirm a close to home effect for road crashes whilst accounting for exposure. It provides insights into the role of inattention in driving, particularly for experienced drivers on familiar roads close to home, and adds to understanding about factors affecting increased risk on urban roads. However, the relationship between familiarity, vigilance and crash risk warrants further research. Naturalistic studies that capture travel exposure and crashes, as well as some measure of familiarity, may help to address these issues. The study's conclusion was made possible through analysis of large and comprehensive travel and crash databases. The close to home effect could be productively considered by transport researchers and practitioners, and those involved in road safety education.

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Study Four: Characteristics of the Close to Home Crash

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Characteristics of the close to home crash

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ABSTRACT

Crashes are over-represented on roads close to home, but it is not clear why. We sought to address this gap by exploring the characteristics of close to home crashes. We used twelve months of crash data that included driver home address, and travel survey data captured over the same period to group crashes based on equivalent amounts of travel at different distances from home, controlling for exposure. We compared crashes on high-speed (rural) and low-speed (urban) roads; crashes caused by different types of error (lapse and violation); and crashes at major intersections (roundabouts and traffic signals), minor intersections (priority intersections and driveways), and midblocks; to find out which road type, error type, and locations were most common in crashes on roads close to home. Findings revealed that crashes over-represented close to home were on low-speed (urban) roads; were more likely to involve lapses of attention than violations; and that crashes related to lapses of attention on low-speed roads were more common at minor intersections and mid-blocks than at major intersections. Although drivers may be most likely to consider busy intersections risky and worthy of effortful focus, these results show that seemingly safe, slow streets and minor intersections account for a surprisingly high proportion of crashes overall, particularly on familiar urban roads close to home. The interplay of drivers' attentional regulation with momentary driving demands, and risk is complex and worthy of continued investigation.

1. Introduction

A high proportion of road crashes happen close to home. Motor vehicle insurance reports have stated that one third of crashes happen within one mile (1.6 km) of home, for example (Telegraph, 2015); and 77% of crashes are within 15 miles (24 km) of home (Driving Today, 2015). More rigorous research has also reported that crashes are common close to home. Steinbach et al. (2013) found that 53% of injured car occupants were within a 5 km (3.1 mile) radius of their home when they crashed, and a study of child injuries found that 95% of trips in which children were injured happened within one hour's drive of home (Chen et al., 2005). None of these studies accounted for exposure, so with this evidence alone, the high proportion of crashes close to home might just be because most driving happens near where we live.

To address this gap, we recently conducted a study to investigate the close to home effect in road crashes whilst accounting for exposure. We calculated distance from home for each kilometre (0.6 mile) travelled across 32,102 trips from New Zealand's household travel survey, and compared the resulting distribution to that of crash distance from home for all reported injury crashes in the same period. Our results showed that in New Zealand, crashes are over-represented compared to travel on roads within 11 km (6.9 miles) of where drivers live (Fig. 1; Burdett et al., 2017). The mean crash distance from home was 25 km (15.6 miles) whereas the average (mean) distance travelled was 38 km (23.8 miles) away. The means were affected by positive skew in the travel and crash data (a lot more travel and crashes happened on roads closer to home than further away), so medians were much lower: half of all travel was on roads within 11 km (6.9 miles) of home, whereas the median crash distance from home was 7 km (4.4 miles). Therefore, the high proportion of crashes close to home is not solely related to exposure.

At this point it is unclear why crashes are over-represented compared with travel on roads close to home. One possibility is that it is due to the types of roads we encounter close to where we live. In highly motorised countries, crash risk is highest per kilometre travelled on *urban* roads (excluding urban motorways), based on analysis of high income countries in Europe and North America (Elvik et al., 2009). This is seemingly implausible as urban roads are relatively low-speed, and we tend to think that higher speed roads generally result in higher crash risk (Aarts and van Schagen, 2006). However, urban roads also have higher traffic volumes, and more pedestrians, cyclists, and intersections than most high speed (rural) roads, so these factors might explain why they are the scene of more crashes overall (Elvik et al., 2009).

If high traffic volumes and an abundance of potential hazards are

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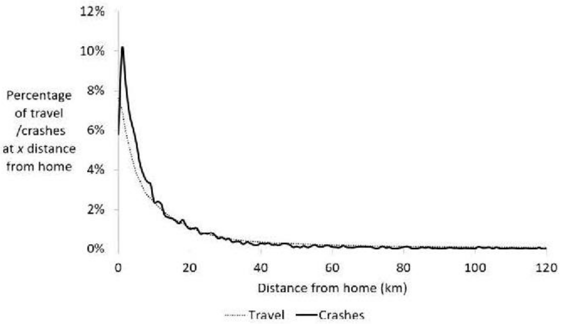

Fig. 1. The percentage of crashes and travel by distance from home. Reprinted from Burdett et al. (2017).

the cause of crashes close to home, we might expect most crashes to occur at busy urban intersections. Traffic volume is one of the main determinants of crash risk (Fridstrøm et al., 1995; Greibe, 2003), so high-volume urban intersections are likely to show relatively high crash rates. The close to home effect may therefore be a consequence of driving through busy intersections, where the demands of driving can exceed a driver's momentary capacity.

It is possible, however, that attention regulation in response to driving demands might also contribute towards high crash rates close to home, but at places of low demand rather than high demand. Driving rapidly becomes habitual with practice, so in undemanding places drivers might not be paying much attention to the driving task (Charlton and Starkey, 2013; Gibson and Crooks, 1938; McKenna and Farrand, 1999). After travelling the same route many times, drivers often report driving without awareness; that is, they have no recollection of the preceding journey (Charlton and Starkey, 2011, 2013; Kerr, 1991). When any activity is repeated so often as to become proceduralised, task-unrelated thoughts (ie, mind wandering) are also much more likely to surface and be maintained (Mason et al., 2007; Smallwood and Schooler, 2015).

Some consequences of mind wandering during driving are that drivers' gaze patterns are narrowed (He et al., 2011) and reaction times increase (Yanko and Spalek, 2013). Mind wandering is also associated with inattentional blindness (Charlton and Starkey, 2011), and reduced subjective engagement in the driving task (Martens and Brouwer, 2013). Familiarity with the driving task generally is known to result in failure to notice changes in the road and roadside environment (Harms and Brookhuis, 2016; Martens, in press; Martens and Fox, 2007). Research has suggested that familiarity may be a risk factor in driving (Intini et al., 2018), although crash patterns close to home are yet to be analysed in depth. It is possible that the close to home effect is related to driving on familiar, undemanding urban midblocks and through minor intersections, where drivers occasionally fail to react in time to uncommon hazards because they allow their minds to wander and are not consciously engaged in the driving task.

One approach to investigating the interaction of attentional regulation and driving demands is by studying the types of errors involved in crashes in different driving environments (major intersection, minor intersection and midblock). Crashes caused by deliberate but illegal behaviours (i.e., violations) are different from those caused by unintentional errors (i.e., lapses of attention). Violations such as excessive speeding have socio-cultural influences (Reason et al., 1990) and have been correlated with risk-taking personality traits (Parker et al., 1995). Excessive speed may also be linked with familiarity, in that drivers may select faster speeds in familiar environments to minimise their travel time (Colonna et al., 2016; Intini et al., 2017). In contrast, a lapse of attention is an unintentional action or failure to act; it is the outcome when a driving situation exceeds the driver's momentary ability to perceive a hazardous situation, select a suitable course of action and respond in time to avoid a collision (Reason et al., 1990). The idea that violations and lapses are distinct has been confirmed multiple times in different jurisdictions, through analyses of driver behaviour surveys and crash data (e.g. Gregory et al., 2014; Măirean et al., 2017; Stephens and Fitzharris, 2016; Useche et al., 2017).

In New Zealand, police officers attending a crash assign codes to describe likely crash causes, which can then be used in research to distinguish between different errors (Reason et al., 1990). For example, 'showing off' and 'excessive speed' can be defined as a violation. In contrast, a code of 'failure to notice' or 'fail to give way' can be categorised as a lapse of attention (Reason et al., 1990). The distinction between violations and lapses is considered robust enough to compare crash patterns based on different psychological mechanisms involved in drivers' behaviour (Blockey and Hartley, 1995).

This study sought to explore factors underlying the close to home effect. We know that crashes are more common both close to home, and on urban roads, but where on these roads are crashes happening and why? Building on our previous study (Burdett et al., 2017) which demonstrated that the close to home effect exists in spite of higher exposure on roads close to home, we sought to explore differences between crashes that happen close to home compared with further away. If the majority of close to home crashes are happening at major intersections, where driving demands are high, the effect might be the result of high traffic volumes with frequent opportunities for conflict. If crashes are over-represented at relatively undemanding minor intersections and midblocks on roads close to home, the effect might be due to lapses of attention and drivers not applying conscious focus to the task, and therefore failing to react in time when confronted with an unexpected hazard on the road.

We addressed this question in three steps: first, studying whether crashes close to home are relatively more common on low speed urban roads as compared to high speed rural roads; second, exploring what types of errors are most common on urban roads close to home (lapses of attention, vs violations); and third, determining where the resulting crashes happen (major intersections, minor intersections or midblocks). The study involved analyses of crash data, accounting for overall exposure on roads at different distances from home.

2. Methods

2.1. Data sources

2.1.1. Crash data

Crash data were all reported injury crashes that happened between 1 July 2013 and 30 June 2014 inclusive, involving a driver with a full New Zealand licence and known home address in New Zealand ($n = 9105$). The dates were a convenience sample to match travel data collected to account for exposure on roads at increasing distance from home (Burdett et al., 2017). The shortest distances by road between the crash locations and drivers' home addresses were calculated to determine the distribution of crash distances from home. Other information extracted from police crash reports included the posted speed limit at the crash site (to determine if the crash occurred in an urban (low speed: lower than 75 km/h (47 mph) posted speed limit) or rural (high speed: greater than 75 km/h posted speed limit) location); causal factors related to driver error (lapse or violation); and the crash location (major intersection, minor intersection or mid-block). Both single and multiple-vehicle crashes were included, but for crashes with more than one driver involved, the driver assigned as 'role one' by attending police officers was used in this analysis so that each crash was used only once ($n = 3901$).

The posted speed limit at the crash site was recorded for every crash in the sample. The speed limit was used to define each crash as low-speed (posted speed limit < 75 km/h) or high-speed, as a proxy for urban and rural roads, according to a definition used by the New Zealand Transport Agency (2017). Although the proxy does not directly

Table 1
Error categories from crash codes, including example behaviours from Reason et al. (1990).

Category[a]	Factor description from police crash report	Example behaviours (Reason et al., 1990)	'Behavioural type' classification (Reason et al., 1990)
Lapse	Failed to notice	Distracted or preoccupied, realise belatedly that the vehicle ahead has slowed	Slip/lapse
	Failed to give way	On turning left, nearly hit a cyclist who has come up on your inside	Slip/lapse
	Did not see or look	Turn left on to a main road into the path of an oncoming vehicle that you hadn't seen	Slip/lapse
	Attention diverted	Drive with only 'half an eye' on the road while looking at a map, etc	Slip/lapse
Violation	Inappropriate speed	Deliberately disregard the speed limits	Violation
	Showing off	'Race' oncoming vehicles for a one-car gap	Violation

[a] Although not all crashes with a particular code necessarily resulted from a sole type of error, we accounted for ambiguity by excluding all crashes with more than one error code assigned. That is, only crashes with one particular error as the most likely cause were included in analysis of error.

relate to the nature of the road environment as 'urban' or 'rural', New Zealand has relatively few high-speed roads in towns and cities, so the definition was deemed suitable for the current analysis.

A subset of the crashes included cause codes suitable for analysis of contributory errors ($n = 717$), which we defined as either violations or lapses, using categories described by Reason et al. (1990). In contrast to Reason et al. (1990) we grouped lapses and violations under the broad heading 'error' in line with recent convention (e.g. Koppel et al., 2017; Park, 2015; Young et al., 2013). Only factors with the clearest link to an error type were included, which meant that we did not include any driver factors (such as fatigue or illness), or factors that could have either a lapse or violation as the underlying error (such as 'misjudged speed of other vehicle'). While Reason et al. (1990) defined three categories of error, we analysed only violations and lapses because there were few crashes (< 30) with the third category ('dangerous errors') as a sole causal factor; that is, we excluded 'dangerous errors' from the current study.

As summarised in Table 1, factors coded as lapses included 'failed to notice'; 'failed to give way'; 'did not see or look'; and 'attention diverted'. We coded 'inappropriate speed' (excluding 'driving too slowly') and 'showing off' as violations. Only crashes with a single error category assigned were included in this analysis ($n = 717$), to avoid dependence between samples where more than one error was involved in the crash (for example, 'inappropriate speed' and 'failed to notice' in combination). There were enough crashes remaining in the sample to identify significant patterns in the data while providing distinction between different types of errors, so exclusion of crashes with more than one error type was not considered detrimental to the study.

Three groups were defined for analysis of crashes according to the complexity of the road environment where they happened. Roundabouts and traffic signals were defined as 'major intersection'. All other crashes at intersections were defined as occurring at a 'minor intersection', which included priority T-intersections and cross-roads with stop or give-way control, as well as crashes at residential and commercial driveways. All other crashes were classed as occurring at mid-blocks.

2.1.2. Travel data

Travel data were used to account for exposure in the crash data. All trips by fully licenced drivers were extracted from New Zealand's Household Travel Survey for travel recorded between 1 July 2013 and 30 June 2014. A total of 29,479 trips by 4143 drivers with a full licence were converted into kilometres travelled at increasing distance from home. The data included weightings to convert the sample into a representative distribution of travel, accounting for variability in response rates around New Zealand. The resulting distribution of travel distance from home was therefore representative of all travel by New Zealand drivers with a full licence. More information about the data sources is included in Burdett et al. (2017).

2.1.3. 'Distance from home' groups

For this study, three 'distance from home' groups were defined based on the travel data, to form 'Close', 'Middle', and 'Far' groups, each accounting for 30% of all travel by New Zealand drivers. The groups were based on the 30th, 60th and 90th percentile travel distances from home. The first group ('close') included all travel and crashes within 4 km (2.5 miles) of home. The second group ('middle') spanned 13 km (8.1 miles) to include all travel and crashes greater than 4 km but less than or equal to 17 km (10.6 miles) from home. The third group ('far') spanned 103 km (64.4 miles), including all travel and crashes greater than 17 km and less than or equal to 120 km (75.0 miles) from home. Each group accounted for 30% of travel by New Zealand drivers. These three groups were used to see how crash patterns changed with increasing distance from home, and the specific percentiles were selected to avoid outliers (i.e., travel and crashes farthest from home).

Fig. 2 shows the distributions of crashes and travel at increasing distance from home. As explained in Burdett et al. (2017), these data show a close to home effect: there is a higher proportion of crashes than travel on roads within 4 km of home. The vertical lines in Fig. 2 differentiate the three 'distance from home' groups for the current analysis, representing equivalent amounts of travel (30% of travel in each group). The asymmetry and positive skew of the data mean that the distances spanned by each group vary, even though they each represent 30% of all travel by New Zealand drivers. Looking at the number of crashes, the roads closest to home (up to 4 km) account for 37% of injury crashes; the 'middle' group (4–17 km) accounts for 32% of injury crashes, while the 'far' group (> 17–120 km) accounts for 23% of injury crashes. In total, the data account for 90% of all travel and 92% of all crashes.

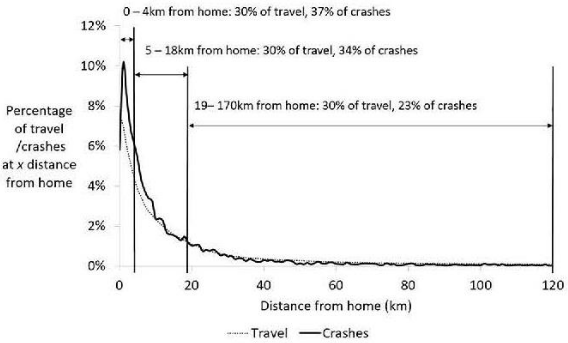

Fig. 2. The percentage of crashes and travel by distance from home. The vertical lines define the close, middle and far distance from home groups, each representing 30% of travel. Adapted from Burdett et al. (2017).

2.2. Analysis

The data were analysed to characterise the circumstances of close to home crashes. All analyses were Chi-square tests of independence, accounting for exposure because the distance from home groups were based on equivalent amounts of travel. Results with $p < .05$ were deemed significant. First, proportions of crashes on low-speed and high-speed roads in each distance from home group were compared to determine whether crashes close to home are more prevalent on low-speed (urban) roads. For low-speed road crashes only, the frequency of different causal errors (lapse/violation) were compared between the distance from home groups. Finally, for crashes involving lapses of attention on low-speed roads only, the proportions of crashes in different road environments (major intersections, minor intersections and midblocks) were compared between those close to home and further away.

3. Results

3.1. Distance from home and road type (high speed vs. low speed)

The relationship between distance from home and speed was tested to find out whether crashes on low-speed roads predominate closest to home. The data in Fig. 3 show that crashes on low-speed roads made up more than half of all reported injury crashes at close and middle distances from home. In the 'far' group, more crashes were on high-speed roads.

A 3 × 2 Chi-square test of independence between 'distance from home' group (close, middle and far) and road type (low-speed/high-speed) showed that crash prevalence is contingent on road type at different distances from home (χ^2 (2, 3691) = 1915.2, $p < .001$). Post-hoc 2 × 2 Chi-square tests showed that crashes closest to home were more prevalent on low-speed roads compared with those at a middle distance from home (χ^2 (1, 2794) = 1716.9, $p < .001$) and farthest from home (X^2 (1, 2337) = 1422.3, $p < .001$). Crashes farthest from home were less likely to be on low-speed roads than those a middle distance from home (χ^2 (1, 2251) = 1841.4, $p < .001$).

3.2. Distance from home and error type

The previous analysis found that most crashes close to home were on low-speed roads, so the relative frequencies of different errors (lapses and violations) associated with crashes on low-speed roads were explored. Proportions of different errors on low-speed roads at different distances from home were compared to determine whether one error type was relatively more common close to home.

The relative prevalence of lapses of attention and violations are shown in Fig. 4. The percentages shown in Fig. 4 are calculated within each 'distance from home' group. Lapses were most common at all distances and declined as a proportion with increasing distance from home, while the proportion of violations increased with increasing distance from home.

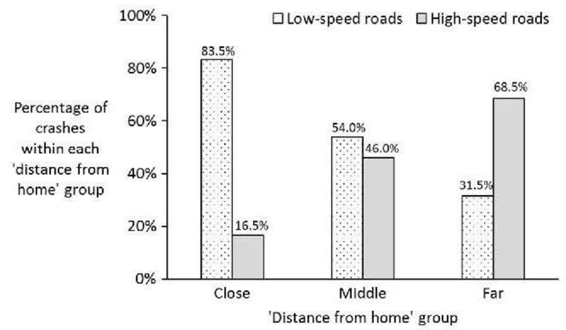

Fig. 3. Percentage of crashes by 'distance from home' group (close, middle or far) and road type (low-speed/high-speed).

Fig. 4. Percentage of crashes by 'distance from home' group (close, middle or far) and error type (lapse or violation), for crashes with a single error assigned.

Differences between the prevalence of each error type at different distances from home were tested with a 2 × 3 Chi-square test of independence, which was not significant (χ^2 (2, 717) = 678.9, $p = .16$). That is, the distribution of error types resulting in crashes on low-speed roads is not contingent on distance from home. Crashes related to lapses of attention are equally common to low-speed roads regardless of distance from home.

3.3. Locations of lapses on low-speed roads

Lapses of attention on low-speed roads were identified as the most prevalent error type on roads close to home, so the final analysis explored the places where lapses of attention happen, comparing crash frequencies at major intersections, minor intersections and midblocks close to home and further away. This analysis was concerned primarily with differences close to home, so 'middle' and 'far' groups were combined for comparison. The data in Fig. 5 show that across these different types of road situation, crashes related to lapses of attention are least common at major intersections, followed by midblocks and minor intersections. Crashes due to lapses at major intersections were the smallest proportion closest to home, whereas lapses at minor intersections were relatively more common close to home.

A 3 (major intersection/minor intersection/midblock) × 2 (close/middle and far) Chi-square test showed contingency between groups (χ^2 (2, 640) = 541.6; $p = .002$); that is, lapses of attention result in crashes at different places close to home compared with further away. Post-hoc 2 × 2 tests to compare prevalence at different road situations between the distance from home groups showed that crashes at major intersections are relatively less likely close to home compared with crashes at minor intersections (χ^2 (1, 434) = 353.8; $p = .002$) and at midblocks (χ^2 (1, 297) = 255.5; $p = .004$). There was no difference in the frequency of crashes at minor intersections and midblocks at different distances from home (χ^2 (1, 549) = 525.4; $p = .24$).

The frequencies of lapses resulting in crashes at different road situations within the closest 'distance from home' group only were tested with a 1 × 3 Chi-square test of independence, which was significant (χ^2 (2, 363) = 145.8; $p < .001$). Overall, most crashes involving lapses of

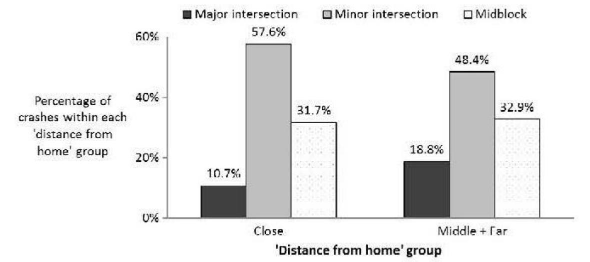

Fig. 5. Percentage of crashes related to lapses of attention on low-speed roads by road situation and 'distance from home' group.

attention on low-speed roads close to home are at minor intersections and midblocks.

4. Discussion

The aim of this study was to explore the characteristics of crashes close to home, which are over-represented (when accounting for exposure) and compare them to crashes further away. We were interested in whether crashes close to home are more likely on low-speed (urban) roads, and whether crashes related to lapses of attention are involved in a high proportion of these crashes.

We analysed relative frequencies of crashes at different distances from home according to posted speed limit as a proxy for urban/rural differences. Crashes on low-speed (urban) roads were most common close to home. At first glance this finding seems to confirm that most crashes happen where most people live, which in urbanised countries such as New Zealand is on low-speed urban roads. To explore the effect further, we looked into different types of error in crashes on these roads. Lapses of attention were the most common error type on low-speed roads at all distances from home. An exploration of the places where lapses of attention lead to crashes on low-speed roads revealed that most of these close to home crashes are at minor intersections and mid-blocks.

In relation to the close to home effect in road crashes, these results suggest that the effect may be due to risk on low-speed urban roads, where many crashes are related to unintentional lapses of attention. Compared to other types of error, lapses are commonly reported on low-speed roads, comprising over three quarters of all crashes (with a sole error assigned) at all distances from home. This suggests that a high proportion of crashes are related to drivers failing to cope with momentary task demands. Relatively few of these crashes happen at busy intersections, where drivers may be occasionally overloaded by an abundance of potential hazards. A higher proportion of lapses of attention result in crashes at relatively quiet places such as at minor intersections and midblocks.

It may seem counterintuitive that on low-speed urban roads, more crashes involving lapses of attention are reported at minor intersections and mid-blocks than at major intersections. However, busy and complex places may be more likely to command drivers' attention. High subjective workload is linked with inhibition of task-unrelated thoughts (Mason et al., 2007), which may help drivers to stay safe in the most complex and busy places on the road. In contrast, minor intersections generally have less traffic, so most of the time they can be negotiated with relatively less effort. In situations of low driving task demand, drivers are more likely to experience mind wandering (Burdett et al., 2016; Yanko and Spalek, 2013). Mind wandering involves perceptual decoupling (Smallwood and Schooler, 2006), whereby responses to sensory cues bypass conscious focus and are largely governed by habit. It is therefore conceivable that drivers negotiating minor intersections and midblocks near their homes might take longer to react to a potential hazard than they would at a major intersection, where demands are usually higher.

Our results add to understanding of crash risk on low-speed roads. Crashes in busy urban environments may seem inevitable due to high traffic volumes and frequent opportunity for conflict at intersections, but the risk associated with unintentional lapses of attention may be higher at places where conflicts are less frequent overall. This risk at minor intersections and midblocks may be related to a relatively higher tendency for drivers to experience mind wandering on the most undemanding urban roads.

The results also support the Malleable Attention Resource Theory (MART, Young and Stanton, 2002). Rather than applying constant focus to a repetitive task such as driving, the MART suggests that drivers apply less conscious focus in situations of low demand. The revelation that crash patterns are different on urban roads close to home compared with further away, combined with results of other research concerning links between route familiarity, low subjective demand and attentional blindness (e.g. Martens, 2011) certainly imply that everyday driving does not command constant conscious focus.

In terms of next steps, the high social cost of injury crashes involving lapses of attention warrants more ecologically valid investigation, involving real drivers in the environments that appear to exceed their capacity from time to time. Although there is good rationale to explain the high proportion of lapses on low-speed roads closest to home, to our knowledge there have been few studies of the ways that drivers regulate their attention in the familiar environments of real streets. Many studies of mind wandering during driving, for example, are between-subject experiments in simulation (e.g. He et al., 2011; Lemercier et al., 2014; Yanko and Spalek, 2013). The ways that drivers regulate their attention are different during everyday driving than they are in novel situations, such as in a one-off drive in a simulator, or in an instrumented vehicle (Charlton and Starkey, 2013). To gain more insight into links between attention and crash risk, more naturalistic methods ought to be pursued.

We have shown that analysis of archival crash data is a useful way to explore what drivers cannot tell us themselves about lapses of attention. Crash data is increasingly sophisticated and accessible to researchers, with detail that can be used to study error. Vehicle technology is also improving, with some cars now equipped with a version of a 'black box', from which police officers can gather valuable information that may help describe the precursors to a crash (Chung and Chang, 2015). These avenues are worthy of exploration by traffic psychologists and others interested in understanding the causes of crashes, as well as interventions that may reduce their frequency.

The main limitation of this study is our inability to specifically account for exposure at different locations and on roads with different speeds, while also accounting for distance from home. The 'distance from home' groups were defined based on travel overall; there was no way of knowing from these data how much travel in each group was on low-speed or high-speed roads, how many or what types of intersections drivers negotiate closer to home compared with further away. Defining exposure to intersections is particularly difficult, because risk varies considerably at different times of the day and year, according to the number and nature of turning movements, and relative proportions of motor vehicles, pedestrians and cyclists.

A further limitation relates to the crash data. Police crash reports are an incomplete account of factors involved in an individual crash, and not all crashes are attended by the police. As a result of not including all possible crashes in the error analysis, we do not have a complete accounting for the ways in which lapses and violations may play a role in crashes close to home. However we overcame this issue somewhat by our focus on only those factors that could be reasonably categorised as lapses or violations, and within the analysis we looked at patterns in terms of distance from home, and not the absolute frequency of any type of error or crash.

In conclusion, it seems that the close to home effect is related to increased crash risk on low-speed urban roads, which in turn is influenced by lapses of attention driving in familiar places. The most common places for lapses on roads closest to home are away from busy intersections. These findings may prove useful to researchers and road safety practitioners interested in addressing the underlying causes of injury crashes, and for local authorities looking to improve safety for local people driving on local roads. The close to home effect along with inherent risk on urban roads is worthy of continued investigation.

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Study Five: Mind Wandering During Everyday Driving

Abstract

This study was an investigation into mind wandering during everyday driving, and its association with crash patterns. We selected a 25km route on urban roads for desktop analysis of crashes, and an on-road study of mind wandering by a sample of drivers familiar with the route. For the desktop study we analysed reported crashes on the route over a five year period from New Zealand's crash database. For the on-road study a researcher accompanied 25 drivers on the route, asking them what they were thinking about at 15 predetermined road sections. The road sections were selected to include a range of different speed limits and traffic volumes as well as roundabouts, priority intersections and midblocks. Thought samples were categorised as either mind wandering or driving focus, and triggered by the senses, or internally. The frequencies of mind wandering at different road sections on the route were compared to the frequencies of reported crashes along the same route over the preceding five years. Results showed that although all drivers reported mind wandering, it was more likely to be reported at slower, quieter, less complex road sections. Overall, more crashes were reported at priority intersections and midblocks than at roundabouts, but the crash rate (per road section) was higher at roundabouts, where mind wandering was least likely to be reported. These findings suggest that although drivers' minds wander constantly, driving focus is commanded in demanding situations and in response to the actions of other road users. While mind wandering is ubiquitous, drivers are least likely to report mind wandering at locations showing the highest crash rates. More work is needed to test these findings and to provide direction for road safety interventions.

1. Introduction

Mind wandering (MW) is a common experience in everyday life. People readily report MW, defined as task-unrelated thought (Smallwood & Schooler, 2006) during both laboratory situations and daily activities (Mooneyham & Schooler, 2013; Smallwood & Schooler, 2015). Experience sampling studies, in which participants are interrupted during their daily life and asked to report their thoughts, have found that MW is reported on between one quarter and half of all responses (Killingsworth & Gilbert, 2010; Song & Wang, 2012; Spronken, Holland, Figner, & Dijksterhuis, 2016).

MW is also common during driving. We have previously asked drivers how often they experience MW across a range of different driving situations, such as on familiar and unfamiliar roads, and in their own or an unfamiliar car. Our results revealed that all drivers report experiencing MW at least occasionally, and we found that drivers were most likely to experience MW driving their own car on familiar roads (Burdett, Charlton, & Starkey, 2016).

The link between MW and route familiarity has been corroborated by others. With repeated practice on a simulated route, drivers report more MW (Yanko & Spalek, 2013), and show an increasing tendency to report "'driving without thinking about it', 'zoning out' or 'going on autopilot'" (Charlton & Starkey, 2011, p131). Drivers also report reduced awareness during familiar drives such as the daily commute (Handy, Weston, & Mokhtarian, 2005; Papp et al., 2004; Steinberger, Moeller, & Schroeter, 2016). Respondents in a survey by Berthie et al. (2015) estimated that their mind wandered for an average of 35% of the time during their most recent (real-world) drive, but if that drive was a commute, they were more likely to report a higher proportion of time spent MW.

In an earlier study we explored how drivers experience MW during their daily commute given that it appears to be the drive where MW is most likely to be experienced. Eleven female participants were asked what they were thinking about (a descriptive experience sampling procedure) between four and six times across each of ten drives per participant. Drivers reported MW on 63% of the 587 thought samples (Burdett, Charlton, & Starkey, 2017). These findings clearly demonstrate that MW is pervasive during the most familiar of everyday trips, and is not an exceptional or unusual experience.

The preceding section highlights that MW is clearly a common experience during everyday driving but its link with crashes is unclear. Intuitively it seems that MW during driving is probably 'unsafe'. Indeed, a small but growing body of research points towards a causative link between MW and crash risk. He et al. (2011) suggested that because MW is associated with performance decrements such as narrowed gaze patterns in driving simulation, it “might easily contribute to… ...increased crash risk” (p18). In a simulated car-following task Yanko & Spalek (2013) measured response times to braking vehicles and pedestrians crossing as a function of drivers’ reported MW and concluded that MW affects drivers’ performance, also in driving simulation, and “may therefore lead to higher crash risk” (p260). Meanwhile, Galera et al. (2012), who interviewed drivers involved in a crash and asked them to recall what they were thinking about before the collision, resolved that MW is a dangerous and undesirable state which is “threatening safety on the roads” (p1). However, there are several reasons to question the veracity of the conclusions drawn from these studies. They all failed to account for the fact that drivers experience MW during normal everyday trips, which do not result in crashes. This is a problem because evidence from everyday driving suggests that MW is not unusual, but commonplace. If everyday driving involves so much MW, it is unclear which drivers face increased or higher crash risk, and in what situations their safety is being threatened. In addition, there is limited understanding of the association between MW during real driving, and crash patterns, so laboratory-based research that ignores everyday drivers’ experiences of MW cannot reasonably be generalised outside of its experimental setting.

It is important to continue investigation into MW and crash risk within an appropriate context (i.e., on roads). There are differences in how people think about a task, and therefore how they experience MW, between the laboratory and everyday life (Kane et al., 2017). During simulated driving studies, the setting as well as the instructions given are likely to affect the way participants think, which is problematic if results about MW are to be generalised beyond the laboratory. For example, participants in the study by He et al. (2011) were “told to keep their attention on the driving task as much as possible” (p15). Instructions concerning attention are not explicit during everyday driving, and our results suggest that drivers do not set out with sustained driving task focus as an obvious goal (Burdett, Charlton, & Starkey, 2017). Therefore, continued investigation of both crashes and MW in a naturalistic driving context is important if we are to understand how MW is experienced during driving, so that we can work towards interventions that improve road safety.

In another study, we explored a potential link between MW and crash risk (Burdett, Starkey, & Charlton, 2017), building on the evidence that MW is most frequently experienced on familiar roads (Berthie et al., 2015; Burdett, Charlton, & Starkey, 2016). Our research into the 'close to home effect' demonstrated that for New Zealand drivers, crashes are over-represented on roads within 10km (6 miles) of home, which are probably more familiar to drivers, on average, than roads further away (Burdett, Starkey, & Charlton, 2017). Even though roads close to home are where most driving happens, New Zealand drivers are more likely to have a crash there, mile for mile driven, than on a road further away.

MW and crashes are both relatively common in familiar places, so we explored crash data on familiar roads close to home in more depth (Burdett, Starkey, & Charlton, 2018). We analysed the errors involved in crashes at different distances from home, differentiating between intentional violations, which are the result of intentional but illegal or dangerous behaviour; and lapses of attention, which are typically unintentional and may be related to MW. We found that in New Zealand, crashes close to home are commonly related to lapses of attention, whereas crashes related to intentional violations are less common. We also explored the places where crashes occur, and found that more crashes close to home happen at relatively simple midblocks (the stretches between intersections) on low-speed (urban) streets than at complex places such as roundabouts (Burdett, Starkey, & Charlton, 2018). However, it is unclear whether crashes are common at midblocks simply because they make up most of each drive, or whether the pattern may be due in part to drivers' tendency to experience MW in places where nothing risky or demanding usually happens. To date, there have been few studies of how or whether drivers regulate their attention in response to changing demands across a drive on real streets. The evidence falls short of establishing any links between MW and crash risk close to home.

As well as building on a potential link with crash risk, studying MW and driving can inform theories of driver behaviour and general theories of MW. Theories of driver behaviour have for many years assumed that drivers apply conscious focus to maintain a feeling of comfort or safety (Fuller, 2005; Fuller, McHugh, & Pender, 2008; Lewis-Evans & Rothengatter, 2009; Wilde, 1982; 1998). For example, Fuller, McHugh, & Pender (2008) suggest that drivers consciously adjust their speed to stay within some subjective level of comfort.

In contrast with many driver behaviour models, there is growing evidence that the driving task rapidly becomes proceduralised, and does not command conscious focus much of the time (Charlton & Starkey, 2011, 2013; Harms & Brookhuis, 2016). Evidence that many aspects of the driving task (such as maintaining an appropriate speed) happen automatically and not with conscious intent led Charlton and Starkey (2011, 2013) to develop the tandem model of driver behaviour. The tandem model suggests that most of the time, an unconscious monitoring process governs safe behaviour. Conscious driving task focus is engaged only temporarily, typically in response to an unfamiliar or demanding situation. The model provides a rationale for why drivers report MW so frequently during familiar trips, because they are well-practiced and therefore less demanding than an unfamiliar trip on a similar route. More research into where drivers are relatively more or less likely to report MW, and how those situations are associated with crash risk, could help to build on models of driver behaviour.

Evidence that has informed general theories of MW also suggest that its likelihood of occurrence is linked with both task familiarity and momentary demand, but to date few studies have explored MW variation in naturalistic contexts to advance understanding of why and how MW happens. Smallwood and Andrews-Hanna (2013) proposed the Context Regulation Hypothesis (CRH), which suggests that MW is more likely in familiar or less demanding situations because they can be successfully negotiated without applied task focus. The CRH is based on evidence that MW is more commonly experienced in familiar situations of low demand, albeit most studies used to derive the theory were in laboratory settings (Smallwood & Andrews-Hanna, 2013). Driving is a useful context in which to explore and potentially build on this hypothesis, because it is familiar to many people, while also comprising situations of varying demand.

In the current study we compared crash locations from the five-year crash history of a 25km urban road route to the locations where a sample of drivers reported MW as they drove the route with us. The route comprised situations of varying demand, such as busy intersections and quiet mid-blocks. We first examined how crashes are distributed according to the different road situations (and varying demands) on the route using New Zealand’s national database of reported crashes. Second, we explored MW on the same 25km route by recruiting drivers familiar with the route, and asking them what they were thinking about at predetermined locations. Overall we set out to compare the locations of reported crashes with the locations of MW on familiar urban roads.

2. Methods

2.1 The Route

A 25km road route around Hamilton City, New Zealand, was selected for a desktop study of reported crashes, and an on-road study of drivers' reported MW (Figure 1). The route was selected to include a range of different speed limits, roads with different traffic volumes, and a variety of intersections and midblock sections (lengths between intersections). Signalised intersections were excluded from both the desktop study of crashes and from the on-road study of drivers' reported MW.

For the desktop analysis of reported crashes, the route was divided into road sections with different characteristics. There were 17 roundabouts and 77 priority intersections in the route, which were defined as 100m in length. There were 112 midblock sections in between intersections along the route. The lengths of midblocks ranged from 10m to 550m (*M* = 122m). Overall therefore, the 25km route comprised 206 defined sections (excluding traffic signals).

Figure 2 the 25km route in Hamilton, New Zealand, used to analyse reported crashes (desktop study) and drivers' reported MW (on-road study)

2.2 Crash Data

Crash data were all reported injury crashes involving a driver of a car at roundabouts, priority intersections and midblocks on the 25km drive route, for the five years 2012 to 2016 inclusive. Data were obtained from the NZ Transport Agency's Crash Analysis System (NZ Transport Agency, 2017). Information extracted from crash reports included the crash location (street and distance from the nearest intersection, to locate the crashes within defined road sections on the route); and for crashes at intersections, the intersection form of control (whether it was a roundabout, traffic signals, priority intersection (Stop or Give-Way controlled) or other, i.e., midblock, including crashes at driveways). Crashes at traffic signals were subsequently excluded.

The crash rate per road section (roundabout, priority intersection or midblock, as defined in Section 2.1 above) for the 25km route was the total number of reported injury crashes per road section, per year. The crash data are summarised in Table 1. These data show that overall, more crashes were reported at midblock sections and at priority intersections. However, the crash rate was more than twice as high at roundabouts than at other road sections.

Table 1 Summary of route crash data by road situation (Roundabout, Priority Intersection and Midblock).

Road situation	Number of Crashes (Five years)	Number of road sections in route	Crash rate: Number of crashes per road section per year
Roundabout	24	17	0.28
Priority Intersection	39	77	0.10
Midblock	63	112	0.11

2.3 On-road Drive

2.3.1 Participants

Twenty-five participants were recruited (7 male; age range 19-77; *M* = 47.6 years, *SD* = 14.8 years) through personal contacts and social media. Most participants were aged between 25 and 65 years (*n* = 21), with two aged less than 25 years and two aged over 65 years. Participants worked in a variety of occupations including student; technician; salesperson; communications advisor; engineer and retired. None of the participants had been involved in an injury crash during their previous five years of driving. Participant characteristics are shown in Table 2.

Table 2 Participant Age, Driving Characteristics and Crash History

	Mean	SD	Range
Age (years)	47.6	14.8	19 – 77
Years with Full NZ Drivers' Licence	25.7	15.5	1 – 48
Km driven per week	220.2	308.2	30 – 1500
Years spent driving in Hamilton City	17.6	15.1	1 – 47
Number of injury crashes, previous five years	0	0	0-0
Number of non-injury crashes, previous five years	0.16	0.37	0-1

The only selection criteria were that participants had a full New Zealand driver's licence and their own registered car to drive for the study. Participants were given a NZ$20 petrol voucher at the start of the study to thank them for volunteering to participate. The study methods were approved by the University of Waikato's School of Psychology Research and Ethics committee.

2.3.2 Drive Route and Thought Sampling Locations

Participants drove their own car, accompanied by a researcher, on the 25km route. Participants were asked 'What are you thinking now?' at 15 preselected road sections including five roundabouts, five priority T-intersections and five midblock sections. That is, there were 15 thought sample questions for each participant and they were all asked the thought sampling question at the same places (Figure 2). The drive was split into three portions so that participants did not need to remember too many directions at once. Each participant chose their starting point from the three shown as 'S' in Figure 2. As well as roundabouts, priority intersections and midblock sections, each of the three portions included road sections with different posted speed limits ranging from 50km/h to 80km/h, and varying traffic volumes (Table 3).

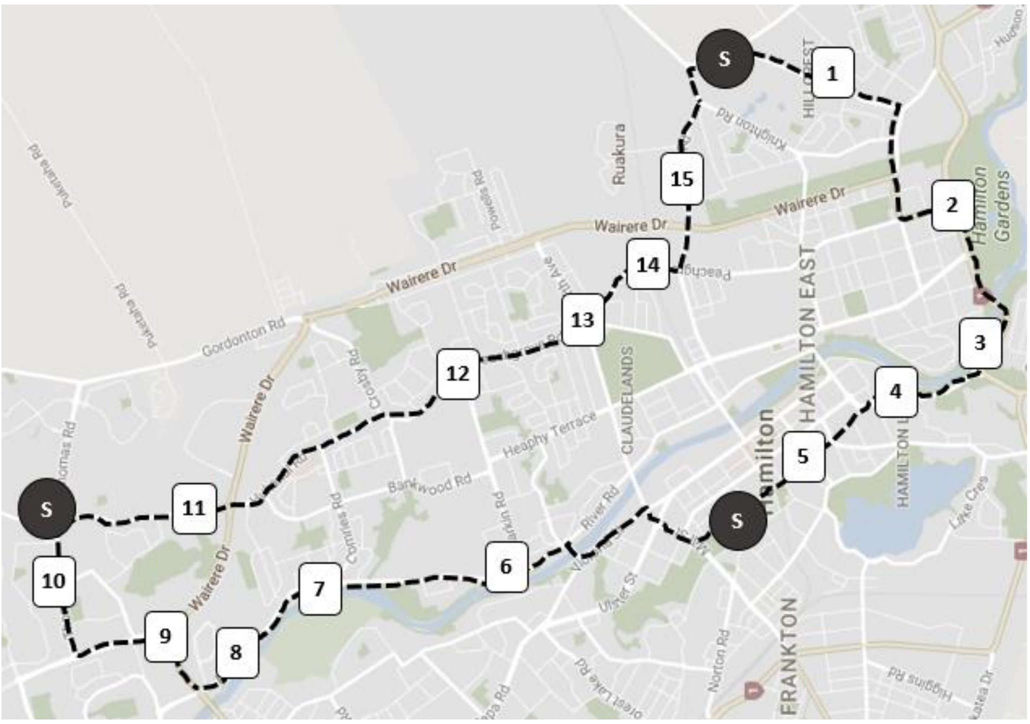

Figure 3 Drive route, showing road sections (numbered) where drivers' thoughts were sampled, and starting points (S), which also defined the start and end of each portion of the route.

Table 3 Road and traffic characteristics at thought sample road sections: Road situation, posted speed limit and traffic volume. The length of each road section was defined as 100m (for Priority Intersections and Roundabouts); or as the actual distance between intersections (for Midblocks).

Thought Sample Road Section	Road situation: Roundabout, Priority Intersection or Midblock	Posted Speed Limit (km/h)	Traffic Volume (2016 Annual Average Daily Traffic)
1	Priority Intersection	50	4,000
2	Roundabout	80	32,000
3	Midblock	80	31,000
4	Roundabout	50	27,000
5	Midblock	50	15,000
6	Priority Intersection	50	18,000
7	Midblock	50	12,000
8	Priority Intersection	50	12,000
9	Roundabout	80	30,000

10	Midblock	50	13,000
11	Priority Intersection	50	11,000
12	Roundabout	50	21,000
13	Roundabout	50	33,000
14	Midblock	50	11,000
15	Priority Intersection	60	16,000

2.3.3 Procedure and Materials

Participants who expressed interest in the study were sent an information sheet and if they wished to participate, confirmed one of the three starting points (Figure 2) to meet at for the study. A researcher met them at the starting point where they talked through the study procedure.

After signing a consent form, participants completed a pre-drive questionnaire. The pre-drive questions included the participant's age, address (to determine whether they lived nearby or not, as a generic indicator of route familiarity in addition to more specific ratings of familiarity provided later); and driving history (including years with a full New Zealand driver's licence; average kilometres driven per week; number of years driving in Hamilton City; and injury and non-injury crash involvement over the previous five years).

After answering the pre-drive questions, participants were shown a map with directions for the first of three portions of the drive. The route was also explained to them verbally. Participants were told that they may be asked "what are you thinking now" during the drive. Participants were not told where or how often they would be asked the thought sampling question. A researcher sat in the front passenger seat of the participant's car, to administer the questionnaires; to prompt the drivers to report what they were thinking about; and to remind participants of the route before they were required to make any turns. The drive was recorded with a camera mounted to the front passenger headrest such that it captured the view through the windscreen, as well as all audio. The recordings were used to review drivers' responses to questions and as a back-up for handwritten responses to thought sampling questions.

Participants were informed at the start of the study that they did not have to provide an answer to any question if they did not want to. Participants' responses were recorded verbatim on paper, a form of descriptive experience sampling.

After completing each portion of the 25km route, participants were asked to pull over into a vacant parking space so that questions for the preceding portion could be asked. Participants were asked to rate the roads they had just driven on in terms of how familiar they were (on a 7-point Likert scale where 1 = completely unfamiliar / never driving on it before; to 7 = as familiar as my daily commute). Participants were free to provide different ratings for different roads within each portion with reference to a map of the route they had just driven. For each portion, participants were also asked how many times they would drive that route, or most of it, in a year; when the last time was that they drove it, or most of it; and what trip purpose was typical for them on those roads (e.g. commute; shopping trip; visiting family, etc).

Participants were given directions for the next portion, and the procedure was repeated for three portions in total until they arrived back at their starting point. At the end of the drive, as well as questions about the previous portion, participants were asked a further set of questions about the drive as a whole. They were asked to estimate what proportion of the drive they estimated that their mind was wandering, described for participants as "not thinking about driving". They were also asked how often (as a percentage) their mind wanders generally during everyday driving on familiar urban streets.

2.3 Analysis

The aim of this study was to investigate variation in both crashes and reported MW on a 25km urban road route. The analysis was conducted in two parts, related in turn to crash data (analyses of reported crashes according to road situation: roundabout, priority intersection or midblock); and thought samples (analyses of categorised thought samples according to different road characteristics).

To explore variation in reported crashes on the route according to road situation (roundabout, priority intersection or midblock), crashes were grouped according by road situation. We plotted the numbers of crashes recorded in each of the 206 road sections, by road situation in the route, with crash numbers ranging from zero to five crashes per section. Because crashes are rare, independent events, we tested whether the crash patterns for each situation followed Poisson distributions using Chi-squared Goodness of Fit tests. We then used Poisson Regression to analyse the differences between the mean crash rate (number of crashes per road section), for roundabouts, priority intersections and midblock sections.

To explore variation in drivers' reported MW in different road situations, we first categorised each thought sample. Thoughts were categorised as MW or driving focus, and their trigger as internal (unrelated to anything the driver could see) or sensory (something the driver saw as they drove), in line with previous taxonomies (Smallwood & Schooler, 2015; Burdett, Charlton, & Starkey, 2017). We analysed thought triggers (sensory or internal) as well as content (MW or driving focus) to better understand drivers' overall sensory engagement in relation to changing task demands. Responses reflecting no particular thought at all (e.g. "not really thinking about anything") were excluded (5.9% of all thought samples). The categorisation scheme and example thought samples are shown in Table 4.

Table 4 Categorisation of thought samples, adapted from Burdett, Charlton, & Starkey (2017). Figures in brackets indicate the percentage of all thought samples in each category (excluding samples reflecting no particular thought at all).

		Thought Content	
		Mind wandering	**Driving focus**
Thought Trigger	**Internal**	MW, Internal trigger, e.g. "I'm hungry" (9%)	Driving focus, Internal trigger, e.g. "Am I in the best lane" (12%)
	Sensory	MW, Sensory trigger, e.g. "Just looking at different houses along here" (40%)	Driving focus, Sensory trigger, e.g. "Driver turning left in front of me" (39%)

Next, we summarised drivers' categorised thought samples to provide an overall picture of the distribution of MW and sensory engagement during the drive. To better understand where and when MW happens during everyday driving, we tested both the content (MW vs task focus) and trigger (internal vs sensory) of drivers' thoughts with three planned comparisons, namely road situation (roundabouts, priority intersections and midblocks); posted speed limit (50km/h and >50km/h); and traffic volume (<17,000 vehicles per day, and >17,000 vehicles per day). Each planned comparison involved a one-way ANOVA.

Finally, we compared MW frequencies and crash rates across roundabouts, priority intersections and midblocks, and for the road sections showing the highest and lowest numbers of crashes. The purpose of these comparisons was to address the main aim of the research, by comparing variation in both crashes and reported MW across different road situations on the same route.

3.0 Results

3.1 Crash data and regulation of attention according to crash risk

Figure 3 shows the distribution of the number of crashes recorded in the five-year analysis period across the 206 road sections in the route, separated by road situation. There were between zero and five reported crashes reported at each road section, across the 17 roundabouts, 77 priority intersections and 112 midblock sections. The data in Figure 3 show that over half of the road sections (114) had zero reported crashes. Overall, more crashes were reported at midblocks and priority intersections, but roundabouts were relatively more likely to show a higher number of reported crashes per road section. That is, roundabouts showed a higher crash rate than both priority intersections and midblock sections, but were the scene of fewer crashes overall because there were many more priority intersections and midblock sections on the route.

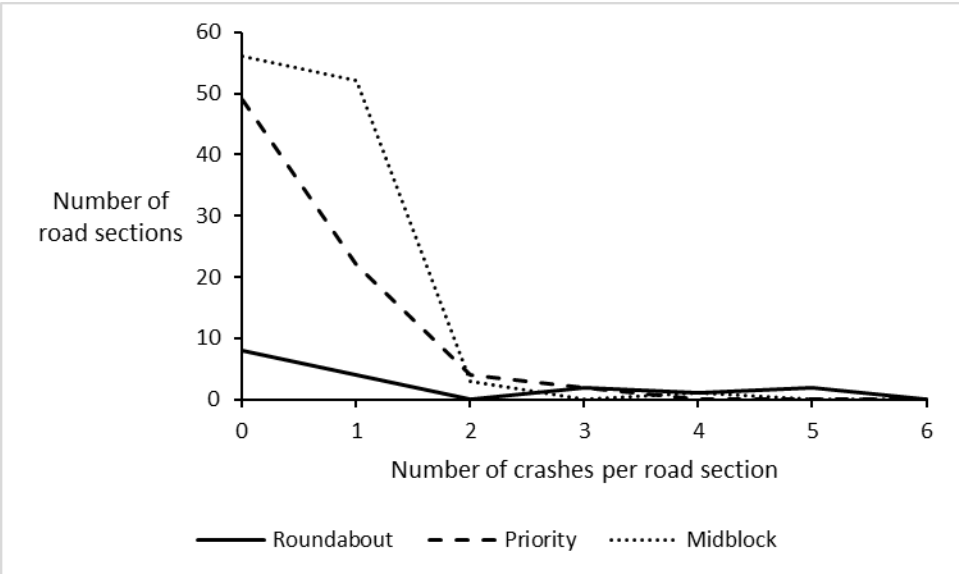

Figure 3 Distribution of injury crashes across different types of road situation for the 25km urban road route. Vertical axis shows the number of road sections with each crash frequency.

Each curve in Figure 3 was confirmed as following Poisson distribution using a Chi-squared Goodness of Fit test (Roundabouts: p = .23; Priority intersections: p = .22; Midblocks: p = .23). Poisson regression was used to test the relationship between road situation and crash rate. Roundabouts (M = 1.41 crashes per section; 95% CI, 0.96 – 2.10) showed a significantly higher crash rate than both priority intersections (M = 0.47 crashes per section; 95% CI, 0.33 - 0.64) and midblocks (M = 0.55 crashes per section; 95% CI, 0.43 - 0.71; p < .001). The difference in mean crash rate between midblocks and priority intersections was not significant (p = .420).

3.2 Thought Samples

3.2.1 Summary of MW during the drive

Descriptive statistics summarising participants' experience driving the study route, their responses to thought sampling questions during the drive and to the post-drive questionnaire are shown in Table 5. These data show that most participants were relatively familiar with the route. All participants reported MW at least once in response to thought sampling questions. When asked to estimate the proportion of time during the drive that they experienced MW, all participants estimated that their mind was wandering at least some of the time. There was no difference in reported MW based on whether or not the participant knew the researcher accompanying them ($t(24)$ = 0.36, p = .641).

Overall these data show that participants experienced both MW and driving task focus in relatively equal measure, across the road sections where drivers were asked to report what they were thinking about. While most thought triggers were sensory, most participants also reported internally-triggered thoughts. Participants' estimated time spent MW during the experimental drive was slightly lower on average, but similar to their estimated time spent MW during driving in everyday life.

Table 5 Thought Samples: Descriptive Statistics (N = 25)

	Mean	SD	Range
Thought content: MW (proportion of responses to thought sampling questions categorised as MW, excluding responses reflecting no particular thought at all)	.50	.19	.20 - .87
Thought trigger: internal (proportion of responses to thought sampling question categorised as internally triggered, excluding responses reflecting no particular thought at all)	.21	.13	.00 - .53
Estimated proportion of time during this drive that mind was wandering: Participants' own estimates	.39	.27	.04 - .99
Estimated proportion of time engaged in MW during everyday driving: Participants' own estimates	.44	.28	.04 - .99
Mean familiarity with thought sampling question locations	5.45	0.89	3.1 – 7.0

3.2.2 Thought content variation across the drive

The proportions of responses categorised as MW by road situation (roundabout, priority intersection or midblock) are shown in Figure 4. A one-way repeated-measures ANOVA conducted on drivers' thought samples (proportions of thoughts categorised as MW) across roundabouts (M = .36), priority intersections (M = .63) and midblocks (M = .59) revealed a significant effect of road situation on reported MW ($F(2,46) = 14.75$, $p < .001$, $\eta_p^2 = .38$). Post-hoc tests with Bonferroni correction revealed significant differences in reported MW between roundabouts and priority intersections ($p_{adj.} = .002$) and between roundabouts and midblocks ($p_{adj.} = .009$). There was no significant difference in reported MW between priority intersections and midblocks ($p_{adj.} = 1.00$). MW was reported more often at midblocks and priority intersections than at roundabouts.

The proportions of responses categorised as MW by speed limit as high (>50km/h; M = .40) or low (50km/h; M = .58) are shown in Figure 4. A one-way repeated measures ANOVA conducted on drivers' thought samples across high speed and low speed road sections revealed a significant difference in terms of reported MW frequency (F(1,23) = 9.62, p = .005, η_p^2 = .29). MW was reported more often at road sections with a speed limit of 50km/h than at road sections with a speed limit greater than 50km/h.

The proportions of responses categorised as MW by high (>17,000 vehicles per day; M = .42) or low (<17,000 vehicles per day; M = .63) traffic volume are shown in Figure 4. Drivers reported MW more often at locations with lower traffic volume than at higher volume locations (F(1,23) = 13.98, p = .001, η_p^2 =.37).

3.2.3 Thought trigger variation across the drive

The proportions of responses categorised as triggered internally by road situation (roundabout, priority intersection or midblock) are shown in Figure 4. A one-way repeated-measures ANOVA conducted on drivers' thought samples (proportions of thoughts categorised as internally-triggered) across roundabouts (M = .20), priority intersections (M = .26) and midblocks (M = .20) revealed no significant effect on reported frequency of internally-triggered thought (F(2,46) = 1.35, p = .269, η_p^2 = .06).

The proportions of responses with an internal trigger, by speed limit as high (>50km/h; M = .32) or low (50km/h; M = .18) are shown in Figure 4. A one-way repeated measures ANOVA conducted on the trigger of drivers' thoughts revealed a significant difference between high speed and low speed road sections (F(1,23) = 8.35, p = .008, η_p^2 = .27). Drivers reported more internally-triggered thoughts at road sections with a speed limit of >50km/h than at road sections with a speed limit of 50km/h.

The proportions of responses with an internal trigger, by traffic volume as high (>17,000 vehicles per day; M = .20) or low (<17,000 vehicles per day; M = .23) are also shown in Figure 4. There was no significant difference between the proportion of internally-triggered thoughts on low volume and high volume road sections (F(1,23) = .714, p = .407, η_p^2 =.03).

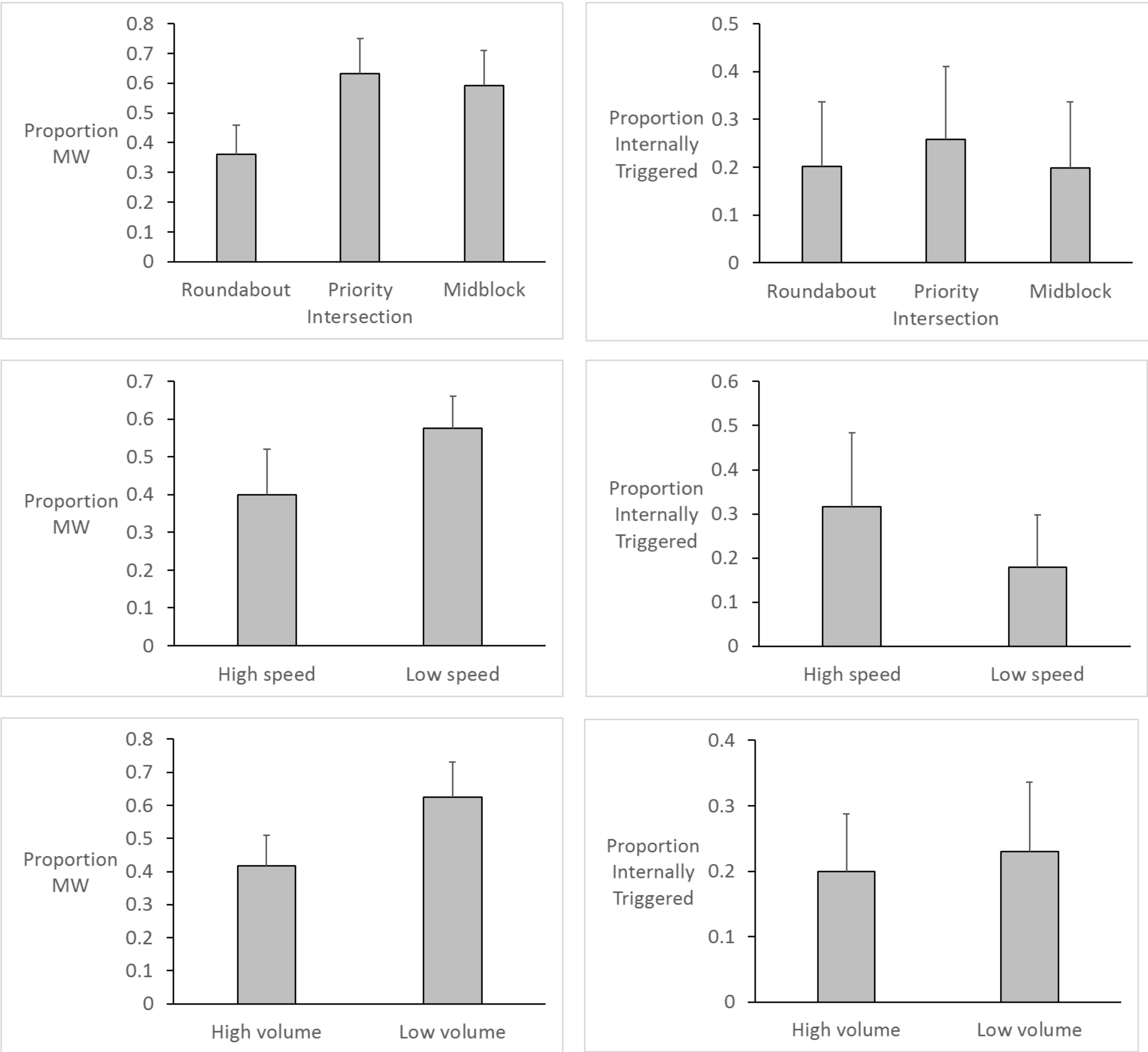

Figure 4 Proportion of thought samples reflecting MW (left) and internally-triggered (right) thought according to road characteristics (top: location (roundabout/priority intersection/midblock); middle: high speed/low speed; bottom: high volume/low volume).

3.3 Variation in Crash Rates and Reported MW

To illustrate variation in both reported crash rates and reported MW on the same 25km route, the proportion of thought samples reflecting MW was plotted alongside the mean number of crashes per road section, per situation. The data in Figure 5 show that there is an inverse relationship between reported MW frequency as reported by a sample of drivers, and crash rates based on nationally collected data (number of reported crashes per road situation). Roundabouts showed a higher crash rate, and lowest overall frequency of reported MW. Drivers were more likely to report MW at priority intersections and midblocks, which had lower crash rates.

In terms of specific locations on the 25km route, Table 6 shows the roundabouts, priority intersections and midblock sections with the highest and lowest reported numbers of crashes, as well as the percentage of participants reporting MW at each road section. The small samples sizes precluded statistical analyses of these data; they are provided as illustration of the association between MW and crash rate. These data show that while generally there are more crashes reported at roundabouts, which is where MW is less likely, the association is not absolute. Drivers' likelihood to report MW was relatively low at both roundabouts in Table 6, even though one of them had zero reported crashes in five years. Conversely, consistently high rates of reported MW was reported at midblocks and priority intersections, even though some midblock sections and priority intersections showed higher numbers of reported crashes than others. The data suggest that drivers' regulation of attention may be associated with the nature of a road situation in general, and other factors unrelated to site-specific crash risk.

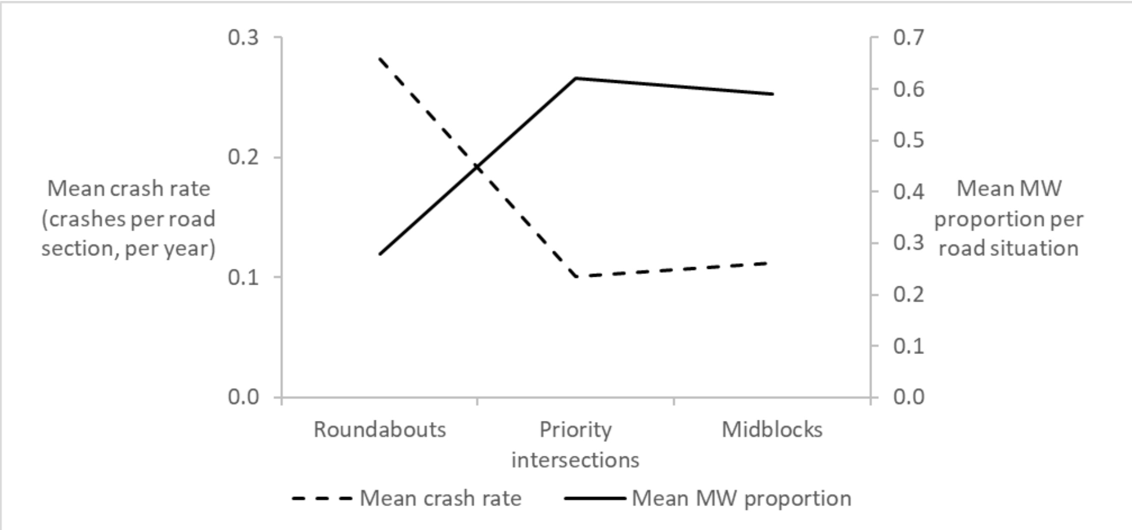

Figure 5 **Mean crash rates (reported injury crashes per road section, per year), by road situation for the 25km route, and mean proportion of thought samples reflecting MW by road situation.**

Table 6 Road sections with highest and lowest reported numbers of crashes, and MW frequency at the same road sections

Road situation (Road section number, Fig. 1)	Number of reported injury crashes, five years 2012 – 2016 inclusive	Reported MW frequency (percentage of participants reporting MW)
Highest number of crashes, Roundabout (12)	3	24%
Lowest number of crashes, Roundabout (2)	0	36%
Highest number of crashes, Priority Intersection (6,11,15)	1	80%, 68%, 76%
Lowest number of crashes, Priority Intersection (8)	0	64%
Highest number of crashes, Midblock (3)	2	68%
Lowest number of crashes, Midblocks (10,14)	0	72%, 48%

4.0 Discussion

We set out to explore variation in crash rates and reported MW on a 25km urban road route. We analysed crash rates across roundabouts, priority intersections and midblocks on the route. We also sampled drivers' thoughts across different road situations including across high and low speed environments, and on roads with high and low traffic volumes. We investigated how MW frequency across intersections and midblocks corresponds with the distribution of crashes across the same types of situations. Our findings provided new evidence about the nature of MW during everyday driving and its association with crash risk.

Drivers reported MW throughout the drive, but most often at quiet, low-speed midblocks and priority intersections, which comprised most of the route. The high frequency of MW during the study supports existing evidence that MW is pervasive during everyday driving on familiar urban roads (Burdett, Charlton, & Starkey, 2017).

Even though MW was reported often, drivers maintained sensory engagement with the environment they were driving through. On average, 78% of all thought samples were triggered by something that drivers could see (or hear), including for example people on the roadside, buildings, or the weather. The proportion of thoughts that were internally-triggered did not vary much across different road situations, or at locations with different average daily traffic volumes. When participants reported driving focus at midblocks, it was typically in response to the actions of another road user, for example “just watching this car, quite close”. When there were no pertinent driving-related cues to think about, drivers’ thoughts moved to what they saw and its significance in their life.

Drivers’ tendency to report more internally-triggered thoughts at higher speed locations may be related to the road design at those locations. Higher-speed locations were typically dual carriageways, and many participants drove the route in off-peak times when traffic was light. The momentary situation of a wide, relatively empty road may have resulted in more drivers thinking about internally-triggered concerns because there was nothing pressing in the road environment to capture their attention.

MW varied systematically rather than randomly, and its pattern was associated with task demand and crash patterns. We found that overall, roundabouts were the most risky individual road sections, with higher crash rates than midblocks and priority intersections. Drivers were least likely to report MW at roundabouts, which were the most demanding places where we collected thought samples, because drivers were required to give way to any other traffic already circulating. More crashes were reported on the route at midblocks and priority T-intersections, but because there were so many of these sections on the route, risk at each section was low. Drivers were more likely to report MW in low risk than in high risk situations, and in situations of low rather than high demand.

To summarise our evidence from thought sampling of drivers on familiar urban roads, we found that MW was pervasive, but controlled. High proportions of thoughts triggered by what drivers saw suggest drivers scan the environment for potential driving-related cues, but most of the time driving does not command conscious focus so their minds wander. Situations of high demand and the highest crashes rates were places where MW was least likely to be reported, suggesting an inverse relationship between MW and crash risk.

Evidence concerning where and when drivers’ minds wander also provides new perspectives to inform theories of MW. The results are consistent with the context regulation hypothesis (Smallwood & Andrews-Hanna, 2013) because MW during everyday driving appears to be regulated with respect to changing task demands. We agree that MW is a “normal rather than an exceptional state” (ibid., p1), even during a demanding task like driving. Despite the complex nature of driving, MW was not disruptive; none of our participants were involved in an injury crash in their recent driving history, or indeed, during the experimental drive. The framing of the context regulation hypothesis, where MW presents as a momentary interruption to task focus, was not supported by our evidence. Rather, drivers' minds wander frequently during everyday driving, where task focus is the exception rather than the rule.

Our suggestion that task focus is an exception during everyday driving does align with the tandem model of driver behaviour developed by Charlton & Starkey (2011, 2013). Indeed, our findings build on the tandem model by describing some kinds of situations that command drivers' focus, namely, high risk roundabouts and unusual or potentially risky actions of other road users.

The findings also suggest that drivers' expectations based on previous experience are involved in the switch between MW and task focus, in essence extending the tandem model. For example, we found that drivers usually focused on driving at roundabouts. Some drivers focused their attention on driving at roundabouts even when they were empty of traffic, for example "I'm thinking we're lucky there's not much traffic here today". Even when the momentary situation presents relatively low demand, the driver's expectations of roundabouts appears to dictate that it is worth their effort to pay attention. Our results comparing site-specific MW frequency and crash rates suggested that drivers may form generalised expectations for types of road features (e.g., roundabouts vs midblocks) and regulate their attention in response to the general nature of a situation rather than site-specific risk.

In terms of road safety applications, our results do not go far enough to suggest that MW causes crashes, or that task focus protects drivers from harm. All manner of factors related to the driver, other road users, the driving environment and vehicle factors affect crash risk. Crashes happen in places where drivers report more MW, and where they report less. It may be that the relatively high number of crashes at places where most MW was reported (midblocks and priority T-intersections) is related to drivers' occasional failure to correctly apply conscious focus. Therefore, road safety practitioners ought to recognise that drivers are not focused on driving for much of the time, but their attention can be readily commanded with conspicuous cues.

There are two main implications of these findings in terms of MW and road design, related to keeping drivers safe when their minds are wandering, and capturing their attention when driving task demands warrant conscious focus. Where possible, roads and roadside environments ought to be designed to align with drivers' schemas. That is, roads ought to be self-explaining, with clear links between the way the road looks and feels, and safe behaviour that is elicited without the need for drivers to apply continual conscious focus (Burdett, 2018; Charlton et al., 2010; Theuwes & Godthelp, 1995). Transport system designers can work with the knowledge that drivers' attention can be readily commanded in situations of objectively high demand. Drivers are adept at applying conscious focus where they have learned that it is worthwhile, and we have found that links between drivers' subjective assessment of demand aligns well with objective risk at situations such as roundabouts. System designers ought to continue to research the kinds of situations that catch drivers unaware, such as places where a high proportion of MW coincides with a high crash rate. Although we found that drivers are less likely to experience MW in risky places, previous research suggests that there are gaps between subjective risk perceived by drivers, and risk assessed through analysis of crashes (Charlton, Starkey, Perrone, & Isler, 2014).

These results provide new perspectives related to the way MW is viewed in the context of everyday tasks, but the study had some limitations. The sample size was relatively small and comprised mostly experienced drivers, on familiar urban streets in a relatively small city. Complexities associated with urban motorways, roadworks, periods of significant congestion, cycleways and areas with a high number of pedestrians were not explored. It is unclear how drivers might regulate their attention on journeys with a higher overall level of demand or on unfamiliar roads. The issue of attentional regulation on rural roads, for example on long cross-country journeys, uninterrupted by any requirement to negotiate intersections, remains to be investigated.

Another limitation and direction for more research lies in our conclusion that MW is an intrinsic characteristic of everyday driving and not a separable state. We used evidence based on discrete thought samples to reach our conclusion, but recognise that each thought sample represented only a snapshot of a driver's complex and swiftly changing stream of consciousness. Our results were interpreted in that context, providing a view of the broad changes in focus over the course of a drive. In doing so we advanced understanding of the way MW is experienced, beyond differences between familiar and unfamiliar situations, to variation within a familiar context. A logical next step would be to explore drivers' thoughts in yet more depth, through continued use of descriptive experience sampling, or other techniques such as protocol analysis. The aim of more research into the complexities of thoughts would be to understand more about what commands drivers' attention and what does not, so that road system designers can respond with improved infrastructure and messaging to keep all road users safe. Descriptive experience sampling could also be used to explore associations between MW and driving performance variables (such as driving speed and maintaining appropriate lane position). Driving is a complex but familiar task for many people, making everyday streets a useful testing ground for understanding more about why peoples' minds wander, building on theories of both driver behaviour and MW generally.

Conclusions

We conclude that MW is characteristic of drivers' thinking during everyday driving and it appears to show an inverse association with crash patterns. Drivers minds are least likely to wander in places where crash risk is highest. In terms of the cognitive basis of MW, treating it as a separable component of cognition belies the nature of thinking during everyday life, and detracts from more pertinent issues. Research correlating MW with performance measures and concluding that it is dangerous is unhelpful, because a driver cannot prevent their mind from wandering.

We have demonstrated that everyday driving is a useful domain in which to study the nature of cognitive processes like MW, because it is such a commonly acquired skill. Furthermore, driving environments are diverse, in terms of their familiarity to individual drivers, as well as variety in the kinds of demands drivers encounter across different road sections within a route. We have also shown how analyses of crash patterns can usefully contribute understanding towards MW and its relationship with risk. Road safety practitioners can use insights into MW during driving to design environments that afford safe behaviour, given that normal driving involves frequent and somewhat predictable shifts between MW and driving focus. We have demonstrated that insights into attention and MW from analysis of well-practiced tasks such as driving can provide rich insights into the nature of everyday thinking.

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General Discussion

This thesis set out to study mind wandering in the context of everyday driving. It aimed to address a gap in understanding the situations in which drivers are most likely to experience mind wandering, and its association with crash risk. The research had two main questions:

1. How often do drivers' minds wander?
2. How is mind wandering during driving related to crash risk?

The first question was important so that more about the nature of mind wandering in an everyday context could be understood. The second question was important to investigate as a contribution towards improving road safety, and in general terms to improve understanding of the consequences of mind wandering.

How Often do Drivers' Minds Wander?

Results from the questionnaire and on-road studies suggest that drivers' minds wander frequently on familiar roads. All participants in this research reported mind wandering at least some of the time. Neither of the on-road studies involved thought sampling in random locations, but nevertheless results suggest a high frequency of mind wandering during everyday driving. On familiar urban streets, drivers reported mind wandering close to two thirds of the time when not negotiating busy intersections such as roundabouts. This finding was new and important because it suggested that studying mind wandering by asking people about the nature of their thoughts is possible, even when related to a potentially challenging and risky everyday task such as driving.

The results of the on-road studies suggested that on familiar roads, drivers reported mind wandering much more often than 'occasionally', which was the mean frequency reported in the retrospective questionnaire. In total, 69% of thought samples across the eleven participants in Study Two were categorised as mind wandering. Around half (48%) of thought samples in Study Five were categorised as mind wandering. The average time spent mind wandering on familiar urban streets is probably somewhere in between these proportions, because Study Two excluded thought sampling in the most demanding situations, whereas one third of thought sample locations in Study Five were at roundabouts which showed the lowest rates of mind wandering. Further, most participants in Study Five said that they experienced less mind wandering while driving as a research participant than they do during normal, everyday driving. Therefore, combined results suggest that mind wandering is not an exceptional state but very common, experienced over half the time on average during everyday driving on familiar urban roads.

Analysis of thought samples also provided insight into what drivers think about on familiar roads. Driving-related thoughts were often anchored in the ‘here and now’, but also included more abstract, internal considerations such as where to park, or reflections on the behaviour of other road users not currently present. Thoughts unrelated to driving covered the widest range of topics, often related to drivers’ lives at home and work, but sometimes including abstract daydreams or philosophical musings, such as reported by a participant in Study Five who said that she was thinking about “why humans just keep having one thought after another, they just never stop”.

Findings suggest that driving task focus is the exception rather than the norm during everyday driving, which means that the situations where drivers focus on driving are easier to define than situations where drivers’ minds might wander. Most thought samples categorised as driving-related reflected momentary engagement in response to some temporarily demanding (or subjectively risky) driving situation.

In summary, to address the question of how often drivers’ minds wander, it is all places and everywhere, but more often in quiet, undemanding locations. Mind wandering is regularly inhibited to negotiate demanding situations, but drivers do not set out to focus entirely on driving. Rather than driving-related thoughts predominating, this research suggests that it is mind wandering that is occasionally interrupted by conscious task focus.

What is the Relationship between Mind Wandering and Crash Risk?

This research has found that both mind wandering and crashes are common in familiar places, such as on urban streets close to home. Roads closest to home are likely to be more familiar to drivers, on average, than roads further away, and therefore the scene of more mind wandering. However, the similarities in mind wandering and crashes (both being more common in familiar places) is not enough to suggest that mind wandering causes crashes.

The places where both mind wandering and crash frequency were relatively high were minor intersections and midblocks on urban roads closest to home. Drivers were significantly more likely to report mind wandering at minor intersections and midblocks, and were more likely to report driving task focus at roundabouts. Further, several drivers' thought samples at roundabouts implied that they had learned to apply focus because they believed the situation was hazardous. In contrast, at midblocks drivers frequently reported that they were relaxed, not thinking about much at all; they were "just driving".

Although drivers are most likely to be found mind wandering in the places where most crashes happen overall, patterns in mind wandering with respect to road and traffic situations were all observed during safe driving. It is unclear whether more crashes happen overall at midblocks because they are the scene of more mind wandering; whether midblocks simply comprise more of a driver's typical route and therefore crash patterns are linked with exposure; or whether other factors that affect crash risk are at play.

If drivers could apply constant focus to the task, it may seem logical that crash frequency would be reduced at minor intersections and midblocks. Results of this research suggest that sustained focus on driving is not a realistic goal for human drivers, because all of them report mind wandering at least some of the time. Rather, if drivers only apply conscious focus intermittently, it is in their interests to attend to driving at the specific places where crashes are most likely to happen. Drivers already apply focus at relatively high-risk roundabouts, and appear to allow their minds to wander across the longer lengths of midblock and at minor intersections, where site-specific risk is usually low despite higher numbers of crashes overall.

Implications

Implications for Theories of Driver Behaviour

Many theories of driver behaviour assume that drivers are consciously motivated to maintain an acceptable level of risk, comfort, or task difficulty (Fuller, 2005; Lewis-Evans & Rothengatter, 2009; Summala, 1988, 1996; Wilde, 1982, 1998). The main implication from this research for motivational theories of driver behaviour is that drivers do not appear to be consciously motivated by any explicit desire to focus on any aspect of driving. Participant drivers frequently reported thoughts indirectly related to avoiding collisions, but these were typically reactions to the behaviour of other road users.

Avoiding risk (for example) may well govern behaviour at an unconscious level, but findings from this research suggest that drivers are not consciously motivated in that way at all. Further analysis of thought samples during everyday driving could be used to understand more about theories of driver behaviour. In particular, thought sampling could be used to explore which aspects of the driving task tend to capture drivers' attention, and whether drivers' focus is triggered by risk; comfort; task difficulty; a combination of these; or by other factors.

Evidence from the on-road studies in this thesis is generally consistent with the findings of Charlton & Starkey (2011, 2013), insofar as it appears that an active, conscious operating process is only engaged temporarily and when necessary, in response to some emergent situation or when a driver simply decides to 'pay attention'. Most of the time, an unconscious monitoring process governs most aspects of the driving task without conscious intervention.

The idea that one or more monitoring processes are constantly scanning the environment suggests that driving is not the only 'task' going on for a driver as they make their way along the road, and driving itself is not a standalone activity. Driving is just part of the day; people drive to get where they are going. For this reason, many drivers on their way to work or home reported thoughts related to where they came from and where they were going. Indeed, several drivers reported that they used driving time to organise their lives, planning their evening or creating a mental shopping list. Other drivers used the time to relax, listening to a favourite radio show or to music. The main conclusions concerning theories of driver behaviour are that drivers are not constantly focused on the driving task by default; they do not appear to be explicitly motivated to avoid risk but may have implicit motivations, as revealed by analysis of driving-related thought samples; and that driving task focus is typically experienced as an interruption to a driver's otherwise meandering stream of consciousness.

Implications for Theories of Mind Wandering

Findings from this research provide evidence both for and against contemporary theories of mind wandering. In general terms, the findings support the Theory of Current Concerns; provide mixed evidence concerning the Theories of Perceptual Decoupling and Failure of Executive Control; and are generally consistent with the Context Regulation Hypothesis.

The Theory of Current Concerns (Klinger, 1975) suggests that people focus on whatever provides the greatest momentary payoff, in a trade-off of risk and reward. Some results from the current research supported this theory. For example, several drivers in the on-road studies reported thinking about a relative when they passed a street where their relative lives, or used to live. These thoughts often triggered deeper reflections on some aspect of their relative's life or of their relationship (for example "My Dad used to live there, he died earlier this year. I was thinking about my Dad"). As humans, drivers do not entirely disconnect from the deeper aspects of their lives when they are driving. Rather, when momentary task demands are low, they sometimes use driving time to dwell on personal concerns and reflect on the nature of their lives. However, in the absence of more understanding of where, when and how mind wandering happens, the suggestion that drivers focus on whatever provides the greatest momentary reward does little to aid understanding of drivers' cognition or of the consequences of mind wandering.

The Theory of Perceptual Decoupling suggests that mind wandering is enabled because ongoing sensory perception and motor control are decoupled from conscious focus (Smallwood & Schooler, 2006), albeit that decoupling is not absolute (Smallwood & Schooler, 2015). Results from on-road studies in this thesis support the notion that perceptual decoupling is not absolute. Drivers appeared to be engaged to some degree in the sensory world even during mind wandering, because task focus was often triggered when warranted. Also, many of drivers' task-unrelated thoughts were triggered by what drivers saw or heard. Sometimes, driving-related thoughts were experienced as an abrupt interruption to mind wandering unrelated to the sensory environment, suggest that mind wandering is more complex than an absolute decoupling of perception from conscious thought.

The most pertinent evidence against the Theory of Failure of Executive Control (McVay & Kane, 2010) was the frequency of mind wandering during everyday driving. It did not appear that drivers set out to focus on driving as an explicit goal. Participants in the on-road studies were no more likely to focus on driving when they were first asked to state what they were thinking about, than at any other time during the drive. If driving focus were an explicit goal, it is conceivable that mind wandering may have been more likely the further the drive progressed, which was not the case. In addition, the finding from the final study that drivers were systematically more likely to apply conscious focus at roundabouts, regardless of momentary demand or site-specific crash risk, suggest that the return to task focus is not driven by an explicit decision but is an implicit, learned behaviour.

In contrast, these findings are consistent with the Context Regulation Hypothesis (Smallwood & Andrews-Hanna) in part, because drivers were significantly more likely to report focus on driving at places where crash risk was higher in general (that is, at roundabouts), which were also places of higher task demand, on average. At roundabouts drivers are required to give way to traffic and negotiate the intersection, which is a higher level of demand than is usually experienced at midblocks or intersections where a driver has priority. The task context affected drivers' likelihood to report mind wandering when asked what they were thinking about. However, the Context Regulation Hypothesis suggests that mind wandering is more likely in situations of low demand (Smallwood & Andrews-Hanna, 2013). Evidence from this research suggests that it is conscious focus that is regulated and temporary, limited to situations of high (or unknown) demand. The difference between these two perspectives is subtle but important because the current results suggest that mind wandering is characteristic of thinking during everyday driving, rather than an exceptional or unusual phenomenon.

Implications for Road Safety

This research has not provided any evidence that mind wandering causes crashes. Rather than an isolated 'behaviour' that practitioners could discourage, these results have demonstrated that mind wandering is a characteristic of normal everyday driving. Improved understanding of the ways that drivers behave, and the knowledge that driving includes mind wandering, can help practitioners to design road networks that keep drives safe regardless of whether their momentary conscious focus is related to driving or not.

Road safety engineers can take mind wandering during driving into account in two main ways. First, designers can build ‘self-explaining roads’ (Theeuwes & Godthelp, 1995). Self-explaining roads afford safe driving behaviour because safe driving speeds are elicited by design, with clear differences in the ‘look and feel’ between different levels of road in a hierarchy. Narrow streets and ‘shared spaces’ are designed for places where people mix with traffic, such as residential streets and shopping centres. At the opposite end of the road hierarchy, motorways afford high speeds with wide traffic lanes, grade-separated intersections and an absence of pedestrians or cyclists. Levels in between the extremes of shared spaces and motorways rely on differences in road markings and the provision of appropriate walking and cycling infrastructure to communicate safe and appropriate speed and behaviour to all road users. Self-explaining roads result in more homogeneity of speeds within categories and a reduction in crash risk compared with roads developed without the same design philosophy (Charlton et al., 2010).

The second way that road safety engineers can account for mind wandering during everyday driving is to capture drivers’ focus with conspicuous, salient cues in the driving environment, where necessary. This research has found that drivers tend to focus their attention at subjectively risky places, or in response to salient cues. Road safety engineers can use this knowledge by placing cues in situations that warrant conscious driving task focus. Intersections with constrained visibility (because of the location of buildings or hills, for example), roadworks sites, and pedestrian crossings in high-speed areas are all examples of situations that may warrant conspicuous cues such as road signs with flashing lights that are activated by an approaching vehicle. Further, road safety practitioners ought to limit their reliance on static road signs that do not add to drivers’ ability to negotiate roads safely. Drivers often fail to detect static road signs (Charlton, 2004), so limiting their use to only the most risky places helps to make those situations conspicuous, and therefore more likely to command drivers’ conscious focus.

Strengths and Limitations

It should be clear from the studies described in this thesis that understanding mind wandering and its association with crash risk is a complex undertaking. Mind wandering is a common but covert, inherently unobservable behaviour. On the other hand, while crashes are well documented, they are extremely rare events. Studying mind wandering during driving using thought sampling of drivers in their own cars was a novel approach. Analysis of crash patterns and comparing their variation to patterns in reported mind wandering was also a different way to address the issue. Findings from all of the studies in this thesis therefore presented new insights towards understanding mind wandering. The on-road studies and analyses of crash patterns also provide precedents for new and adapted research methods to explore the nature of mind wandering and its association with risk.

The methods used in this thesis (on-road experience sampling, and large-scale analyses of crash and travel data) were novel in the context of mind wandering research. The success of the experience sampling methods in the present research suggests that it could be usefully extended to other situations and other aspects of driving. The investigations of mind wandering and crash risk based on patterns in travel and crashes at a population level were also a new way to explore potential consequences of mind wandering. Using a range of different research methods can lead to new and more detailed insights into conscious experience than are likely from application of a limited selection of approaches. It is therefore recommended that researchers continue to seek out new methods to address complex mental phenomena.

Notwithstanding the usefulness of the novel methods presented in this thesis, several important limitations must be considered if results are to be built on to improve understanding of mind wandering and to inform road safety interventions. The main limitations relate to the relatively small sample sizes in the on-road studies, and the limited range of road situations studied for both the crash analyses, and on-road driving studies.

Only 11 participants were recruited for Study Two, and 25 participants for Study Five. Although rich, useful data were obtained, studies with more (or different) participants may have potential to reveal more subtle insights concerning the nature of mind wandering during everyday driving, particularly in terms of age differences. All of the participants in Study Two were women aged 25-50, so more research with younger or older drivers may have built on differences found in Study One, wherein younger drivers reported most mind wandering and older drivers reported least. It is unclear whether the differences in mind wandering frequencies would have resulted in the same kinds of regulation of drivers' attention on real streets.

The on-road studies were almost entirely limited to familiar urban roads in a relatively small city. The setting was useful to explore a range of road situations, but future research ought to consider a broader range of driving contexts. Some different types of roads that could be used to study mind wandering in more depth might include long rural roads; motorways; and busier urban environments such as Central Business Districts.

This research included analyses of crash patterns, but individual crashes were not analysed to establish whether mind wandering may have played a causal role. Such analysis (as attempted by Galera et al., 2012) would in any case be problematic, because establishing mind wandering in retrospect, based on a driver's memory, is unreliable (Corballis, 2015). Furthermore, even if a driver is focused on the task, they may not have been focused on the specific emerging hazard that ultimately led to the crash. Mind wandering is common during safe driving, and there is no strong evidence from crash patterns to suggest that it causes crashes.

Finally, the nature of thought sampling means that research is limited to analysis of what participants report about their contents of consciousness. Analysis of mind wandering as a distinct and separable component of the stream of consciousness is necessary but insufficient to understand its true nature. Reliance on thought samples is necessary because we have no more authentic insight into thought content. However, the stream of consciousness is dynamic and complex. For as long as psychologists have studied attention, they have recognised that its reduction to discrete components is incomplete. As noted by William James (1890), attention has a focus, a fringe, and a margin. Further research into the interaction of drivers' unconscious and conscious processes may help to illuminate what is at the margins of conscious thought. Driving is a useful domain in which to study these processes, because it is clear that drivers process a considerable amount of sensory information that does not reach consciousness.

Recommendations for Future Research

It is recommended that thought sampling of drivers in their own cars on real streets is adopted by more researchers as a valid and useful way to study conscious experience. As well as providing insights into driver behaviour, research in everyday contexts provides opportunity to test mind wandering theories and results from laboratory studies, benefitting the science of mind wandering while providing potential for practical applications that can help understand human performance.

Thought sampling methods could be usefully extended to explore more about differences in thought content, beyond dichotomies of mind wandering and task focus, and sensory versus internal triggers. There is potential to look deeper to understand more about the consequences of being ‘lost in thought’, compared with more ‘shallow’ mind wandering where a person is relatively more engaged in the task.

In relation to mind wandering and driving, a useful next step would be to extend the methods beyond urban roads, exploring mind wandering and its variation on longer trips where demanding situations are rare. The interaction of patterns of mind wandering with fatigue would be a useful extension.

In summary, it is recommended that researchers continue to explore the nature and prevalence of mind wandering, to better understand why it occurs; how its occurrence varies in different contexts; and what cognitive mechanisms support it. It may be possible in future to use technology such as fMRI to gain increasingly detailed insights into how mind wandering is experienced. Conscious experience is complex and largely covert. Understanding of mind wandering can only benefit from continued application of creative and sophisticated research methods.

Conclusions

This thesis set out to explore how often drivers’ minds wander, and to investigate the association between mind wandering and crash risk. It is concluded that drivers’ minds wander often, over half of the time on familiar urban roads. There is no clear causal link between mind wandering and crash risk. Mind wandering is a normal characteristic of safe, everyday driving.

The research has contributed several novel insights about mind wandering during everyday driving. Results supported aspects of the Context Regulation Hypothesis (Smallwood & Andrews-Hanna, 2013), and built on evidence from Kane et al. (2017) suggesting that research of mind wandering in everyday contexts is important. The results suggested that drivers may have implicit motivations based on factors such as risk (Summala, 1988), but do not set out with driving focus of any kind as an explicit goal. Results were consistent with the tandem model of driver behaviour (Charlton & Starkey, 2011), suggesting that driving task focus is the exception rather than the rule during everyday driving.

Synthesis of crash data and thought samples suggest an inverse association between mind wandering and crash risk, although the link is not clearly causal. Occasional failures in the interaction of drivers' conscious and unconscious processes might sometimes contribute towards crashes, but proving a causal link between mind wandering and crash risk would be difficult. Pursuit of mind wandering as a harmful form of distraction is unlikely to help efforts to improve road safety, because mind wandering is normal and widespread. Conversely, drivers can be kept safe through consistent, self-explaining road design that allows for mind wandering.

As a whole this thesis has contributed to growing knowledge about mind wandering, but in the context of everyday driving as a common activity in everyday life. Mind wandering is ubiquitous, not a separable state, and therefore ought to be recognised as a normal component of a driver's stream of consciousness. Researchers and practitioners can work with this new knowledge to continue to learn more about attention, and to design environments that afford normal mental behaviours while keeping people safe from their consequences.

Future research could usefully extend this work by looking beyond dichotomies of broad experience sampling and artificial laboratory studies. Analysis of thought samples could also be improved through exploring their complexities beyond basic categories of mind wandering or task focus. More creative and nuanced analyses of the way people think when going about everyday activities could provide useful advances in understanding the workings of human minds.

What must be admitted is that the definite images of traditional psychology form but the very smallest part of our minds as they actually live. The traditional psychology talks like one who should say the river consists of nothing but pailful, spoonful, quartpotsful, barrelsful, and other moulded forms of water. Even were the pails and the pots all actually standing in the stream, still between them the free water would continue to flow. It is just this free water of consciousness that psychologists resolutely overlook.

James, 1890, p225

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Appendix: Publication Co-Authorship Forms

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Chapter 3, Study One.

Published article: Burdett, B. R., Charlton, S. G., & Starkey, N. J. (2016). Not all minds wander equally: The influence of traits, states and road environment factors on self-reported mind wandering during everyday driving. *Accident Analysis & Prevention*, *95*, 1-7.

Nature of contribution by PhD candidate	Bridget Burdett developed the research question and study methods in collaboration with co-authors; collected all of the data; analysed the data with advice from co-authors; and wrote the manuscript with advice and feedback from co-authors.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

Name	Nature of Contribution
Samuel G. Charlton	Assistance developing research questions and methods; advice regarding analysis; review of drafts
Nicola J. Starkey	Assistance developing research questions and methods; advice regarding analysis; review of drafts

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
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Chapter 4, Study Two.

Published article: Burdett, B. R., Charlton, S. G., & Starkey, N. J. (2017). Inside the commuting driver's wandering mind. *Transportation Research Part F: Traffic Psychology and Behaviour*.

Nature of contribution by PhD candidate	Bridget Burdett developed the research question and study methods in collaboration with co-authors; collected all of the data; analysed the data with advice from co-authors; and wrote the manuscript with advice and feedback from co-authors.
Extent of contribution by PhD candidate (%)	80%

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Nicola J. Starkey	Assistance developing research questions and methods; advice regarding analysis; review of drafts

Certification by Co-Authors

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Chapter 5, Study Three.

Published article: Burdett, B. R., Starkey, N. J., & Charlton, S. G. (2017). The close to home effect in road crashes. *Safety Science, 98*, 1-8.

Nature of contribution by PhD candidate	Bridget Burdett developed the research question and study methods in collaboration with co-authors; collected all of the data; analysed the data with advice from co-authors; and wrote the manuscript with advice and feedback from co-authors.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

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Samuel G. Charlton	Assistance developing research questions and methods; advice regarding analysis; review of drafts

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Chapter 6, Study Four.

Published article: Burdett, B. R., Starkey, N. J., & Charlton, S. G. (2018). Characteristics of the close to home crash. *Safety Science*, *105*, 222-227.

Nature of contribution by PhD candidate	Bridget Burdett developed the research question and study methods in collaboration with co-authors; collected all of the data; analysed the data with advice from co-authors; and wrote the manuscript with advice and feedback from co-authors.
Extent of contribution by PhD candidate (%)	80%

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Chapter 7, Study Five.

Manuscript under review: Burdett, B. R., Charlton, S. G., & Starkey, N. J. (2018). Mind wandering during everyday driving. *Manuscript under review.*

Nature of contribution by PhD candidate	Bridget Burdett developed the research question and study methods in collaboration with co-authors; collected all of the data; analysed the data with advice from co-authors; and wrote the manuscript with advice and feedback from co-authors.
Extent of contribution by PhD candidate (%)	80%

CO-AUTHORS

Name	Nature of Contribution
Samuel G. Charlton	Assistance developing research questions and methods; advice regarding analysis; review of drafts
Nicola J. Starkey	Assistance developing research questions and methods; advice regarding analysis; review of drafts

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and

Name	Signature	Date
Samuel G. Charlton	[signature]	15-06-18
Nicola J. Starkey	[signature]	15/6/18