Mind Wandering and Young Driver Crash Risk:

Examining a Causal Mechanism and Mitigation Strategy

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List of Abbreviations

FD = Focused Driving

GLMM = General Linear Mixed Model

H = Hypothesis

IMI = Intrinsic Motivation Inventory

LMM = Linear Mixed Model

MT = Mindfulness Training

MW = Mind Wandering

Neg = Negative Mood

Neu = Neutral Mood

PANAS = Positive and Negative Affect Schedule

PMR = Progressive Muscle Relaxation

PMW = Probe-Caught Mind Wandering

RAT = Remote Associates Test

RRS = Ruminative Response Scale

SMS = State Mindfulness Scale

SMW = Self-Caught Mind Wandering

T1 = Pre-Manipulation / Pre-Intervention

T2 = Post-Manipulation / Post-Intervention

Abstract

Road traffic crashes are the leading killer of young people. Driver distraction is a major contributor to crashes, especially in young drivers. Evidence links mind wandering, a form of distraction involving task-unrelated thoughts, to unsafe driving and crashes. However, a lack of research into potential causes and mitigators of unsafe driving linked to mind wandering currently leaves young drivers exposed to this threat. Therefore, in two manuscripts, the present thesis assessed: i) whether negative mood causally contributes to mind wandering and associated unsafe driving behaviours, with potential moderation of these effects by individual traits; and ii) whether brief online mindfulness training can feasibly enhance awareness of mind wandering and reduce its occurrence in young drivers as a potential means to reduce unsafe driving and crashes. The first manuscript reports on a randomized, controlled, and single-blinded experiment in which 40 healthy male drivers, aged 20–24, were assigned to either a negative mood (experimental condition) or a neutral mood (control condition). Following exposure to negative mood, driving simulation results revealed greater mind wandering and unsafe driving linked to mind wandering, in terms of headway variability and steering behaviour. Rumination tendency positively moderated the relationship between negative mood and mind wandering while driving. The second manuscript reports on a randomized, placebo-controlled, and double-blinded pilot trial in which 26 young drivers (male and female), aged 21–25, were exposed to 4–6 days of either mindfulness training (experimental condition) or progressive muscle relaxation (control condition), delivered through online audio recordings. Compared to controls, exposure to mindfulness training reduced mind wandering while driving in simulation. Mindfulness training elicited greater self-reported mindfulness. Motivation did not differ between groups or explain

the effects of mindfulness training. Variation in driving behaviour as well as adherence, dropout, and acceptability of mindfulness training, were also explored. Results from these preliminary studies suggest that mind wandering and related unsafe driving can be: i) caused by negative mood; and ii) mitigated by mindfulness training. These results may inform the development and targeting of interventions to address the threat of mind wandering to vulnerable young drivers.

Résumé

Les collisions routières sont la première cause de mortalité chez les jeunes. La distraction au volant est un facteur important associé à ces collisions. Des études ont démontré un lien entre l'errance mentale (ou *mind wandering*), une forme de distraction impliquant des pensées sans rapport avec la tâche et l'implication dans les comportements routiers à risque et les collisions. Cependant, le manque d'études sur les causes potentielles et les facteurs atténuants de la conduite à risque associée à l'errance mentale empêche de protéger les jeunes conducteur·rice·s face à ce danger. Par conséquent, deux manuscrits de la présente thèse évaluent: i) si l'humeur négative contribue de manière causale à l'errance mentale et aux comportements routiers à risque, avec une modération potentielle de ces effets par des traits individuels; et ii) si une brève formation en ligne à la pleine conscience peut améliorer la prise de conscience de l'errance mentale et en atténuer l'apparition chez les jeunes conducteur·rice·s comme moyen potentiel de réduire les comportements routiers à risque et les collisions liés à l'errance mentale. Le premier manuscrit rend compte d'une expérimentation contrôlée, randomisée, à simple insu, dans laquelle 40 jeunes conducteurs masculins, âgés de 20 à 24 ans, sont assignés aléatoirement à une humeur négative (condition expérimentale) ou neutre (condition contrôle). Suite à l'exposition à une humeur négative, les résultats de la simulation de conduite ont révélé une errance mentale plus élevée et plus de comportements à risque liés à l'errance mentale, en termes de variabilité dans la distance de suivi du véhicule précédent et dans la position du volant. La tendance à la rumination modère à la hausse la relation entre l'humeur négative et l'errance mentale pendant la conduite. Le second manuscrit rend compte d'un essai pilote randomisé, à double insu, dans lequel 26 jeunes conducteur·rice·s âgé·e·s de 21 à 25 ans ont été exposé·e·s pendant quatre à six jours à une formation à la pleine conscience (groupe expérimental) ou à la relaxation musculaire progressive (groupe témoin), dispensée par le biais d'enregistrements audio en ligne. Pendant la conduite en simulation, l’errance mentale était moins élevée chez le groupe expérimental que chez le groupe témoin. L'entraînement à la pleine conscience a suscité une plus grande capacité d’autoévaluation de la pleine conscience. La motivation ne diffère pas entre les groupes et n'explique pas les effets de la formation à la pleine conscience. Les variations dans les comportements de conduite ainsi que l'adhésion, l'abandon et l'acceptabilité des formations en ligne ont également été explorées. Les résultats de ces études montrent que l’errance mentale et les comportements routiers à risque peuvent être: i) causés par l’humeur négative; et ii) atténués par la pleine conscience. Les résultats de ces études peuvent contribuer à l'élaboration et au ciblage d'interventions visant à lutter contre les dangers de l’errance mentale pour les jeunes conducteur·rice·s vulnérables.

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I would like to express my sincere gratitude to my supervisor, Dr. Thomas G. Brown, for his unfailing support and dedicated mentorship. This thesis would not have been possible without his inspiration, guidance, and feedback. The intellectual rigor that I have learned from him over the years will undoubtedly support me in my career moving forward.

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In Study 1, we would like to thank: Jay Olson for consulting on the deception used for blinding, and for programming computerized tasks; Amédée d'Aboville for retrofitting the driving simulator with thought sampling and psychophysiological measurement capabilities; Nevicia Case, Nathan Moxley-Kelly, and Manal Eldeb for inspiration and feedback on the study design and methods; Lucie Legault and Lysiane Robidoux-Leonard for administrative and coordination activities; and Ali Kerem Araboglu for assisting with piloting, recruitment, and data collection.

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Contribution to Original Knowledge

Research has yet to fully explain why young drivers are overrepresented in road traffic crashes (Rolison & Moutari, 2020). Mind wandering (MW), which includes thoughts that are unrelated to ongoing tasks or the immediate environment, has recently been recognized as a prevalent crash risk factor (Galéra et al., 2012). Despite a growing number of studies on MW while driving, few appear to address its potential contribution to young driver crash risk (Albert et al., 2018; Burdett et al., 2016; Walker & Trick, 2018). This thesis aims to address the threat of MW in young drivers by isolating negative mood as a potential cause and exploring mindfulness as a potential mitigator of MW while driving in this population. This thesis reports on two novel experiments that directly test the effects of these factors on MW and MW-related unsafe driving in simulation. Existing cross-sectional evidence links individual differences in driver emotions and thoughts to self-reported unsafe driving (Scott-Parker, 2017; Suhr, 2016; Suhr & Dula, 2017; Suhr & Nesbit, 2013). A few experiments also test the impact of negative mood on driver attention and behaviour (Steinhauser et al., 2018; Techer et al., 2017; Zimasa et al., 2019). None appear to directly test the causal contribution of negative mood to MW while driving and acute changes in driving behaviour associated with it, however (Study 1). Existing cross-sectional evidence links greater mindfulness to less MW and safer driving (Koppel et al., 2019; K. L. Young et al., 2019). Two studies also explore the viability of mindfulness training (MT) as a means to enhance driver attention and reduce unsafe driving (Baltruschat et al., 2021; Kass et al., 2011). None appear to directly examine the effects of MT on driver awareness and MW while driving in simulation, however (Study 2). Study 2 further explores the feasibility of brief online mindfulness training, deployed via a custom website designed to facilitate randomized controlled trials, in young drivers.

Contribution of Authors

I conceptualized both Study 1 and Study 2. I also designed both of the studies, under the guidance and supervision of Dr. Brown and Dr. Ouimet. The driving simulator, used to measure driving behaviour in both studies, was developed by Dr. Ouimet and her team at the University of Sherbrooke. With the assistance of a software developer colleague (Amédée d'Aboville), I developed the thought sampling and electrocardiography apparatus, which was retrofitted to the driving simulator, and used to measure MW while driving in both of the studies, and heart rate in Study 1. With the assistance of a software developer colleague (Sam Watkinson), I also developed the custom study website that was used in Study 2 to automatically and blindly randomize participants to interventions, deliver assigned intervention recordings, objectively track adherence, and administer post-session questionnaires. I recorded and produced the audio mindfulness training and progressive muscle relaxation intervention sessions, used as the experimental and control interventions, respectively, in Study 2, with the assistance of a voice-actor colleague (Colin Courtney). I collected and supervised the collection of data for both studies. I analyzed and visualized the data for both studies, under the guidance and supervision of Dr. Brown and Dr. Ouimet. I wrote and edited both Study 1 and Study 2 manuscripts, with review and editing support from Dr. Brown and Dr. Ouimet. Finally, Dr. Brown and Dr. Ouimet were involved in funding acquisition for both studies.

General Introduction

The Young Driver Problem

Each year more than 1.35 million people die from road traffic crashes worldwide, while approximately 50 million suffer life-altering injuries. Road traffic crashes are the leading cause of death among young people from ages 5–29 years (World Health Organization, 2015, 2018). In Canada and abroad, young drivers under 25 are consistently overrepresented in crashes resulting in fatalities and injuries (Transport Canada, 2020). An estimated 90% of road traffic crashes are caused by human factors (Dingus et al., 2016). In young drivers, inexperience, risk-taking, and alcohol or drug-related impairment partially account for their disproportionate involvement in fatal and injurious crashes (Ivers et al., 2009; Jonah & Boase, 2016). Yet, these factors leave unexplained a substantial proportion of young driver crashes (Rolison & Moutari, 2020). Therefore, clarifying additional pathways that lead to crashes in young drivers may be necessary to effectively address this endemic threat to their safety (Ouimet et al., 2011).

Driver Distraction in Young Drivers

A prevalent contributor to road traffic crashes that distinguishes young from older drivers is driver distraction – when drivers divert their attention from critical aspects of driving towards a competing activity (Regan et al., 2011; Regan & Strayer, 2014). For instance, texting and making phone calls are competing activities that have dominated concern among researchers, parents, and government officials for over a decade (Huemer et al., 2018). Drivers spend approximately 50% of their real-world driving time engaged in some form of distraction, which is estimated to account for more than half of all road traffic crashes (Dingus et al., 2016). Recent evidence suggests that young drivers are particularly prone to distraction and distraction-related crashes.

Specifically, drivers under 30 years of age have been found to engage in 11–13% more distraction than drivers 30–64 years of age, and 41–44% more distraction than drivers over 65 years of age (Guo et al., 2017). Furthermore, the likelihood of a crash resulting from distraction is up to 1.61 times higher in young compared to older drivers (Rahman et al., 2021). Given these age-related differences, driver distraction may be a significant contributor to the young driver problem.

Young drivers may be particularly susceptible to certain forms of distraction. Driver distraction can be characterized as visual, manual, and/or cognitive (K. L. Young & Salmon, 2012). For instance, texting on a mobile phone engenders visual and manual distraction, since it requires drivers to glance away from the road (i.e., visual distraction) and remove their hands from the steering wheel (i.e., manual distraction). In contrast, cognitive distraction may occur in the absence of these behaviours, as it specifically relates to engagement in driving-unrelated thoughts (Qin et al., 2019; Savage et al., 2020). For instance, hands-free phone calls engender cognitive distraction, since drivers divert their attention to the conversation, despite maintaining a normal driving posture (i.e., eyes and head forward, hands on the steering wheel). Like visual and manual distraction, cognitive distraction is linked to crashes (Caird et al., 2018; Horrey & Wickens, 2006). Notably, crash risk linked to cognitive distraction is greater in young compared to older drivers (Choudhary & Velaga, 2018; Guo et al., 2017). Therefore, uncovering prevalent sources of cognitive distraction in young drivers may be key to addressing this vulnerability.

Mind Wandering While Driving

MW is an ubiquitous source of cognitive distraction. MW encompasses thoughts, including daydreams, that are typically unintentional, unrelated to ongoing tasks, and/or independent from events in one's environment (Seli et al., 2018). Thinking about a past conversation, unfinished work tasks, or upcoming weekend plans while reading this text, for example, would constitute MW. Studies reveal that people spend 30–50% of their daily lives engaged in MW (Kane et al., 2007; Killingsworth & Gilbert, 2010). Although MW adaptively facilitates planning and creative problem solving (McMillan et al., 2013; Mooneyham & Schooler, 2013), it also competes with ongoing tasks for attention (Kane et al., 2007; Smallwood & Schooler, 2006). Thus, MW can be distracting. MW has been linked to poor task performance and absentminded errors, such as looking at but failing to see a lost item or losing track of an ongoing task (Smilek et al., 2010). Thus, MW can impact performance of everyday tasks, which may have fatal consequences in the context of driving.

Until recently, MW was largely overlooked in traffic safety research. Since its inclusion in Regan and colleagues' (2011) seminal taxonomy of driving distraction, however, MW has gained recognition as a likely contributor to crashes. Evidence linking retrospective self-reports of MW to crashes supports this hypothesis. Specifically, case-control studies with drivers interviewed immediately following a crash, consistently find that MW predicts crash responsibility, with odds ratios ranging from 1.90 to 2.51 (Farouki et al., 2014; Galéra et al., 2012; Gil-Jardiné et al., 2017; Née et al., 2019). A large survey of Australian drivers similarly found that 8.82% of respondents attributed one or more of their crashes in the past three years to MW, which accounted for 42% of all distraction-related crashes (McEvoy et al., 2006). In a sample of German drivers, MW was reported as the leading cause of at-fault crash and near-crash events (Fofanova & Vollrath, 2012). These findings suggest that MW can lead to crashes, but research has yet to elucidate its specific contribution to crashes in young drivers.

Young drivers may be particularly vulnerable to the risks of MW while driving. Across various contexts, young people are found to engage in more MW than older adults (Jordão et al., 2019; Maillet et al., 2018; McVay et al., 2013; Seli et al., 2020). In the driving context, self-reported MW frequency is inversely related to driver age (Burdett et al., 2016). Legislation prohibiting the use of mobile phones while driving has proven effective in managing visual-manual distraction (Rudisill et al., 2018; Rudisill & Zhu, 2017). Compliance and enforcement issues prevent such laws from addressing MW, however. In fact, evidence suggests that drivers are likely to engage in more cognitive distraction, including MW, when no other distraction sources are present (Carpenter & Nguyen, 2015; Nijboer et al., 2016; Nowosielski et al., 2018). Therefore, MW currently represents an unmitigated threat to young driver safety.

In sum, road traffic crashes are a prevalent and ongoing threat to drivers under 25 years of age. The vast majority of crashes in this population are linked to human factors, yet research has yet to account for a substantial proportion of driver-related factors. Driver distraction is a major contributor to road traffic crashes. While effective legal interventions exist, they cannot address cognitive distraction, which is particularly prevalent and risky in young drivers. MW is a newly recognized form of cognitive distraction that has been linked to crashes. MW is particularly prevalent in young drivers, but its causes in this population are unclear. Furthermore, mitigating factors and strategies that may reduce the threat of MW have yet to be investigated.

The Present Thesis

The present thesis aims to address the contribution of MW to young driver crash risk by isolating negative mood as a potential cause and exploring mindfulness as a potential mitigator of MW while driving in this population. The ultimate aim of this research, is to inform the development of interventions capable of disrupting MW-related crash-risk pathways and that can be targeted to address the specific needs of vulnerable young drivers.

Structure of the Thesis

The present thesis consists of four main sections: a narrative literature review, two manuscripts, and a general discussion. The narrative review incorporates evidence from psychology, neuroscience, and traffic safety research to address three questions pertaining to the mechanisms by which MW may contribute to crashes in young drivers. Specifically, the review addresses: i) how MW may contribute to road traffic crashes; ii) what potentially makes young drivers susceptible to MW; and iii) whether negative mood potentially causes and mindfulness potentially mitigates MW while driving in young drivers. The first manuscript (study 1) reports on a randomized controlled experiment examining the effects of negative mood on MW frequency and MW-related unsafe driving behaviours that are associated with crashes, such as speeding, in a sample of young male drivers. Young males were selected for Study 1 because of their frequent involvement in fatal and injury crashes, and their propensity for unsafe driving. Study 1 also examines the moderating contributions of individual differences in attention regulation capacities. The second manuscript (study 2) reports on a pilot randomized controlled trial exploring the feasibility and preliminary efficacy of brief online mindfulness training for reducing MW-related distraction in a sample of young male and female drivers. Finally, a general discussion section summarizes and synthesizes main findings of the thesis, discusses its strengths and limitations, and proposes future directions for research on MW while driving in young drivers.

Common Methods

Studies 1 and 2 share three common methodological elements: pre-post, randomized, controlled, and blinded (single and double, respectively) experimental designs; thought sampling to measure MW; and driving simulation to measure driving behaviour. Furthermore, many studies referenced in the narrative review incorporate thought sampling and driving simulation, although randomized, controlled experimental designs are less common.

Experimental Design

Randomized, controlled designs are the gold standard for delivering high-quality evidence in experimental and clinical research. MW is highly variable both between (Robison et al., 2020) and within (Thomson et al., 2015) individuals. Hence, the capacity of randomized, controlled designs to minimize confounds pertaining to individual differences and time is critical for ensuring internal validity in MW studies (Hariton & Locascio, 2018). Blinding is also critical to control for non-specific factors that can influence MW, such as motivation (Seli et al., 2019) and participant-experimenter interactions (M. D. Mrazek et al., 2011). Blinding is relatively rare in traffic safety research and studies of MW in psychology, however. Finally, using a pre-post methodology and mixed modeling enabled us to maximize power by eliminating baseline variability and including all participants in analyses despite missing data. Use of these strong methods usures that findings, while preliminary, are high-quality and worthy of future replication attempts.

Driving Simulation

Both studies used the same driving simulator and driving scenario to measure unsafe driving behaviour. This consistency between studies facilitates comparisons of findings in the general discussion. Driving simulators are capable of both relative and absolute validity in predicting real-world driving behaviour (Wynne et al., 2019). Specifically, for relative validity, both between-group and between-condition differences in driving behaviour in simulation predict similar relationships in real-world driving (e.g., Group A drives faster than Group B in both simulation and on the road). For absolute validity, findings from simulation match those from real-world driving (e.g., driving speed was 50 km/h both in simulation and on the road). Validity varies by simulator, however. The simulator used in both studies of the present thesis demonstrates convergent validity, with simulated driving behaviour predicting self-reported real-world driving (Brown et al., 2016; Ouimet et al., 2020), and ecological validity, with simulated driving behaviour predicting real-world traffic violations (Brown et al., 2017). Thus, findings from driving simulation in the present thesis are likely to concord with real-world driving.

Thought Sampling

Both studies used thought sampling to measure MW in driving simulation. Thought sampling is a self-report measure of MW that is commonly used both inside and outside of the lab (Killingsworth & Gilbert, 2010; McVay et al., 2009). Self-report measures are essential for measuring MW, since it is an inherently covert phenomenon (Smallwood & Schooler, 2015). Thought sampling is an "online" measure insofar as participants report on their thoughts in the moment, as distinct from "offline" measures where they report on their thoughts retrospectively. Thought sampling may incorporate thought probes (e.g., sounds or on-screen messages), which prompt participants to indicate whether, immediately before the probe, they were engaged in MW (probe-caught MW) or focused on the current task. Thought sampling may also involve have participants indicate (e.g., by pressing a button) whenever they catch themselves engaging in MW (self-caught MW). Thought sampling facilitates a more fine-grained assessment of momentary

MW-related changes in behaviour and physiology than retrospective self-reports, while minimizing potential confounds related to memory. At the same time, thought sampling has been found to corroborate findings from retrospective MW measures (Barron et al., 2011; Franklin, Broadway, et al., 2013; Kam et al., 2010; Smallwood et al., 2011, 2012).

A Narrative Review of Potential Mechanisms Linking Mind Wandering to Young Driver Crashes

In this section, findings from psychology, neuroscience, and traffic safety research are reviewed to uncover the mechanisms by which MW may contribute to crashes in young drivers. This review addresses three questions. First, the question of how MW may contribute to road traffic crashes (question 1) is addressed by reviewing evidence for sensory-motor decoupling, a cognitive process implicated in MW-related task performance deficits, and its potential contribution to poor driver vigilance and unsafe driving behaviours that are associated with crashes (e.g., speeding). Second, the question of what makes young drivers particularly susceptible to MW (question 2) is addressed by reviewing evidence for developmental changes in attention that may predispose young drivers to dysregulation of MW while driving. Third, the question of whether negative mood potentially causes and mindfulness potentially mitigates MW while driving in young drivers (question 3) is addressed by reviewing evidence linking these factors to variation in real-world attention, unsafe driving, and crashes. Finally, the review concludes with a summary of findings.

Methods

A narrative review methodology was selected to accommodate the disparate and interdisciplinary nature of research on MW, young drivers, and traffic safety. Research on MW while driving was used to address all three questions posed in the review. Therefore, an extensive search for relevant studies on this topic was conducted using the following search query of titles, abstracts, and keywords from journal articles and conference publications: (“self-generated thought" OR "mind wandering" OR "daydreaming" OR "task-unrelated thought" OR "irrelevant thought" OR "stimulus-independent thought" OR "internalized thought" OR "internal thought”)

AND driving AND vehicle. Primary sources included Web of Science, PubMed, Scopus, and the Transportation Research International Documentation database. Google Scholar was used as a supplementary source. Inclusion criteria were the following: the study incorporated a self-report, behavioral, or physiological measure of state or trait MW; the study incorporated a self-report or behavioral measure of driving behavior or crash risk; the study was written in English. Student theses, white papers or reports, and conference publications based on the same data as full journal articles were excluded. Google Scholar and literature review citations were used to locate studies on the following: the cognitive mechanisms of MW as well as links between driving behaviors and crashes to address question 1; links between neurocognitive development and attention to address question 2; and links between negative mood, mindfulness, MW, and unsafe driving, to address question 3.

How Does Mind Wandering Contribute To Road Traffic Crashes?

Sensory-Motor Decoupling

Sensory-motor decoupling (a.k.a. perceptual decoupling), a cognitive process proposed to explain associations between MW and task-performance deficits, may also explain associations between MW and crashes. MW engenders a diversion or decoupling of attention from sensory inputs, such as vision, and motor outputs, such as hand movements, to self-generated thoughts (Schooler et al., 2011; Smallwood, 2013). This process of sensory-motor decoupling is evident from electrocortical and behavioural data revealing a global attenuation of sensory information processing and behavioural performance monitoring associated with self-reports of MW (Kam & Handy, 2013). For instance, MW has been linked to reduced orienting of attention to task-relevant cues (Hu et al., 2012; Kam et al., 2013) as well as attenuated cortical responses to both task-relevant and task-irrelevant, visual and auditory stimuli (Barron et al., 2011; Kam et al., 2010). These findings reveal an attenuation of sensory information processing associated with MW, which could impact the ability of drivers to quickly detect and respond to unexpected road hazards. Associations between MW and variable response times (Seli et al., 2013), failures to inhibition automatic responses (Smallwood et al., 2004; Smallwood, McSpadden, et al., 2007), and imprecise fine motor movements (e.g., error in tracking a moving target with a computer mouse)(Dias da Silva & Postma, 2021; Kam et al., 2012) reveal its attenuation of behavioural performance monitoring. These findings suggest that MW could interfere with the ability of drivers to safely maintain control of their vehicles. Taken together, sensory-motor decoupling may be a critical mechanism linking MW to unsafe driving and crashes.

Sensory-Motor Decoupling and Poor Hazard Detection

MW is linked to behavioural and neural indicators of poor hazard detection in drivers, which may reflect sensory-motor decoupling and could increase crash risk. A behavioural predictor of hazard detection is horizontal eye movements. Greater horizontal gaze dispersion in particular (i.e., standard deviation of horizontal gaze position), facilitates the detection of peripheral roadway hazards, such as passing vehicles, or pedestrians entering the roadway (Rosner et al., 2019). Hence, a decrease in horizontal gaze dispersion could contribute to a crash. Self-reported MW, and induced MW-like distraction, have been linked to lower horizontal gaze dispersion compared to focused driving in simulation (He et al., 2011; Lemercier et al., 2014). MW is also associated with longer gaze fixations, which indicates less visual scanning of the roadway (Pepin et al., 2018). Other oculomotor predictors of poor hazard detection, such as decreased pupil diameter, greater blink frequency, and longer blink durations have also been associated with

MW (Körber et al., 2015). In addition to these behavioural findings, neural evidence links MW to attenuated visual-event-related potentials from lead-vehicle brake lights (Pepin et al., 2020). This finding aligns with those linking MW to attenuated sensory information processing in attention tasks. Taken together, these findings suggest that poor hazard detection associated with sensory-motor decoupling may mediate the relationship between MW and crashes.

Sensory-Motor Decoupling and Slow Reaction Times

MW is also associated with slow reaction times to road hazards, which further suggests that sensory-motor decoupling mediates the relationship between MW and crashes. Compared to undistracted drivers, those distracted by secondary tasks (e.g., phone use) exhibit slow reaction times to unexpected road hazards (e.g., lead vehicle braking)(Gao & Davis, 2017; Savage et al., 2020). These slow reactions are proposed to reflect the additional time needed to reorient attention before assessing the situation and generating a response. In simulation, MW is similarly found to predict slow reaction times to sudden braking (Pepin et al., 2020) and peripheral hazards (Yanko & Spalek, 2014). Thus, reorienting, or recoupling, attention from self-generated thoughts similarly imposes a reaction time delay as seen with visual-manual distraction. Reaction time data from simulation also links sensory-motor decoupling to MW-related changes in lane-keeping, which relates to the ability of drivers to keep their vehicle in its lane. In one study, drivers performed a lane-keeping task while their cortical activity was recorded. In the task, drivers had to course-correct as soon as their vehicle automatically started to drift from its lane. Results revealed a correlation between greater MW-related cortical activity slow reaction times, which meant that the vehicle was allowed to drift further from its lane (C.-T. Lin et al., 2016). These findings suggest that MW-related sensory-motor decoupling may prevent drivers from quickly detecting and responding to hazards, which may, in turn, lead to a crash.

Sensory-Motor Decoupling and Poor Vehicle Control

Sensory-motor decoupling may also impact performance monitoring in drivers, which could explain links between MW and potentially unsafe changes in vehicle control. Longitudinal control relates to variations in driving behaviour in terms of forward and backwards motion of the vehicle. For instance, speeding is a longitudinal control-related crash risk factor (Aarts & van Schagen, 2006; Hamzeie et al., 2017). In driving simulation, faster and more variable driving speeds have been observed prior to self-reports of MW versus focused driving (Baldwin et al., 2017; Rajendran & Balasubramanian, 2019; Yanko & Spalek, 2014; Zhang & Kumada, 2017). Furthermore, individual differences in the tendency to engage in MW, based on sustained attention task performance, were found to predict faster driving in simulation (Albert et al., 2018). Interestingly, the same study also found a positive correlation between MW tendency and mean gaze position, which may reflect less glances towards the speedometer. Hence, MW-related sensory-motor decoupling may reduce longitudinal control as a function of decreased performance monitoring. Self-reports of MW have also been linked to shorter headways in simulation, which relates to the distance between the driver's vehicle and the nearest vehicle ahead (i.e., lead vehicle)(Yanko & Spalek, 2014). Shorter headways, especially when coupled with faster driving, reduce the time available for drivers to react before crashing into a lead vehicle, if it were to suddenly brake. Accordingly, shorter headways are associated with greater crash likelihood (Hyun et al., 2019). In sum, sensory-motor decoupling associated with MW may increase crash risk as a function of poor longitudinal control.

Lateral control relates to variations in driving behavior in terms of side-to-side motion of the vehicle. Common metrics of lateral control include steering wheel position variability and steering reversal rate (i.e., number of clockwise to counter-clockwise, or vice versa, turns of the steering wheel over a certain degree threshold). These behaviors are mainly relevant to crashes in terms of how they relate to lane-keeping. Poor lane-keeping can lead to run-off-road crashes (Allen et al., 1996; Ghasemzadeh & Ahmed, 2017, 2018). Some lane-keeping-specific indices of lateral control include mean deviation (distance) from lane center, lane position variability, time-to-line crossing, and number of lane excursions. Evidence from driving simulation reveals positive associations between MW and steering wheel position variability, deviations from lane center, and lane position variability, compared to focused driving (Almahasneh et al., 2014; Cowley, 2013; Zhang & Kumada, 2017). These findings suggest that sensory-motor decoupling associated with MW may decrease the ability of drivers to monitor and regulate their lane position. One study found MW-related improvement in lane-keeping, however (i.e., fewer steering reversals, decreased lane deviation, decreased standard deviation of lane position)(Baldwin et al., 2017). This contradictory finding may relate to methodological differences. For instance, the studies that reported poor lane-keeping from MW incorporated turns or curves in simulation, whereas the study reporting improved lane-keeping used straight roads. Thus, the association between MW and poor lane-keeping may be limited to curved roads. Overall, these findings suggest that MW-related sensory-motor decoupling may contribute to crashes as a function of poor lateral control.

What Makes Young Drivers Particularly Susceptible To Mind Wandering?

Exploration Versus Exploitation

Exploration and exploitation reflect different modes of attention and thought. Exploration reflects a diffuse and open-ended state of attention, while exploitation reflects a focused and goal-directed state of attention (Hills et al., 2015). MW is associated with exploration, since it typically involves frequent and random transitions from one thought to another. Furthermore, the collection of brain regions that support MW are found to be functionally distinct from those that support goal-directed attention and thought (Sripada, 2018). Compared to older adults, young adults engage in less exploitation and more exploration, as indicated by less time spent searching within a given area (e.g., for fish in a pond) and more time spent searching between areas (e.g., different ponds)(Mata et al., 2013). Greater exploration-related behaviour has also been found to correlate with greater MW in young compared to older adults (Moran et al., 2021). Thus, the propensity of young drivers to engage in MW while driving could be explained by their developmental bias towards exploration.

Context Regulation of MW

MW represents the default state of human attention (Thomson et al., 2015). However, individuals regulate their MW to account for their circumstances, or context. This functions to prevent MW from interfering with ongoing task performance (Smallwood, 2013; Smallwood & Andrews-Hanna, 2013). Accordingly, MW is least frequent during complex or novel tasks that demand significant attention (Smallwood, Nind, et al., 2009; Turnbull et al., 2019) and most frequent during simple or familiar tasks that demand little attention (Christoff et al., 2009; McVay & Kane, 2010; Smallwood & Schooler, 2006). In real-world driving, MW in drivers was found to be negatively associated with traffic volume, speed limit, and roadway complexity (e.g., roundabout = high complexity)(Berthié et al., 2015; Burdett et al., 2016, 2019). Driving simulation experiments reveal similar findings (Geden et al., 2018; Rajendran & Balasubramanian, 2019), including low MW in harsh weather conditions (He et al., 2011). Thus, drivers reduce their MW to account for the complexity of driving scenarios. Although MW is less likely to occur in a complex driving scenario, it may be particular unsafe when it does. For instance, in one study, MW was associated with faster driving in a complex driving condition, whereas it was associated with slower driving in a simple driving condition (Geden et al., 2018). Therefore, failure to regulate MW in complex driving scenarios may significantly increase unsafe driving and crash risk.

Developmental Processes Linked to Unsafe Driving and Driver Distraction

The dual-process framework is proposed to explain why young people are prone to maladaptive risk-taking, but it may also have implications for distraction in young drivers. The theory posits that asynchronous processes of neurocognitive development predispose adolescents and young adults to engage in risk-taking behaviours, including drug use, unsafe sex, and risky driving (Shulman et al., 2016; Steinberg et al., 2008). Two neurocognitive systems are implicated: the socioemotional system, which includes limbic and paralimbic areas of the brain, and; the cognitive control system, which includes the lateral prefrontal and parietal cortices, as well as parts of the anterior cingulate cortex. The socioemotional system underpins sensation and reward seeking, particularly in terms of romantic motivation, sexual interest, and emotional intensity. Development of this system is proposed to start in puberty, with its level of sensitivity following an inverted U-shaped curve that peaks in mid-adolescence (≈ 16 years of age)(Luna & Wright, 2016; Shulman et al., 2015; Steinberg et al., 2008). The cognitive control system underpins impulse control and is proposed to develop linearly until it plateaus in late-adolescence or early adulthood (≈ 25 years of age)(Harden & Tucker-Drob, 2011; Quinn & Harden, 2013). The mismatch in maturity between these two systems (i.e., high sensation seeking, low impulse control) is proposed to increase risky driving and crashes in later adolescents and young adults (Lambert et al., 2014; Ross et al., 2016). These processes have also been proposed to interact with young driver attention (Romer et al., 2014). Therefore, the dual-process framework may have similar implications for MW-related crash risk in this population.

Developmental Processes Linked to MW

Brain networks (i.e., functionally connected groups of brain regions) that make up the socioemotional and cognitive control systems are proposed to regulate MW (Christoff et al., 2016). The salience network, which attributes emotional significance to thoughts and stimuli, is an important part of the socioemotional system (Rosen et al., 2018; van Hoorn et al., 2019). It is proposed to automatically (i.e., without effort or intention) constrain attention to emotionally salient thoughts, which can result in certain forms of MW (e.g., thinking about a recent breakup). Conversely, the frontoparietal control network, which facilitates goal-directed thoughts and behaviours, makes up part of the cognitive control system (Hwang et al., 2010; van Belle et al., 2014) and is proposed to inhibit MW when it could interfere with an active goal (e.g., studying for an exam or driving safely). Therefore, the developmental asynchrony between systems that is attributed to risky driving and driver distraction may also contribute to risky MW in young drivers.

Which Factors Might Cause And Mitigate Mind Wandering In Young Drivers?

Negative Mood

Young drivers are particularly susceptible to negative moods, which may increase MW-related crash risk. Young people frequently experience intense emotions due to early maturation of the socioemotional system and exposure to novel stressors (e.g., academic and social)(Casey et al., 2010). Slower maturation of cognitive control in young adults also limits their capacity for emotion regulation, or the ability to override automatic emotion-related thoughts and behaviours (K. Young et al., 2019). Accordingly, young people are at greater risk of developing psychiatric disorders involving mood and MW dysregulation (Beesdo et al., 2010; Lee et al., 2014), which can increase crash risk. For example, relative to the general population, crash risk is higher among sufferers of depression, which is characterized by negative mood and rumination, a form MW that is negatively valanced, repetitive, and intrusive (Aduen et al., 2018; Hill et al., 2017). Notably, depression-related crash risk is higher in young (aged 18–24) compared to older drivers (aged 25–44) (McDonald et al., 2014). Stressful life events (e.g., divorce, work or financial issues) in the general population are also associated with crashes attributable to ruminative MW (Cunningham & Regan, 2016). In healthy young drivers, negative mood predicts self-reports of MW and difficulty concentrating in simulation (Walker & Trick, 2018). Therefore, developmental factors may predispose young drivers to crashes linked to negative mood-related MW.

Negative mood can increase MW frequency and intensity. In the general population, self-reports of negative mood and MW, collected via smartphones, correlate across various real-life contexts (Franklin, Mrazek, et al., 2013; Killingsworth & Gilbert, 2010). Similarly, negative mood has been found to predict subsequent, negatively valanced MW (i.e., negative MW) (Poerio et al., 2013). Experimental evidence from inducing negative mood supports a causal relationship to MW and associated lapses in sustained attention (i.e., as indicated by errors on sustained attention tasks)(Marcusson-Clavertz et al., 2020; Smallwood, Fitzgerald, et al., 2009). Therefore, negative mood may increase the frequency of MW while driving. Negative mood may also increase the intensity of MW and related unsafe driving behaviours. Task performance deficits associated with negative MW are more pronounced than those associated with neutral or positive MW (Banks et al., 2016; Goller et al., 2020). Faster heart rates have been found to accompany elevated task performance deficits associated with MW among sufferers of dysphoria, a psychiatric condition characterized by persistent negative mood (Smallwood, O'Connor, et al., 2007). This finding suggests that their poor performance may be linked to MW that is more emotionally arousing. Therefore, negative mood may cause frequent and intense MW that increases unsafe driving.

Simulation studies have used mood and attention manipulations to indirectly assess the role of MW in unsafe driving caused by negative mood. For example, relative to neutral mood, negative mood was found to result in poor lateral control accompanied by attenuated visual event-related potentials, which may be indicative of sensory-motor decoupling from MW (Techer et al., 2017). Interactions revealed in studies where both negative mood and task demands were manipulated imply a mediating contribution of MW to negative mood-related unsafe driving. In particular, unsafe driving was observed following a negative versus positive mood induction, but only in the simpler of two driving tasks (Steinhauser et al., 2018). In another study, the effects of negative mood on driving behaviour were found to decrease when drivers were continuously asked driving-related questions in simulation (Zimasa et al., 2019). Given the tendency for MW to decrease as task demands on attention increase, findings from both studies implicate MW in unsafe driving resulting from negative mood.

Trait rumination may predispose some young drivers more than others to negative MW, unsafe driving, and crashes. Trait rumination describes the habit or tendency to ruminate in response to negative moods (Nolen-Hoeksema et al., 2008; van Vugt et al., 2018). Trait rumination has been linked to concentration difficulties (Lyubomirsky et al., 2003), self-reports of unintentional MW (Vannucci & Chiorri, 2018), and sustained attention task errors (Nayda & Takarangi, 2021). Furthermore, poor emotion regulation, characterized by high trait rumination, was found to moderate increases in sustained attention task errors resulting from a negative versus neutral mood induction (King, 2020). Thus, high trait ruminators may be less capable of regulating negative MW to account for task demands. In the driving context, survey data reveals trait rumination (i.e., anger rumination) to be a mediator in the relationship between proneness to negative emotions while driving (i.e., driving anger) and engagement in unsafe driving behaviours (Suhr & Dula, 2017; Suhr & Nesbit, 2013). Similarly, high trait MW (i.e., the tendency to engage in MW, generally) was found to predict negative mood-related unsafe driving (Qu et al., 2015). Taken together, these findings suggest that trait rumination may moderate associations between negative mood, MW, and unsafe driving.

Inhibitory control may also explain variability in negative mood-related MW and unsafe driving. Inhibitory control is a facet of cognitive control involved in stopping or overriding thoughts and behaviours that could interfere with an active goal (Diamond, 2013; Miller & Cohen, 2001; Miyake et al., 2000). For instance, it negatively predicts MW during activities that require concentration (Kane et al., 2007; McVay & Kane, 2009). Inhibitory control is proposed to be a core mechanism of emotion regulation (Bartholomew et al., 2021; Carver & Johnson, 2018). Accordingly, poor inhibitory control hinders disengagement from rumination (Y. Yang et al., 2017; Zetsche et al., 2018). For example, inducing negative mood was found to increase MW in an attention task, but only among individuals with poor inhibitory control (i.e., high sub-clinical Attention Deficit Hyperactivity Disorder symptoms)(Jonkman et al., 2017). In the driving context, poor inhibitory control predicts faster driving and more self-reported driving errors (e.g., failing to see pedestrians)(Albert et al., 2018; Daly et al., 2014; Sani et al., 2017). Therefore, poor inhibitory control may prevent young drivers from regulating negative mood-related MW, which may, in turn, increase unsafe driving and crash risk.

Mindfulness

Metacognition may support MW regulation and thus compensate for the immature cognitive control capacities of young drivers. Metacognition refers to processes of thinking about thinking which facilitate conscious awareness, knowledge, and control of one's mental states (Schooler & Smallwood, 2009). Metacognition interacts with cognitive control to direct and focus attention (Fleming & Dolan, 2012; Roebers, 2017). Development and training of metacognitive skills (i.e., self-reflection, monitoring and analyzing behaviour) have been found to enhance cognitive control and learning in children and adolescents (Fleur et al., 2021; Pozuelos et al., 2019; Schaeffner et al., 2021; Weil et al., 2013). Furthermore, metacognitive skills were found to negatively mediate maladaptive outcomes (i.e., emotional distress) associated with developmental susceptibilities of young people (McKewen et al., 2019). Thus, metacognitive skills may be protective in this population. Furthermore, training metacognitive skills may reduce unsafe MW and driving associated with developmental susceptibilities in young drivers.

Metacognitive skills associated with mindfulness may protect against MW-related distraction. The concept of mindfulness originates from Buddhist traditions (Dunne, 2015). In psychology, mindfulness is defined as a state and trait capacity for “paying attention in a particular way: on purpose, in the present moment, and non-judgementally” (Kabat-Zinn, 1994). Operationalizations of mindfulness vary (Davidson & Kaszniak, 2015; Van Dam et al., 2018), but most include attentive awareness of present-moment experience (Anālayo, 2019; Baminiwatta & Solangaarachchi, 2021; Bishop et al., 2004). Since MW typically involves disengaging attention from present-moment experience, mindfulness is proposed to represent an opposing mode of sustained non-distraction (M. D. Mrazek et al., 2012, 2014). This notion is supported by negative correlations between mindfulness (both state and trait) and self-report as well as behavioural indications of MW (Fountain-Zaragoza et al., 2018; Ju & Lien, 2018; M. D. Mrazek et al., 2012). Mindfulness is thought to involve metacognitive skills related to detection and disengagement from MW (Bernstein et al., 2019; Jankowski & Holas, 2014). Therefore, mindfulness training may enhance these metacognitive skills, thus leading to reductions in MW while driving.

Mindfulness training (MT) incorporates metacognitive practices, such as meditation, that aim to cultivate state mindfulness and, over time, trait mindfulness (Kiken et al., 2015). Of particular relevance to reducing MW is focused attention meditation, which involves sustaining attention to a chosen focal point, such as the breath, noticing when MW occurs (i.e., metacognitive monitoring), and non-judgementally reorienting attention back to the focal point (i.e., metacognitive control)(Lutz et al., 2008; Wielgosz et al., 2019). MT interventions, of which Mindfulness-Based stress Reduction (MBSR) is the most prolific, typically involve eight weeks of daily individual practice and weekly group practice (Santorelli, 2014; Santorelli et al., 2017).

Mounting evidence from randomized controlled trials reveals MBSR, and related interventions, to be effective in enhancing cognitive control and reducing MW (Feruglio et al., 2021; Prakash, 2021; Verhaeghen, 2021). Furthermore, brief MT interventions, consisting of only four to five sessions, have also been shown to reduce MW (Rahl et al., 2017; Tang et al., 2007, 2009; Zeidan et al., 2010). Therefore, MT may be effective in reducing MW while driving.

MT is proposed to reduce MW-related distraction, in part, by enhancing metacognitive awareness of its occurrence (Brandmeyer & Delorme, 2021). Metacognitive awareness, or meta-awareness, refers to reflexive awareness of ongoing thoughts and sensations (Schooler, 2002). MW can occur in the absence of meta-awareness. For example, it is common to catch oneself MW after having scanned, but failed to read, several sentences. If meta-awareness was present, one would likely stop reading to engage in MW, or discontinue MW to read, to avoid distraction. Thus, meta-awareness may enable the regulation of MW, which could explain why MW-related task performance deficits are less pronounced when meta-awareness is present (Schooler et al., 2011). Studies using both spontaneous self-reports and thought probes to assess MW with meta-awareness (i.e., meta-aware) and without meta-awareness (i.e., meta-unaware), respectively, show greater reading comprehension deficits (Smallwood et al., 2008) and poorer behavioural inhibition associated with meta-unaware MW (Smallwood, McSpadden, et al., 2007). In the driving context, survey evidence suggests that immediate noticing of MW is protective against MW-related unsafe driving (i.e., 88.7% of immediate noticers indicated no impairment, 55.1% of delayed noticers indicated significant impairment) (Berthié et al., 2015). Similarly, both trait and state meta-awareness of MW have been found to predict safer driving behaviour in simulation

(Albert et al., 2018; Cowley, 2013). Therefore, cultivating meta-awareness of MW through MT may reduce its occurrence and contribution to unsafe driving.

MT exposure may reduce MW-related crash risk. Greater trait mindfulness is protective against driver distraction, including MW. Specifically, drivers that are high compared to low in trait mindfulness report less engagement in MW (Burdett et al., 2016; G. Murphy & Matvienko-Sikar, 2019) and visual-manual distraction (e.g., phone use)(Feldman et al., 2011; Moore & Brown, 2019; G. Murphy & Matvienko-Sikar, 2019; Panek et al., 2015) while driving. Trait mindfulness also negatively predicts distraction-related unsafe driving, such as driving errors, traffic violations, and near-crash events (Burdett et al., 2016; G. Murphy & Matvienko-Sikar, 2019; Terry & Terry, 2015). Relatedly, driver trait mindfulness positively predicts consideration of future consequences, which is a cognitive control process that negatively predicts risky driving (e.g., speeding, tailgating, driving while impaired)(L. Murphy & Murphy, 2018). Critically, while few studies test the effects of MT exposure in the context of driving, available evidence suggests that MT can enhance driver situational awareness (Kass et al., 2010), reduce risky driving, and reduce crashes in simulation. Therefore, MT may reduce MW, MW-related unsafe driving, and crashes in young drivers.

Summary

We set out to determine: how MW may contribute to road traffic crashes; why young drivers may be prone to MW; and which factors may cause and mitigate MW in young drivers. Firstly, in psychology, sensory-motor decoupling has been implicated in MW-related task performance deficits. Evidence from the traffic safety literature supports this notion with respect to MW-related unsafe driving behaviours. Specifically, this is supported by links between MW and poor detection of road hazards, delayed reaction times to hazards, and poor longitudinal and lateral vehicle control. Secondly, a developmental bias towards an exploration versus exploitation mode of attention is proposed to explain why young people are prone to adaptive MW and risk-taking behaviour. Asynchronous development of certain neurological systems is proposed to contribute to maladaptive risk-taking young people. These systems overlap with those that regulate attention and thus young drivers may similarly be predisposed to maladaptive or unsafe MW. Finally, we found evidence that young drivers may be particularly susceptible to negative moods due to poor emotion regulation. Negative mood has been found to causes increases in MW. Therefore, negative mood may increase MW while driving and related unsafe driving behaviours in young drivers. Furthermore, individual differences in trait rumination and inhibitory control may particularly disadvantage some young drivers to negative mood-related MW. We also found evidence to suggest that metacognitive training may enhance development of cognitive control in young people. Mindfulness appears to rely on metacognitive skills that contribute to sustained non-distraction from MW. Evidence suggests that MT, involving meditation practices that cultivate metacognitive skills, such as meta-awareness, is effective in reducing MW-related distraction. Furthermore, evidence suggests that trait mindfulness may be protective against MW unsafe driving, and crashes. Preliminary evidence also suggests that MT may reduce unsafe driving and crashes. In conclusion, MW is a likely contributor to the young driver problem. Further research investigating the underlying causes of MW-related crash risk in young drivers, as well as potential mitigating factors, may inform strategies to address this endemic threat.

Preface to Study 1

In the previous section, evidence was found to suggest that young drivers are particularly susceptible to negative mood-related MW due to their developmental propensity to experience intense emotions and limited capacity to regulate associated thoughts and behaviours. Evidence was also found linking negative mood to MW while driving in young drivers (Walker & Trick, 2018). Furthermore, negative mood was revealed to cause MW in non-driving contexts (Marcusson-Clavertz et al., 2020; Poerio et al., 2013; Smallwood, Fitzgerald, et al., 2009). Review evidence also suggested that negative mood may increase the intensity of MW or cause it to become more ruminative, which may increase crash risk associated with MW. For instance, dysphoric individuals were found to exhibit more task errors, coupled with higher heart rates associated with MW (Smallwood, O'Connor, et al., 2007). Furthermore, depression symptoms, including negative mood and rumination, were found to predict unsafe driving behaviours associated with crashes (McDonald et al., 2014), while stressful life events predicted distraction-related driving errors and crashes (Cunningham & Regan, 2016). Taken together, these findings suggest that in young drivers, negative mood may increase MW frequency and intensity, in terms of greater sensory-motor decoupling, which could manifest and more unsafe driving associated with MW.

The following section reports on Study 1, which aimed to test whether, compared to neutral mood, negative mood leads to more: H1) frequent MW while driving; H2) unsafe driving linked to MW; and H3) intense or emotionally arousing MW while driving. Study 1 also examined the potential moderating contributions of trait rumination and inhibitory control to supported relationships along this pathway. The manuscript that follows was submitted for publication in Accident Analysis and Prevention and is currently under revision (please see letter from the editor in Appendix A). A summary of results for the main hypotheses of Study 1, including all effect sizes, can be found in Tables S.1 and S.2 of the supplementary material that follows. Furthermore, sample size calculations for future studies powered to detect small-to-medium effects of negative mood on MW-related unsafe driving can also be found in the supplementary material of Study 1.

Negative Mood Mind Wandering and Unsafe Driving in Young Male Drivers

Abstract

Objective

Road traffic crashes disproportionately affect young male drivers. Driver distraction, which includes mind wandering (MW), is a leading cause of unsafe driving and crashes. Negative mood can lead to MW, and thus may represent a causal pathway to unsafe driving linked to MW. This preliminary pre-post (T1, T2), randomized, controlled, single-blinded experiment tested whether negative mood, compared to neutral mood, increases MW while driving, unsafe driving linked to MW, and emotional arousal linked to MW. It also tested the moderating contribution of trait rumination and inhibitory control to this proposed causal pathway.

Methods

Forty healthy male drivers aged 20 to 24 were randomly allocated to a negative or neutral mood manipulation involving deception. Individual differences in trait rumination and inhibitory control were measured at T1. At T1 and T2, participants drove in a driving simulator measuring driving speed, headway distance, steering behaviour, and overtaking. Heart rate and thought probes during simulation measured emotional arousal and MW, respectively.

Results

Negative mood exposure led to more MW while driving. Trait rumination positively moderated the relationship between negative mood and MW. Unsafe driving, in the form of greater headway variability and steering behaviour during MW, increased following negative versus neutral mood exposure. Between-group differences in emotional arousal were not significant.

Conclusion

Results support a causal pathway from negative mood to unsafe driving via MW, including the moderating contribution of trait rumination. These findings may inform the development and targeting of interventions to disrupt this crash-risk pathway and in young driver subgroups.

Keywords: young drivers, negative mood, mind wandering, driving simulation

Introduction

Drivers under 25 years of age are overrepresented in fatal crashes (World Health Organization, 2018). In young drivers, distraction is a leading contributor to crashes (Guo et al., 2017), which are particularly prevalent in males (Cullen et al., 2021). Driver distraction entails a diversion of attention from activities critical for safe driving towards a competing activity. This may include secondary tasks, such as texting or calling, which have been studied extensively in the context of traffic safety (Lipovac et al., 2017; Zatezalo et al., 2018). Another competing activity is mind wandering (MW), involving driving-unrelated thoughts (Regan & Hallett, 2011; Seli et al., 2018). MW is gaining recognition as a distraction-related contributor to crashes (Lerner et al., 2015). Little is known about the causal factors involved in MW-related crashes, a gap that hinders the development of interventions targeting this risk factor in young drivers.

MW adaptively facilitates planning, decision-making, and creativity, but can also engender distraction (Smallwood et al., 2013; Smallwood & Schooler, 2006). MW accounts for 30–50% of waking thoughts and thus potentially represents a pervasive source of driver distraction (Kane et al., 2007; Killingsworth & Gilbert, 2010). Specifically, MW entails a diversion or *decoupling* of attention from ongoing tasks and external stimuli to personal concerns and other self-generated thoughts (Schooler et al., 2011). MW is linked to unsafe driving behaviours, such as faster and more variable driving speeds, shorter headway distances, and more variable steering (Baldwin et al., 2017; Yanko & Spalek, 2014; Zhang & Kumada, 2017), which may account for its association with crashes (Aarts & Van Schagen, 2006; Ding et al., 2020; Gil-Jardiné et al., 2017; Li et al., 2018). Thus, MW while driving can be maladaptive, yet it is especially frequent in young drivers (Burdett et al., 2019). Exploring factors that may compel young drivers to engage in MW while driving could reveal amenable intervention targets to reduce MW-related crashes.

Driver-related factors, such as negative mood, may increase the frequency of MW while driving. Contextual factors are known to cause fluctuations in MW. For example, increasing driving task difficulty decreases MW (Geden & Feng, 2015; Zhang & Kumada, 2017). In contrast, negative mood is associated with greater MW across a variety of contexts, including driving (Ottaviani et al., 2015; Poerio et al., 2013). Specifically in young drivers, negative mood is associated with greater MW while driving in a simulator and post-drive self-reports of concentration difficulties (Walker & Trick, 2018). Furthermore, inducing negative mood leads to greater MW in attention tasks (Marcusson-Clavertz et al., 2020; Smallwood et al., 2009). Therefore, negative mood may increase MW frequency and, in turn, unsafe driving in young drivers.

Negative mood may increase MW intensity and thereby its acute effects on driving. Rumination refers to an intense form of MW that persistently centres on one's emotional distress and its circumstances. It is a hallmark of mood disorders, but also pervasively affects healthy individuals (Nolen-Hoeksema et al., 1997; Watkins, 2008). Rumination, or ruminative MW, is often intrusive and difficult to inhibit (Ottaviani et al., 2013). It is associated with greater emotional arousal, objectively observable through increased heart rate, and greater task performance deficits compared to non-ruminative MW (Smallwood et al., 2007). Young people are particularly susceptible to fluctuations in emotional arousal (Lambert et al., 2014; Steinberg, 2010). Therefore, negative mood may increase the intensity or ruminative quality of MW, thereby increasing its effects on unsafe driving in this population. Together, these findings implicate MW in a causal pathway from negative mood to unsafe driving.

Individual differences in trait rumination and inhibitory control may moderate links between negative mood, MW, and unsafe driving. Trait rumination denotes the tendency to engage in ruminative MW (Nolen-Hoeksema et al., 2008). In attention tasks, trait rumination positively predicts self-reports of MW, while trait brooding, a judgmental subcomponent of trait rumination, also predicts MW-related errors (Nayda & Takarangi, 2021). Trait rumination, coupled with a propensity to experience negative moods while driving, also correlates with self-reported unsafe driving behaviours (Suhr & Dula, 2017; Suhr & Nesbit, 2013). Thus, young drivers high in trait rumination may be particularly susceptible to negative mood MW (i.e., negative mood-related MW) and unsafe driving.

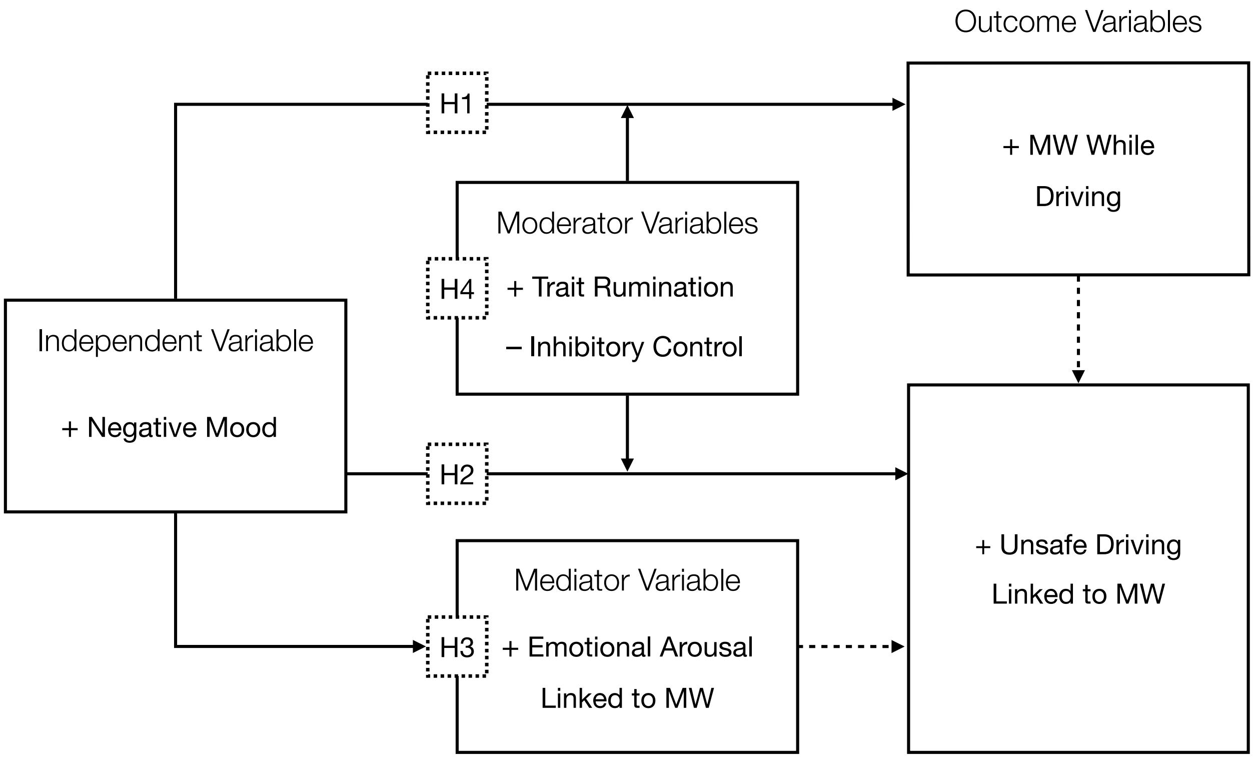
Low inhibitory control may impede efforts to mitigate the effects of negative mood on MW and driving. Inhibitory control denotes the capacity to override thoughts and behaviours that may result from negative moods (Diamond, 2013). Low inhibitory control is associated with greater MW in lab tasks and daily activities that require concentration (Kane et al., 2007; McVay & Kane, 2009). It also predicts unsafe driving behaviours linked to MW, such as speeding and failing to notice pedestrians (Albert et al., 2018; Sani et al., 2017). Thus, low inhibitory control may prevent young drivers from regulating negative mood MW, thereby strengthening its involvement in the proposed pathway from negative mood to unsafe driving.

Mounting evidence supports a causal relationship between negative mood and unsafe driving (Cunningham & Regan, 2016; Pêcher et al., 2011; Scott-Parker, 2017). Some studies also hint at the involvement of MW, but none directly test this possibility. For example, negative mood was found to cause more unsafe driving in low versus high-difficulty driving tasks (Steinhauser et al., 2018) and in the absence versus presence of a secondary task (Zimasa et al., 2019). Since MW is most frequent when task demands on attention are low (Geden & Feng, 2015; Smallwood, 2013), these findings suggest that MW may partially explain the effects of negative mood on unsafe driving. Findings also suggest that negative mood MW may contribute to specific unsafe driving behaviours previously associated with negative moods, such as greater headway variability (Steinhauser et al., 2018) and risky overtaking (Emo et al., 2016; Matthews et al., 1998). This preliminary study aimed to address these possibilities by directly observing the role of MW in the relationship between negative mood and unsafe driving.

Accordingly, we tested the proposed causal pathway, illustrated in Figure 1, leading from negative mood to unsafe driving behaviours via increases in MW frequency and intensity in healthy young male drivers. Specifically, we hypothesized that, compared to neutral mood, negative mood leads to more: H1) frequent MW while driving; H2) unsafe driving linked to MW; and H3) intense or emotionally arousing MW while driving. This study also examined the moderating contributions of trait rumination and inhibitory control to supported relationships along this pathway. We hypothesized that H4) trait rumination positively moderates and inhibitory control negatively moderates mood-related differences in MW and unsafe driving linked to MW. Furthermore, this study explored whether increases in MW frequency and intensity mediate relationships between negative mood and unsafe driving behaviour. Understanding the causal relationships between negative mood, MW frequency, MW intensity, and unsafe driving may inform the development of interventions to disrupt this crash-risk pathway. Examining the contribution of individual differences could facilitate the targeting of interventions to address vulnerable young driver subgroups, and thus better prevent crashes in this population.

Figure 1

Proposed Causal Pathway from Negative Mood to Mind Wandering and Unsafe Driving



Note. MW = mind wandering. Solid-lines represent the hypothesized effects of negative mood on mind wandering, emotional arousal, and unsafe driving linked to mind wandering. They also show the proposed moderation of these relationships by trait rumination and inhibitory control. Dashed-lines represent exploratory hypotheses for the mediating roles of mind wandering and emotional arousal in the relationship between negative mood and unsafe driving.

Materials and Methods

Study Site and Ethical Compliance

The study took place at the Addiction Research Program Laboratory of the Douglas Hospital Research Centre, a McGill University-affiliated site in Montreal, Canada. Study procedures were approved by the Douglas Mental Health University Institute Research Ethics Board (IUSMD-17-20).

Recruitment

Participants were recruited via advertisements on Facebook, Kijiji, and university classifieds. Study candidates responding to the advertisements were first screened online and again at the lab to verify their online responses and assess additional inclusion/exclusion criteria. To participate, study candidates had to meet the following criteria: self-reported male sex; age 20–24, based on date of birth; valid driving license; self-reported normal or corrected vision and hearing. Males between 20–24 were recruited to isolate a particularly risky young driver subgroup (Rhodes et al., 2015). This age range also controlled for developmental changes in attention and behaviour regulation (Quinn & Harden, 2013).

Candidates were excluded if they self-reported the following: a history of driving while impaired, since offenders exhibit neuropsychological and behavioural differences from average drivers (Brown et al., 2016); a diagnosed head injury, chronic illness, neurological condition, or mental disorder (e.g., seizures, attention deficit hyperactivity disorder, or bipolar disorder); depression symptoms (i.e., total scores ≥ 14 on the Beck Depression Inventory II; Beck et al., 1996); alcohol dependence symptoms (i.e., total scores ≥ 2 on items 4 and 6 of the Alcohol Use Disorders Identification Test; Johnson et al., 2013; Saunders et al., 1993); drug dependence symptoms (i.e., total scores ≥ 2 on items 6 and 8 of the Drug Use Disorders Identification Test; Berman et al., 2003; Hildebrand, 2015). Candidates with these mental or physical health issues or symptoms were excluded to control for their confounding influence on normal MW rates and content (Sayette et al., 2009, 2010; Smallwood, 2013). The following exclusion criteria were assessed at the lab: detectable blood alcohol content, measured with an Alco-Sensor® IV; driving simulator sickness, self-reported after a practice simulation. Intoxicated drivers and those with driving simulator sickness were excluded to prevent data contamination.

Study Design and Randomization

The present study used a pre-post (T1, T2), randomized, controlled, single-blinded design. Participants were allocated equally (1:1) to undergo either a negative mood (experimental) or neutral mood (control) manipulation, using biased-coin minimization (Saghaei, 2011; Saghaei & Saghaei, 2011). It accounted for T1 positive mood (low: 0–3.80, high: 3.90–5.00) and negative mood (low: 0–1.30, high: 1.40–5.00), measured by mean response scores on the Positive and Negative Affect Schedule (PANAS-NA; Watson et al., 1988). It also accounted for T1 MW (low: 0–0.43, high: 0.57–1), measured with thought probes in computerized tasks (Smallwood & Schooler, 2015). Randomization took place immediately before the mood manipulation.

Mood Manipulation

Participants were exposed to a pass-fail manipulation designed to induce either a negative mood (fail) or neutral mood (pass) (Chartier & Ranieri, 1989; Nummenmaa & Niemi, 2004). The manipulation involved deception. Participants were told they would undergo a "verbal reasoning and intelligence test" when, in fact, they completed the Remote Associations Test (Mednick, 1962), which measures creativity. Participants had 30 seconds, indicated by a timer in the bottom-right corner of the screen, to type a word that paired with each of three given words (e.g., political, surprise, line; answer: party). There were 30 trials.

Negative Mood (experimental group)

Following the task, negative mood participants saw low absolute and relative accuracy scores displayed on the computer screen (i.e., "verbal reasoning accuracy: 36%" and "relative performance: -3.04 SD"). The experimenter acted surprised and quietly, but within earshot of the participant, pretended to phone the principal investigator to ask whether the score was too low to continue testing. Participants were asked whether they understood the task or if they had trouble inputting their responses. Then, the experimenter ended the pretend call and proceeded with the remainder of the study.

Neutral Mood (control group)

Participants randomized to the neutral mood condition briefly saw the words, "verbal reasoning accuracy: OK," presented on the computer screen before the experimenter advanced the computer to the next task.

Measures

Outcome Variables

Unsafe Driving. Mean speed, speed variability, mean headway, headway variability, steering reversals, and overtaking in a driving simulator task assessed unsafe driving at T1 and T2. Unsafe driving was measured with a driving simulator developed at the Université de Sherbrooke (Couture et al., 2020). Participants sat in a vehicle seat in front of three 19-inch monitors (1920 x 1080 resolution) and stereo speakers. Participants interacted with the virtual driving environment using a Logitech GT Driving Force steering wheel, accelerator, and brake pedals. A virtual speedometer, in the bottom-right corner of the centre screen, indicated driving speed (km/h). Driver input was recorded at a rate of 10 Hz. The relative and absolute validity of driving simulation in predicting real-world driving are established (see Wynne et al., 2019 for a review). The present simulator has demonstrated convergent validity and ecological validity, with simulated driving behaviour predicting self-reported driving (Brown et al., 2016) and traffic violations (Brown et al., 2017).

The driving simulator task was repetitious and lacked variety (i.e., monotonous) to facilitate MW. It also afforded measurement of each hypothesized unsafe driving behaviour. The task took place on a curved highway with one oncoming and one ongoing lane. The speed limit, verbally indicated by the experimenter and posted at the start of each simulation, was 90 km/h. During each drive, participants encountered intermittent oncoming vehicles and a series of large trucks travelling in the ongoing lane at 65 km/h. The size of the trucks and curvature of the road limited visibility of oncoming traffic, thus making overtaking risky. Participants were verbally instructed to drive normally and told that they could overtake the trucks if they would do so in a real driving situation.

Driving variables were derived from 10-second samples of driving behaviour prior to self-reports of MW and focused driving. Therefore, each participant had a MW score and focused driving score, at T1 and T2, per variable. Mean speed and speed variability (i.e., *SD*) were calculated from driving speeds in km/h. Mean headway and headway variability were calculated from distances, in metres, between the front of the driver's vehicle and the rear of the nearest lead vehicle, within 100 metres (Biswas et al., 2021). Steering reversals, representing the per-sample rate of clockwise and counter-clockwise (or vice versa) steering wheel rotations > 2° (Markkula & Engstrom, 2006), were derived from steering wheel position data (values ranging from 0–1, representing 900° of full wheel rotation). Per-sample rates of overtaking were calculated from instances in which headways crossed zero.

MW. Self-reports of MW, and focused driving, were collected using thought probes in simulation at T1 and T2. A tone prompted participants to indicate their state by pressing a button on the steering wheel. One button represented MW (i.e., "having thoughts unrelated to driving or your immediate surroundings"; e.g., “thinking about something that happened the other day or plans for the weekend”), and another, focused driving (i.e., "only having thoughts that are necessary for performing the driving task"). Thought probes began five minutes from the start of each simulated drive, to allow time for drivers to start MW. Probes were then presented at random intervals ranging from 30–90 seconds (i.e., *Mdn* = 11 probes over 10 minutes). Probes without responses were automatically scored as MW. MW was operationalized as the proportion of probes to which participants indicated MW (Smallwood & Schooler, 2015).

Moderator Variables

Trait Rumination. Mean response scores on the Short Ruminative Response Scale brooding component (RRS-Brood; Nolen-Hoeksema & Morrow, 1991; Treynor, Gonzalez, & Nolen-Hoeksema, 2003) measured trait rumination at T1. The RRS-Brood includes five items consisting of thoughts or behaviours (item 13: “[I] think about a recent situation, wishing it had gone better”). Participants indicate how often they engage in each when in a negative mood using a Likert scale (1 = "*almost never*" to 4 = "*almost always*"). The RRS-Brood shows good internal consistency, α = .72. Test-retest reliability is .60 over one year (Treynor, Gonzalez, & Nolen-Hoeksema, 2003).

Inhibitory Control. Accuracy scores on the Simon Task (Brinker et al., 2013; Hajcak et al., 2003) assessed inhibitory control at T1. Coloured arrows pointing left or right, were presented on a computer screen. Participants had to quickly and accurately press the 'F' key for red arrows, and the 'J' key for green arrows. Trials were congruent if arrows pointed in the direction of the appropriate key for their colour (e.g., red arrow pointing left), and incongruent if arrows pointed away from the appropriate colour key (e.g., red arrow pointing right). There were 576 trials, half congruent and half incongruent, presented in random order. Accuracy scores reflected the proportion of correct to total incongruent trials by participant. Test-retest reliability is stable for similar tasks (e.g., r = .49–.90 over 25 days) (Delis, Kaplan, Kramer, 2001).

Mediator Variables

Emotional Arousal. Mean heart rate objectively assessed emotional arousal in simulation at T2. A BIOPAC® system (BioNomadix respiration & electrocardiogram amplifier, BN-RSPEC) recorded heart rate at a sampling frequency of 1000 Hz using a three-electrode chest montage. The Pan & Tompkins (1985) heart beat detection method was applied to the raw electrocardiogram signal. For each participant, instantaneous heart rates, in beats per minute, were calculated and averaged over 10-second samples prior to self-reports of MW and focused driving via thought probes.

Other Variables

Negative Mood. Mean response scores on the Positive and Negative Affect Schedule, negative affect subscale (PANAS-NA; Watson et al., 1988) measured negative mood at T1 and T2. The PANAS-NA contains 10 items, each consisting of a feeling word (item 13: "ashamed"). Participants indicate the extent that each applies to them in the moment using a Likert scale (1 = "*very slightly or not at all*" to 5 = “*extremely*”). The PANAS-NA shows good internal consistency with a Cronbach’s alpha of .85 (Crawford & Henry, 2004).

Demographic Characteristics. A demographics questionnaire measured the following at T1: Date of birth, ethnicity (e.g., Caucasian, Arab, Asian), relationship status (e.g., single, married, divorced), children (i.e., yes, no), highest education level (e.g., primary school, high school, graduate university), income (i.e., ≤ $999 to ≥ $50,000), employment status (e.g., unemployed, caregiver, full-time studies + full-time work). Means, with standard deviations, for continuous responses and counts, with percentages, for ordinal responses were calculated by mood group.

Clinical Characteristics. Depression symptoms, alcohol dependence, and drug dependence were assessed at T1. Total scores on the Beck Depression Inventory II (BDI; Beck et al., 1996) measured depression symptoms. Drivers responded to 21 groups of four statements each (Sadness: 0 = "I do not feel sad" to 3 = "I am so sad or unhappy that I can't stand it") by indicating those that best described their experience over the past two weeks. Total scores on Items four and six from the Alcohol Use Disorders Questionnaire (AUDIT; Saunders et al., 1993) measured alcohol dependence. Drivers responded to a question about their self-control over drinking (item 4) and another about drinking in the morning (item 6), using a five-point Likert scale (0 = "Never" to 5 = "Daily or almost daily"). Total scores on Items six and eight from the Drug Use Disorders Questionnaire (DUDIT; Berman et al., 2003) similarly assessed self-control over drug use (item 6) and drug use in the morning (item 8) with a five-point Likert scale (0 = "Never" to 5 = "Daily or almost every day").

Procedure

Testing took approximately two hours. The study candidates' driving license and age were verified upon arrival to the laboratory. Following informed consent, candidates underwent a breath alcohol test and completed a screening questionnaire. Then, candidates drove a 10-minute practice simulator task while reporting MW. Immediately afterwards, they responded to questions for ruling out simulation sickness. At T1, participants completed a 15-minute driving simulator task while reporting MW. Then, they completed the demographics questionnaire and RRS-Brood before being fitted with heart rate monitoring electrodes. Participants then completed the PANAS-NA on the computer, followed by the Simon Task (among other tasks not used in the present study). Each task began with an instruction screen, a verbal description of the task by the experimenter, and a brief practice period. The experimenter left the testing room while participants performed each task. The Remote Associations ("verbal reasoning and intelligence") Test was the last task in the series. After the tasks were complete, randomization took place. Upon re-entering the testing room, the experimenter pressed a key on the computer keyboard to initiate the mood manipulation by displaying the participant's assigned performance feedback. At T2, participants completed a second PANAS-NA, then drove another 15-minute simulator task while reporting MW. Heart rate was recorded throughout the drive. Participants were debriefed.

Analytic Strategy

One-tailed planned comparisons of estimated marginal means tested between-group differences in T2-T1 changes (ΔT_{NEG} vs. ΔT_{NEU}) in the following variables: negative mood, to assess mood manipulation effectiveness; MW, to assess whether negative mood increases MW while driving (H1); and unsafe driving behaviours linked to MW (MW-focused driving), to assess whether negative mood increases unsafe driving via MW (H2). A one-tailed planned comparison also tested between-group differences in heart rate linked to MW, to assess whether negative mood increases emotional arousal via MW (H3).

Estimated marginal means came from linear mixed models (LMM), for continuous dependent variables, and general linear mixed models (GLMM), for non-continuous dependent variables. LMMs and GLMMs used restricted maximum likelihood estimation. Maximal random effects controlled for repeated measures (Brauer & Curtin, 2018). Mixed models were fitted with the lme4 package (Bates et al., 2014) for R (Team, 2013), while the emmeans package (Lenth et al., 2018) conducted planned comparisons and calculated effect sizes. Effect sizes were reported using Cohen's d (*d*) for linear models, odds ratios (*OR*) for binomial models, and rate ratios (*RR*) for Poisson models.

One-tailed planned comparisons tested the moderating contributions of trait rumination and inhibitory control to significant relationships between mood group, MW and unsafe driving linked to MW (H4). Planned comparisons used estimated coefficients from linear (continuous) and general linear (non-continuous) regression models (LM, GLM) that accounted for T1 MW or unsafe driving linked to MW, irrespective of focused driving. State (MW, focused driving) was excluded from the models to reduce their complexity.

One-tailed, bootstrapped causal mediation analyses, conducted with the mediation package for R (Tingley et al., 2014), explored the mediating roles of ΔT MW, in relationships between mood group and unsafe driving, irrespective of state, and emotional arousal at T2, in relationships between mood group and T2 unsafe driving linked to MW, if significant between-group differences in these variables were detected.

Power

This preliminary study recruited a sample size of N = 40. Minimum detectable effect sizes, approximated from ANOVA F-tests at a power-level of .80, for one-tailed tests (α = .05) of directional hypotheses were medium for both two-way (Cohen's f ≥ 0.33) and three-way interactions (Cohen's f ≥ 0.26).

Model Diagnostics

Cells were unbalanced in cases where: participants reported one state but not the other in simulation; no headways < 100 metres were recorded. Missing data excluded participants from moderation models (LMs, GLMs) predicting headway distance (n_{NEG} = 8, n_{NEU} = 6) and steering reversals (n_{NEU} = 2). Kenward-Roger degrees of freedom adjusted for unbalanced cells in LMMs and GLMMs to make use of all available data. Singular random effects terms were removed from LMMs predicting headway variability and speed variability. The following dependent variables were log-transformed: PANAS-NA, mean speed, headway variability, and heart rate. Speed variability was square-route-transformed. Results are presented on the original response scale. Trait rumination and inhibitory control scores were standardized for moderation analyses. A Gamma distribution modelled steering reversal rates in moderation analyses. GLMM assumptions were tested with the DHARMa package (Hartig, 2017) and all were met. Outliers were detected (Cook's distance > 0.30) in models for mean speed (n_{NEU} = 1), moderation of MW (n_{NEU} = 2), and moderation of headway variability (n_{NEG} = 1). Sensitivity analyses revealed no impact on results.

Results

Participants

Forty-one participants were recruited. One participant was excluded due to a prior Generalized Anxiety Disorder diagnosis. The final sample included 40 males. Table 1 displays demographic and clinical characteristics of the sample, and reveals no significant differences between experimental conditions (i.e., negative mood group, neutral mood group).

Table 1

Demographic and Clinical Characteristics of the Young Male Driver Sample by Mood Group

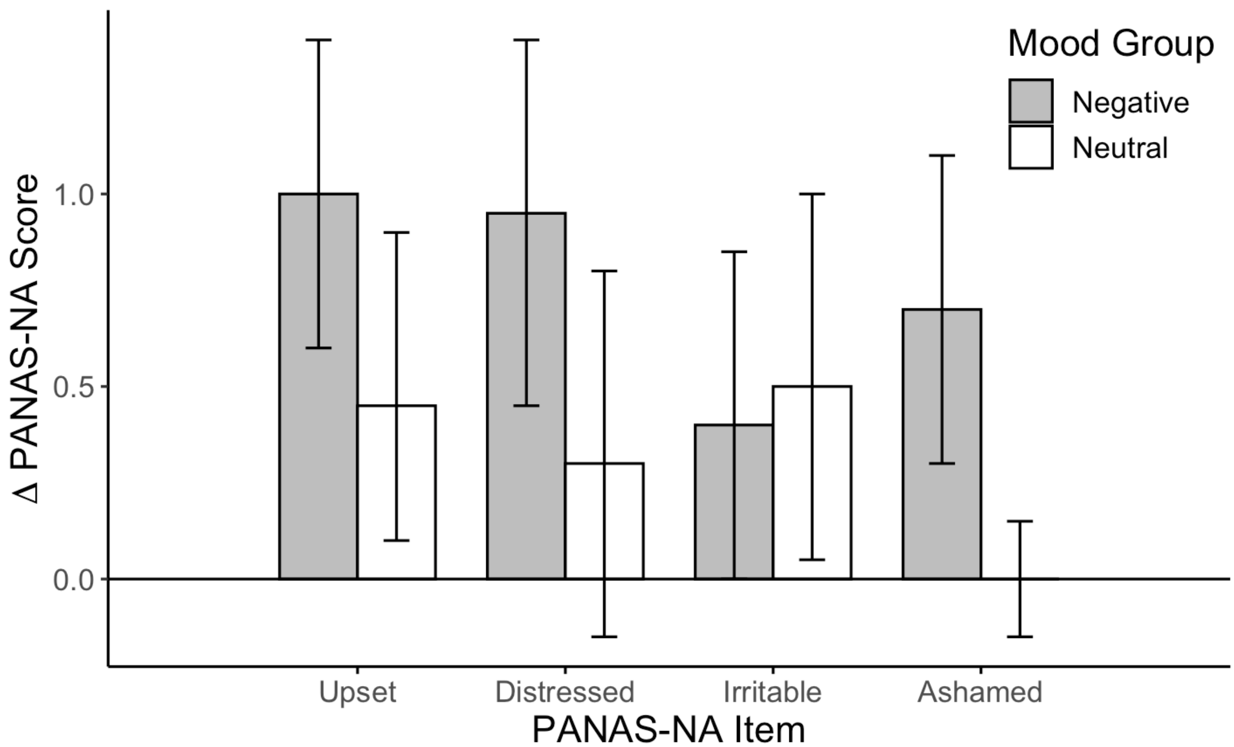
Variable	Negative Mood (n = 20)	Neutral Mood (n = 20)	X^2 (*t*)
Demographic Characteristics			
Age, *M* (*SD*)	22.2 (1.56)	22.3 (1.30)	(0.22)
Ethnicity, *n* (%)			1.60
White	12 (60.0)	8 (40.0)	
Other	8 (40.0)	12 (60.0)	
Education level, *n* (%)			0.00
High school[a]	5 (25.0)	5 (25.0)	
At least some university	15 (75.0)	15 (75.0)	
Annual income, *n* (%)			0.10
$0 – $5,999	9 (45.0)	10 (50.0)	
$6,000 or more	11 (55.0)	10 (50.0)	
Employment status, *n* (%)			4.80
Full-time studies or full-time work[b]	7 (35.0)	13 (65.0)	
Full-time studies and part-time work	9 (45.0)	3 (15.0)	
Other	4 (20.0)	4 (20.0)	
Relationship status, *n* single (%)	20 (100)	20 (100)	0.00
Number of children, *M* (*SD*)	0.00 (0.00)	0.00 (0.00)	(0.00)
Driving License type, *n* probationary[c] (%)	9 (45.0)	8 (40.0)	0.10
Number of traffic violations, *n* (%)			0.36
None	19 (95.0)	18 (90.0)	
One within past 2 years	1 (5.00)	2 (10.0)	
Clinical Characteristics			
Beck Depression Inventory, *M* (*SD*)	2.90 (3.89)	3.25 (4.42)	(0.27)
Alcohol Use Disorders Identification Test, *M* (*SD*)	0.14 (0.36)	0.11 (0.32)	(-0.35)
Drug Use Disorders Identification Test, *M* (*SD*)	0.00 (0.00)	0.00 (0.00)	(0.00)

Note. Monte Carlo resampling was used to accommodate small cell sizes for chi-square tests.
a. High school includes vocational college (CEGEP) in Quebec, Canada.
b. Full-time work ≥ 35 hours per week
c. A probationary license can be obtained at ≥ 17 years old in Quebec (following 12 months with a learner's license, starting from 16 years of age). Drivers may obtain a full license after 2 years with a probationary license.
**p* < .05

Figure 2 displays changes in PANAS-NA items by mood group. Comparing ΔT PANAS-NA scores between mood groups revealed a significant difference, $t(38.0) = 2.34$, $p = 0.01$, $d = 1.05$. The negative mood group reported a significant T1 to T2 increase in PANAS-NA scores, $t(38.0) = 4.10$, $p < .001$, $d = 1.30$. Change in PANAS-NA was not significant for the neutral mood group. The PANAS-NA item "Ashamed" showed the largest between-group difference, $d = 0.96$.

Figure 2

Mean Change in PANAS-NA Score by Item and Mood Group



Note. PANAS-NA = Positive and Negative Affect Schedule - Negative Affect sub-scale. PANAS-NA items include those that showed significant increases from before to after the negative or neutral mood inductions. Values are based on raw data. Error bars represent 95% confidence intervals.

Main Hypotheses

Comparing ΔT MW between mood groups revealed a significant difference, $z = 2.01$, $p = .022$, $OR = 1.79$. The negative mood group reported a significant increase in MW, $z = 2.81$, $p = .005$, $OR = 1.78$. Change in MW was not significant for the neutral mood group.

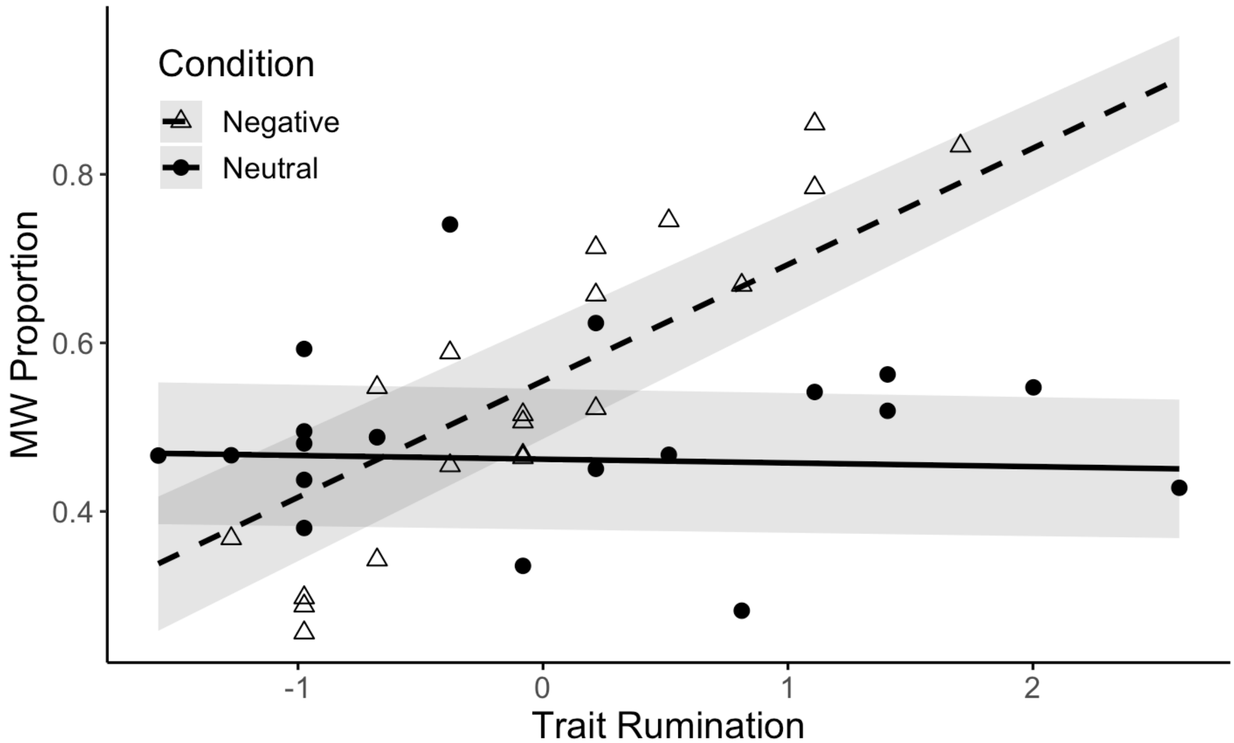
Comparing ΔT unsafe driving linked to MW between mood groups revealed a significant difference in headway variability, $t(58.4) = 1.99$, $p = .026$, $d = 1.46$. Neither the negative mood group nor the neural mood group exhibited a significant T1 to T2 change in headway variability linked to MW. A significant difference in steering reversals was also revealed, $z = 1.86$, $p = .032$, $RR = 1.33$. Neither the negative mood group nor the neutral mood group exhibited a significant T1 to T2 change in steering reversals linked to MW. Results for ΔT mean speed, speed variability, mean headway, and overtaking were not significant. Results for ΔT unsafe driving behaviours, irrespective of state, were also not significant.

Comparing T2 heart rate linked to MW between mood groups revealed no significant difference. The result for heart rate, irrespective of state, was also not significant.

Between-group comparisons of coefficients for trait rumination and inhibitory control predicting MW, headway variability and steering reversals during MW, revealed a significant moderation effect of trait rumination on MW, $z = 2.96$, $p = .002$, $OR = 2.11$. For the negative mood group, greater trait rumination significantly predicted more MW at T2, after controlling for MW at T1, $z = 3.25$, $p = .001$, $OR = 2.07$. Trait rumination did not significantly predict T2 MW in the neutral mood group. Figure 3 displays trait rumination moderating between-group differences in T2 MW, after controlling for T1 MW. Results for inhibitory control moderating MW were not significant. Results for trait rumination and inhibitory control moderating between-group differences in headway variability and steering reversals during MW were also not significant.

Figure 3

Moderating Effect of Trait Rumination on the Relationship Between Mood and Mind Wandering



Note. MW = mind wandering. Trait rumination values represent standardized scores on the Ruminative Response Scale brooding component. MW proportion values represent the number of thought probes, out of the total number presented, to which participants indicated MW at T2, following the experimental mood induction, after controlling for T1 values. Grey ribbons represent 95% confidence intervals.

Exploratory Hypotheses

Results from mediation analyses of ΔT MW contributing to between-group differences in ΔT headway variability and ΔT steering reversals were not significant. Since the relationship between mood group and heart rate linked to MW was not significant, heart rate was not explored as a mediator.

Discussion

This study tested whether negative mood leads to more MW (H1), unsafe driving linked to MW (H2), and greater emotional arousal linked to MW (H3) in healthy young male drivers. A main finding was that MW increased following exposure to negative versus neutral mood. Negative mood was also found to increase unsafe driving in terms of greater headway variability and steering reversals linked to MW. This study also tested whether individual differences moderate these relationships (H4). Trait rumination moderated the relationship between negative mood and MW, with high ruminators exhibiting the greatest increases in MW following negative mood exposure. These results support a causal pathway from negative mood to unsafe driving via MW.

The observed influence of negative mood on MW while driving corroborates other findings in laboratory task settings (Marcusson-Clavertz et al., 2020; Smallwood et al., 2009). It also extends evidence from studies showing effects of mood on driver attention and unsafe driving, but without direct observation of MW (Steinhauser et al., 2018; Techer et al., 2017; Zimasa et al., 2019). Theoretical accounts of MW propose that context plays a significant role in determining its frequency (Smallwood & Schooler, 2015). Hence, this finding supports the generalizability of negative mood-induced increases in MW from attention tasks to the driving context. Given previous reports of associations between MW, unsafe driving behaviour (He et al., 2011; Yanko & Spalek, 2014), and crashes (Galéra et al., 2012; Gil-Jardiné et al., 2017), this result substantiates a mechanism by which negative mood may contribute to crashes. Additional studies are needed to confirm whether this causal link between negative mood and MW generalizes to real-world driving, possibly through post-drive self-reports collected via smartphones.

The observed increase in headway variability associated with negative mood MW mirrors the effect of secondary task distraction on unsafe driving behaviours (Hosking et al., 2009; Regan & Hallett, 2011; Young & Salmon, 2012). Interestingly, headway variability was previously found to increase when drivers performed a secondary task under time pressure, but not when they performed the task at their own pace (Wandtner et al., 2016). Hence, observed increases in headway variability may indicate that the intrusiveness of negative mood MW prevented drivers from "pacing" or timing their driving-unrelated thoughts such that they did not interfere with driving. Future research may investigate this possibility by asking drivers about the intrusiveness of their MW post-drive. Since headway variability positively predicts crashes (Hyun et al., 2019), this finding suggests that negative mood MW may be particularly risky.

Steering reversals also increased during negative mood MW, similarly to when drivers are distracted by secondary tasks (Choudhary & Velaga, 2017; Kountouriotis et al., 2016; Kountouriotis & Merat, 2016). Cognitive load, associated with a secondary task's demands on attention, has been found to positively predict steering reversals (He et al., 2014; Li et al., 2018). MW is generally associated with decreased steering reversals (Baldwin et al., 2017), possibly because it most frequently occurs when task demands are low (Smallwood & Schooler, 2015). MW involving emotionally arousing content may increase cognitive load (Chan & Singhal, 2013; Smallwood et al., 2007) or cause MW to occur in moments when cognitive load linked to driving is high. Future research may distinguish between these possibilities by comparing negative and neutral mood MW frequencies between easy and difficult sections of a simulated drive.

Negative mood MW may uniquely affect driving behaviour, which could account for inconclusive findings regarding unsafe driving linked to MW. The observed increase in headway variability associated with negative mood MW has not been found in previous MW and driving studies (He et al., 2011). Thus, relative to focused driving, negative mood MW may have a distinct driving behaviour profile that differs in quality rather than quantity from neutral mood MW. Cognitive load increases are hypothesized to mainly affect complex versus basic driving behaviours, which may explain this qualitative difference (Engström et al., 2017). To test this, future studies may compare drivers' anticipation of road hazards during negative versus neutral mood MW, since this ability deteriorates as cognitive load increases (Baumann et al., 2008; Cooper et al., 2003; Muttart et al., 2007).

The moderating effect of trait rumination on negative mood MW corroborates cross-sectional evidence linking trait driving anger to trait anger rumination and self-reported risky driving (Suhr & Dula, 2017). The present study's randomized controlled design extends these findings by demonstrating a causal pathway from negative mood to MW as a function of trait rumination. This finding implies that a significant portion of MW accompanying negative mood constituted rumination. It further suggests that the ruminative quality of MW accounts for the relative increase in unsafe driving observed following exposure to negative mood. Young drivers high in trait rumination could benefit from tailored interventions designed to reduce ruminative MW (Winston et al., 2016). Mindfulness training is effective in treating certain psychiatric conditions characterized by negative mood and rumination, such as depression and anxiety (Goldberg et al., 2018). Thus, future studies may evaluate its efficacy in reducing ruminative MW while driving, particularly among high trait ruminators.

Findings from this study did not replicate those from studies reporting main effects of negative mood on unsafe driving. This may be due to methodological differences. For example, our randomized, controlled, experimental design, may have eliminated sources of confounding, including interactions between traits, states, and environment, that complicate interpretations of correlational evidence (Scott-Parker, 2017). Our use of deception and blinding also likely reduced the influence of demand characteristics, which were unaccounted for in previous experiments (Steinhauser et al., 2018; Zimasa et al., 2019). Inter-study variability in mood manipulation methods, induced mood states, and driving scenarios could also explain our non-replication (Chan & Singhal, 2015; Du et al., 2020; Jallais et al., 2014; Jeon & Zhang, 2013). Standardizing research methods for investigating mood-induced changes in driving behaviour, such as the incorporation of randomization, blinding, and a common set of driving scenarios, may remedy these issues.

Exploratory analyses of MW's mediating role in relationships between negative mood and unsafe driving were inconclusive. Yet, it follows that negative mood-induced increases in MW would mediate overall changes in driving behaviour, given between-group differences in driving linked to MW. Our mediation analyses were likely underpowered, however, since our sample size was smaller than recommended for testing mediation effects (Fritz & MacKinnon, 2007). At the same time, our choice to use a more naturalistic and dynamic driving scenario may have increased the variability of driving behaviour, thus diluting the overall effects of MW. Using larger samples and less dynamic driving scenarios may uncover a mediating effect of MW in future studies.

Negative mood MW did not elicit greater emotional arousal, as indicated by heart rate, relative to neutral mood MW. Heart rate increases during MW were previously found among dysphoric individuals (Smallwood et al., 2007). Our sample consisted of healthy individuals, however. Therefore, this finding in a dysphoric sample may not generalize to healthy populations, despite the two sharing negative mood symptoms in the present case. Heart rate increases have been observed following self-reports of MW while driving, which may reflect drivers' cognitive effort to refocus their attention (Pepin et al., 2018). Thus, future research may use heart rate to explore mood-related variation in the cognitive effort required to refocus attention to driving.

The moderating contribution of inhibitory control was inconclusive. Poor inhibitory control is linked to rumination (Joormann & Gotlib, 2008; Whitmer & Banich, 2007), but this capacity is multifaceted. For example, individual differences in emotional inhibition, but not cognitive inhibition, were found to predict risky driving in young drivers (Botdorf et al., 2017). While inhibitory control is impacted by negative mood (Brinker et al., 2013) and predicts MW (Rummel & Boywitt, 2014), the particular facet that we measured did not show evidence of this in the context of driving. Therefore, future research should examine multiple facets of inhibitory control to assess its links to negative mood, MW, and unsafe driving.

Limitations

This study used rigorous experimental methods to examine the causal influence of negative mood on unsafe driving via MW, but it also had certain limitations. Though the constrained sample of this preliminary study prevented detection of small effects, its findings provide compelling justification for future studies with larger samples.

The findings were derived from young male drivers exclusively. Evidence for sex differences in unsafe driving linked to negative mood MW is mixed. High MW males, for example, report more negative emotions and thoughts while driving compared to high MW females (Qu et al., 2015). Females exhibit a stronger link between driving anger and aggressive driving compared to males, however (Bogdan et al., 2016). Future studies using larger male and female samples are needed to elucidate sex differences in susceptibility to unsafe driving via negative mood MW.

Recording heart rate only at T2 may have limited detection of group differences. Heart rate monitoring electrodes were fitted at T2 to minimize skin irritation from prolonged exposure to the adhesive. Lacking T1 heart rate data may have prevented detection of negative mood effects on emotional arousal, especially given high variability in resting heart rate and heart rate reactivity between individuals (Manuck et al., 1989). Recording T1 and T2 heart rate may boost sensitivity to emotional arousal changes from negative mood MW in future studies.

Thought probes, used to detect MW in this study, may underestimate unsafe driving linked to MW. While considered the gold standard for accurately detecting MW in tasks (Smallwood & Schooler, 2015), thought probes interrupt MW, which may limit its impact on driving. For instance, retrospective self-reports of MW predict more unsafe driving than MW measured with though probes (Walker & Trick, 2020). Using a variety of methods to measure negative mood MW while driving may clarify the extent of its contribution to unsafe driving.

Conclusion

This preliminary study provided evidence of a causal pathway from negative mood to unsafe driving behaviours via MW. Moderation of these relationships by trait rumination supported the role of individual differences in predicting susceptibility to negative mood MW, at least in young male drivers. These findings, if replicated, may facilitate the identification of drivers who are vulnerable to negative mood MW. They also warrant further investigation of negative mood MW's crash risk implications and interventions targeting this risk factor in young drivers.

References

Aarts, L., & Van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis and Prevention*, *38*(2), 215–224. https://doi.org/10.1016/j.aap.2005.07.004

Albert, D. A., Ouimet, M. C., Jarret, J., Cloutier, M.-S., Paquette, M., Badeau, N., & Brown, T. G. (2018). Linking mind wandering tendency to risky driving in young male drivers. *Accident Analysis & Prevention*, *111*, 125–132. https://doi.org/10.1016/j.aap.2017.11.019

Baldwin, C. L., Roberts, D. M., Barragan, D., Lee, J. D., Lerner, N., & Higgins, J. S. (2017). Detecting and quantifying mind wandering during simulated driving. *Frontiers in Human Neuroscience*, *11*, 406. https://doi.org/10.3389/fnhum.2017.00406

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *ArXiv Preprint ArXiv:1406.5823*.

Baumann, M. R., Petzoldt, T., Groenewoud, C., Hogema, J., & Krems, J. F. (2008). *The effect of cognitive tasks on predicting events in traffic*. 3–11.

Beck, A. T., Steer, R. A., Brown, G. K., & others. (1996). Beck depression inventory-II. *San Antonio, TX: Psychological Corporation*, *78*(2), b9.

Berman, A. H., Bergman, H., Palmstierna, T., & Schlyter, F. (2003). *The Drug Use Disorders Identification Test: Manual*. 1–16.

Biswas, R. K., Friswell, R., Olivier, J., Williamson, A., & Senserrick, T. (2021). A systematic review of definitions of motor vehicle headways in driver behaviour and performance studies. *Transportation Research Part F: Traffic Psychology and Behaviour*, *77*, 38–54. https://doi.org/10.1016/j.trf.2020.12.011

Bogdan, S. R., Măirean, C., & Havârneanu, C. E. (2016). A meta-analysis of the association between anger and aggressive driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *42*, 350–364. https://doi.org/10.1016/j.trf.2016.05.009

Botdorf, M., Rosenbaum, G. M., Patrianakos, J., Steinberg, L., Chein, J. M., Botdorf, M., Rosenbaum, G. M., Patrianakos, J., & Steinberg, L. (2017). *Adolescent risk-taking is predicted by individual differences in cognitive control over emotional , but not non-emotional , response conflict*. *9931*. https://doi.org/10.1080/02699931.2016.1168285

Brauer, M., & Curtin, J. J. (2018). Linear mixed-effects models and the analysis of nonindependent data: A unified framework to analyze categorical and continuous independent variables that vary within-subjects and/or within-items. *Psychological Methods*, *23*(3), 389–411. https://doi.org/10.1037/met0000159

Brinker, J. K., Campisi, M., Gibbs, L., & Izzard, R. (2013). Rumination, Mood and Cognitive Performance. *Psychology*, *4*(3A), 224–231. https://doi.org/10.4236/psych.2013.43A034

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, Executive Control, and Neurobiological Characteristics Associated with Different Forms of Risky Driving. *PLOS ONE*, *11*(2), e0150227. https://doi.org/10.1371/journal.pone.0150227

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2017). The effect of age on the personality and cognitive characteristics of three distinct risky driving offender groups. *Personality and Individual Differences*, *113*, 48–56. https://doi.org/10.1016/j.paid.2017.03.007

Burdett, B. R. D., Charlton, S. G., & Starkey, N. J. (2019). Mind wandering during everyday driving: An on-road study. *Accident Analysis & Prevention*, *122*, 76–84. https://doi.org/10.1016/j.aap.2018.10.001

Chan, M., & Singhal, A. (2013). The emotional side of cognitive distraction: Implications for road safety. *Accident Analysis and Prevention*, *50*, 147–154. https://doi.org/10.1016/j.aap.2012.04.004

Chan, M., & Singhal, A. (2015). Emotion matters: Implications for distracted driving. *Safety Science*, *72*, 302–309. https://doi.org/10.1016/j.ssci.2014.10.002

Chartier, G. M., & Ranieri, D. J. (1989). Comparison of two mood induction procedures. *Cognitive Therapy and Research*, *13*(3), 275–282. https://doi.org/10.1007/BF01173408

Choudhary, P., & Velaga, N. R. (2017). Analysis of vehicle-based lateral performance measures during distracted driving due to phone use. *Transportation Research Part F: Traffic Psychology and Behaviour*, *44*, 120–133. https://doi.org/10.1016/j.trf.2016.11.002

Cooper, P. J., Zheng, Y., Richard, C., Vavrik, J., Heinrichs, B., & Siegmund, G. (2003). The impact of hands-free message reception/response on driving task performance. *Accident Analysis & Prevention*, *35*(1), 23–35. https://doi.org/10.1016/S0001-4575(01)00083-5

Couture, S., Ouimet, M. C., Dedovic, K., Laurier, C., Plusquellec, P., & Brown, T. G. (2020). Blunted cortisol reactivity and risky driving in young offenders – a pilot study. *International Journal of Adolescent Medicine and Health*, *32*(1). https://doi.org/10.1515/ijamh-2017-0123

Crawford, J. R., & Henry, J. D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology*, *43*(3), 245–265. https://doi.org/10.1348/0144665031752934

Cullen, P., Möller, H., Woodward, M., Senserrick, T., Boufous, S., Rogers, K., Brown, J., & Ivers, R. (2021). Are there sex differences in crash and crash-related injury between men and women? A 13-year cohort study of young drivers in Australia. *SSM - Population Health*, *14*, 100816. https://doi.org/10.1016/j.ssmph.2021.100816

Cunningham, M., & Regan, M. (2016). The impact of emotion, life stress and mental health issues on driving performance and safety. *Road and Transport Research*, *25*, 40–50.

Delis, D., Kaplan, E., Kramer, J. (2001). *Delis–Kaplan executive function system technical manual.* Psychological Corporation.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Ding, N., Zhu, S., Jiao, N., & Liu, B. (2020). Effects of peripheral transverse line markings on drivers' speed and headway choice and crash risk in car-following: A naturalistic observation study. *Accident Analysis and Prevention*, *146*(July), 105701. https://doi.org/10.1016/j.aap.2020.105701

Du, N., Zhou, F., Pulver, E. M., Tilbury, D. M., Robert, L. P., Pradhan, A. K., & Yang, X. J. (2020). Examining the effects of emotional valence and arousal on takeover performance in conditionally automated driving. *Transportation Research Part C: Emerging Technologies*, *112*(September 2019), 78–87. https://doi.org/10.1016/j.trc.2020.01.006

Emo, A. K., Matthews, G., & Funke, G. J. (2016). The slow and the furious: Anger, stress and risky passing in simulated traffic congestion. *Transportation Research Part F: Traffic Psychology and Behaviour*, *42*, 1–14. https://doi.org/10.1016/j.trf.2016.05.002

Engström, J., Markkula, G., Victor, T., & Merat, N. (2017). Effects of cognitive load on driving performance: The cognitive control hypothesis. *Human Factors*, *59*(5), 734–764. https://doi.org/10.1177/0018720817690639

Fritz, M. S., & MacKinnon, D. P. (2007). Required sample size to detect the mediated effect. *Psychological Science*, *18*(3), 233–239. https://doi.org/10.1111/j.1467-9280.2007.01882.x

Galéra, C., Orriols, L., M'Bailara, K., Laborey, M., Contrand, B., Ribéreau-Gayon, R., Masson, F., Bakiri, S., Gabaude, C., Fort, A., Maury, B., Lemercier, C., Cours, M., Bouvard, M.-P., & Lagarde, E. (2012). Mind wandering and driving: Responsibility case-control study. *BMJ : British Medical Journal*, *345*, e8105. https://doi.org/10.1136/bmj.e8105

Geden, M., & Feng, J. (2015). Simulated driving environment impacts mind wandering. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 776–780. https://doi.org/10.1177/1541931215591240

Gil-Jardiné, C., Née, M., Lagarde, E., Schooler, J., Contrand, B., Orriols, L., & Galera, C. (2017). The distracted mind on the wheel: Overall propensity to mind wandering is associated with road crash responsibility. *PLOS ONE*, *12*(8), e0181327. https://doi.org/10.1371/journal.pone.0181327

Goldberg, S. B., Tucker, R. P., Greene, P. A., Davidson, R. J., Wampold, B. E., Kearney, D. J., & Simpson, T. L. (2018). Mindfulness-based interventions for psychiatric disorders: A systematic review and meta-analysis. *Clinical Psychology Review*, *59*, 52–60. https://doi.org/10.1016/j.cpr.2017.10.011

Guo, F., Klauer, S. G., Fang, Y., Hankey, J. M., Antin, J. F., Perez, M. A., Lee, S. E., & Dingus, T. A. (2017). The effects of age on crash risk associated with driver distraction. *International Journal of Epidemiology*, *46*(1), 258–265. https://doi.org/10.1093/ije/dyw234

Hajcak, G., McDonald, N., & Simons, R. F. (2003). To err is autonomic: Error-related brain potentials, ANS activity, and post-error compensatory behavior. *Psychophysiology*, *40*(6), 895–903. https://doi.org/10.1111/1469-8986.00107

Hartig, F. (2017). DHARMa: Residual diagnostics for hierarchical (multi-level/mixed) regression models. *R Package Version 0.1*, *5*.

He, J., Becic, E., Lee, Y.-C., & McCarley, J. S. (2011). Mind wandering behind the wheel: Performance and oculomotor correlates. *Human Factors*, *53*(1), 13–21. https://doi.org/10.1177/0018720810391530

He, J., McCarley, J. S., & Kramer, A. F. (2014). Lane keeping under cognitive load: Performance changes and mechanisms. *Human Factors*, *56*(2), 414–426. https://doi.org/10.1177/0018720813485978

Hildebrand, M. (2015). The Psychometric Properties of the Drug Use Disorders Identification Test (DUDIT): A Review of Recent Research. *Journal of Substance Abuse Treatment*, *53*, 52–59. https://doi.org/10.1016/j.jsat.2015.01.008

Hosking, S. G., Young, K. L., & Regan, M. A. (2009). The Effects of Text Messaging on Young Drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *51*(4), 582–592. https://doi.org/10.1177/0018720809341575

Hyun, K. (Kate), Jeong, K., Tok, A., & Ritchie, S. G. (2019). Assessing crash risk considering vehicle interactions with trucks using point detector data. *Accident Analysis and Prevention*, *130*(March 2018), 75–83. https://doi.org/10.1016/j.aap.2018.03.002

Jallais, C., Gabaude, C., & Paire-Ficout, L. (2014). When emotions disturb the localization of road elements: Effects of anger and sadness. *Transportation Research Part F: Traffic Psychology and Behaviour*, *23*, 125–132. https://doi.org/10.1016/j.trf.2013.12.023

Jeon, M., & Zhang, W. (2013). Sadder but wiser? Effects of negative emotions on risk perception, driving performance, and perceived workload. *Proceedings of the Human Factors and Ergonomics Society*, 1849–1853. https://doi.org/10.1177/1541931213571413

Johnson, J. A., Lee, A., Vinson, D., & Seale, J. P. (2013). Use of AUDIT-based measures to identify unhealthy alcohol use and alcohol dependence in primary care: A validation study. *Alcoholism: Clinical and Experimental Research*, *37*(s1), E253–E259. https://doi.org/10.1111/j.1530-0277.2012.01898.x

Joormann, J., & Gotlib, I. H. (2008). Updating the contents of working memory in depression: Interference from irrelevant negative material. *Journal of Abnormal Psychology*, *117*(1), 182–192. https://doi.org/10.1037/0021-843X.117.1.182

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science*, *18*(7), 614–621. https://doi.org/10.1111/j.1467-9280.2007.01948.x

Killingsworth, M. A., & Gilbert, D. T. (2010). A Wandering Mind Is an Unhappy Mind. *Science*, *330*(6006), 932–932. https://doi.org/10.1126/science.1192439

Kountouriotis, G. K., & Merat, N. (2016). Leading to distraction: Driver distraction, lead car, and road environment. *Accident Analysis and Prevention*, *89*, 22–30. https://doi.org/10.1016/j.aap.2015.12.027

Kountouriotis, G. K., Spyridakos, P., Carsten, O. M. J., & Merat, N. (2016). Identifying cognitive distraction using steering wheel reversal rates. *Accident Analysis and Prevention*, *96*, 39–45. https://doi.org/10.1016/j.aap.2016.07.032

Lambert, A. E., Simons-Morton, B. G., Cain, S. A., Weisz, S., & Cox, D. J. (2014). Considerations of a Dual-Systems Model of Cognitive Development and Risky Driving. *Journal of Research on Adolescence*, *24*(3), 541–550. https://doi.org/10.1111/jora.12126

Lenth, R., Singmann, H., & Love, J. (2018). Emmeans: Estimated marginal means, aka least-squares means. *R Package Version*, *1*(1).

Lerner, N., Baldwin, C., Higgins, J. S., Lee, J., & Schooler, J. (2015). Mind wandering while driving: What does it mean and what do we do about it? *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 1686–1690. https://doi.org/10.1177/1541931215591364

Li, P., Merat, N., Zheng, Z., Markkula, G., Li, Y., & Wang, Y. (2018). Does cognitive distraction improve or degrade lane keeping performance? Analysis of time-to-line crossing safety margins. *Transportation Research Part F: Traffic Psychology and Behaviour*, *57*, 48–58. https://doi.org/10.1016/j.trf.2017.10.002

Lipovac, K., Đerić, M., Tešić, M., Andrić, Z., & Marić, B. (2017). Mobile phone use while driving-literary review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *47*, 132–142. https://doi.org/10.1016/j.trf.2017.04.015

Manuck, S. B., Kasprowicz, A. L., Monroe, S. M., Larkin, K. T., & Kaplan, J. R. (1989). Psychophysiologic reactivity as a dimension of individual differences. In N. Schneiderman, S. M. Weiss, & P. G. Kaufmann (Eds.), *Handbook of research methods in cardiovascular behavioral medicine* (pp. 365–382). Springer US. https://doi.org/10.1007/978-1-4899-0906-0_23

Marcusson-Clavertz, D., Kjell, O. N. E., Kim, J., Persson, S. D., & Cardeña, E. (2020). Sad mood and poor sleep are related to task-unrelated thoughts and experience of diminished cognitive control. *Scientific Reports*, *10*(1), 8940. https://doi.org/10.1038/s41598-020-65739-x

Markkula, G., & Engstrom, J. (2006). A steering wheel reversal rate metric for assessing effects of visual and cognitive secondary task load. *13th World Congress on Intelligent Transport Systems and Services*.

Matthews, G., Dorn, L., Hoyes, T. W., Davies, D. R., Glendon, A. I., & Taylor, R. G. (1998). Driver stress and performance on a driving simulator. *Human Factors*, *40*(1), 136–149. https://doi.org/10.1518/001872098779480569

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(1), 196–204. https://doi.org/10.1037/a0014104

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220–232. https://doi.org/10.1037/h0048850

Muttart, J. W., Fisher, D. L., Knodler, M., & Pollatsek, A. (2007). Driving without a clue: Evaluation of driver simulator performance during hands-free cell phone operation in a work zone. *Transportation Research Record*, *2018*(1), 9–14. https://doi.org/10.3141/2018-02

Nayda, D. M., & Takarangi, M. K. T. (2021). The cost of being absent: Is meta-awareness of mind-wandering related to depression symptom severity, rumination tendencies and trauma intrusions? *Journal of Affective Disorders*, *292*, 131–138. https://doi.org/10.1016/j.jad.2021.05.053

Nolen-Hoeksema, S., McBride, A., & Larson, J. (1997). Rumination and psychological distress among bereaved partners. *Journal of Personality and Social Psychology*, *72*(4), 855–862. https://doi.org/10.1037//0022-3514.72.4.855

Nolen-Hoeksema, S., & Morrow, J. (1991). A Prospective Study of Depression and Posttraumatic Stress Symptoms After a Natural Disaster: The 1989 Loma Prieta Earthquake. *Journal of Personality and Social Psychology*, *61*(1), 115–121. https://doi.org/10.1037/0022-3514.61.1.115

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on Psychological Science*, *3*(5), 400–424. https://doi.org/10.1111/j.1745-6924.2008.00088.x

Nummenmaa, L., & Niemi, P. (2004). Inducing affective states with success-failure manipulations: A meta-analysis. *Emotion (Washington, D.C.)*, *4*(2), 207–214. https://doi.org/10.1037/1528-3542.4.2.207

Ottaviani, C., Shahabi, L., Tarvainen, M., Cook, I., Abrams, M., & Shapiro, D. (2015). Cognitive, behavioral, and autonomic correlates of mind wandering and perseverative cognition in major depression. *Frontiers in Neuroscience*, *8*, 433. https://doi.org/10.3389/fnins.2014.00433

Ottaviani, C., Shapiro, D., & Couyoumdjian, A. (2013). Flexibility as the key for somatic health: From mind wandering to perseverative cognition. *Biological Psychology*, *94*(1), 38–43. https://doi.org/10.1016/j.biopsycho.2013.05.003

Pan, J., & Tompkins, W. J. (1985). A real-time QRS detection algorithm. *IEEE Transactions on Bio-Medical Engineering*, *32*(3), 230–236. https://doi.org/10.1109/TBME.1985.325532

Pêcher, C., Lemercier, C., & Cellier, J.-M. (2011). The influence of emotions on driving behaviour. *Traffic Psychology: An International Perspective*, 145–158.

Pepin, G., Malin, S., Jallais, C., Moreau, F., Fort, A., Navarro, J., Ndiaye, D., & Gabaude, C. (2018). Do distinct mind wandering differently disrupt drivers? Interpretation of physiological and behavioral pattern with a data triangulation method. *Consciousness and Cognition*, *62*, 69–81. https://doi.org/10.1016/j.concog.2018.04.006

Poerio, G. L., Totterdell, P., & Miles, E. (2013). Mind-wandering and negative mood: Does one thing really lead to another? *Consciousness and Cognition*, *22*(4), 1412–1421. https://doi.org/10.1016/j.concog.2013.09.012

Qu, W., Ge, Y., Xiong, Y., Carciofo, R., Zhao, W., & Zhang, K. (2015). The relationship between mind wandering and dangerous driving behavior among Chinese drivers. *Safety Science*, *78*, 41–48. https://doi.org/10.1016/j.ssci.2015.04.016

Quinn, P. D., & Harden, K. P. (2013). Differential changes in impulsivity and sensation seeking and the escalation of substance use from adolescence to early adulthood. *Development and Psychopathology*, *25*(1), 223–239. Cambridge Core. https://doi.org/10.1017/S0954579412000284

Regan, M. A., & Hallett, C. (2011). Driver distraction: Definition, mechanisms, effects, and mitigation. In *Handbook of traffic psychology* (pp. 275–286). Elsevier.

Rhodes, N., Pivik, K., & Sutton, M. (2015). Risky driving among young male drivers: The effects of mood and passengers. *Transportation Research Part F: Traffic Psychology and Behaviour*, *28*, 65–76. https://doi.org/10.1016/j.trf.2014.11.005

Rummel, J., & Boywitt, C. D. (2014). Controlling the stream of thought: Working memory capacity predicts adjustment of mind-wandering to situational demands. *Psychonomic Bulletin & Review*, *21*(5), 1309–1315. https://doi.org/10.3758/s13423-013-0580-3

Saghaei, M. (2011). An overview of randomization and minimization programs for randomized clinical trials. *Journal of Medical Signals and Sensors*, *1*(1), 55.

Saghaei, M., & Saghaei, S. (2011). Implementation of an open-source customizable minimization program for allocation of patients to parallel groups in clinical trials. *Journal of Biomedical Science and Engineering*, *04*(11), 734–739. https://doi.org/10.4236/jbise.2011.411090

Sani, S. R. H., Tabibi, Z., Fadardi, J. S., & Stavrinos, D. (2017). Aggression, emotional self-regulation, attentional bias, and cognitive inhibition predict risky driving behavior. *Accident Analysis & Prevention*, *109*, 78–88. https://doi.org/10.1016/j.aap.2017.10.006

Saunders, J. B., Aasland, O. G., Babor, T. F., De la Fuente, J. R., & Grant, M. (1993). Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption-II. *Addiction*, *88*(6), 791–804.

Sayette, M. A., Reichle, E. D., & Schooler, J. W. (2009). Lost in the sauce: The effects of alcohol on mind wandering. *Psychological Science*, *20*(6), 747–752. https://doi.org/10.1111/j.1467-9280.2009.02351.x

Sayette, M. A., Schooler, J. W., & Reichle, E. D. (2010). Out for a smoke: The impact of cigarette craving on zoning out during reading. *Psychological Science*, *21*(1), 26–30. https://doi.org/10.1177/0956797609354059

Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*, *15*(7), 319–326. https://doi.org/10.1016/j.tics.2011.05.006

Scott-Parker, B. (2017). Emotions, behaviour, and the adolescent driver: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *50*, 1–37. https://doi.org/10.1016/j.trf.2017.06.019

Seli, P., Kane, M. J., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J. W., & Smilek, D. (2018). Mind-wandering as a natural kind: A family-resemblances view. *Trends in Cognitive Sciences*, *22*(6), 479–490. https://doi.org/10.1016/j.tics.2018.03.010

Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process–occurrence framework for self-generated mental activity. *Psychological Bulletin*, *139*(3), 519–535. https://doi.org/10.1037/a0030010

Smallwood, J., Fitzgerald, A., Miles, L. K., & Phillips, L. H. (2009). Shifting moods, wandering minds: Negative moods lead the mind to wander. *Emotion (Washington, D.C.)*, *9*(2), 271–276. https://doi.org/10.1037/a0014855

Smallwood, J., O'Connor, R. C., Sudbery, M. V., & Obonsawin, M. (2007). Mind-wandering and dysphoria. *Cognition & Emotion*, *21*(4), 816–842. https://doi.org/10.1080/02699930600911531

Smallwood, J., Ruby, F. J., & Singer, T. (2013). Letting go of the present: Task unrelated thought is associated with reduced delay discounting. *Consciousness and Cognition*, *22*(1), 1–7. http://dx.doi.org/10.1016/j.concog.2012.10.007

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*(6), 946–958. https://doi.org/10.1037/0033-2909.132.6.946

Smallwood, J., & Schooler, J. W. (2015). The Science of Mind Wandering: Empirically Navigating the Stream of Consciousness. *Annual Review of Psychology*, *66*(1), 487–518. https://doi.org/10.1146/annurev-psych-010814-015331

Steinberg, L. (2010). A dual systems model of adolescent risk-taking. *Developmental Psychobiology*, *52*(3), 216–224. https://doi.org/10.1002/dev.20445

Steinhauser, K., Leist, F., Maier, K., Michel, V., Pärsch, N., Rigley, P., Wurm, F., & Steinhauser, M. (2018). Effects of emotions on driving behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *59*, 150–163. https://doi.org/10.1016/j.trf.2018.08.012

Suhr, K. A., & Dula, C. S. (2017). The dangers of rumination on the road: Predictors of risky driving. *Accident Analysis and Prevention*, *99*, 153–160. https://doi.org/10.1016/j.aap.2016.10.026

Suhr, K. A., & Nesbit, S. M. (2013). Dwelling on ‘road rage’: The effects of trait rumination on aggressive driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *21*, 207–218. https://doi.org/10.1016/j.trf.2013.10.001

Team, R. C. (2013). *R: A language and environment for statistical computing*.

Techer, F., Jallais, C., Corson, Y., Moreau, F., Ndiaye, D., Piechnick, B., & Fort, A. (2017). Attention and driving performance modulations due to anger state: Contribution of electroencephalographic data. *ALS: New Molecular Mechanisms and Emerging Therapeutic Targets*, *636*, 134–139. https://doi.org/10.1016/j.neulet.2016.11.011

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). Mediation: R package for causal mediation analysis. *Journal of Statistical Software*, *59*(5), 1–38. https://doi.org/10.18637/jss.v059.i05

Treynor, W., Gonzalez, R., & Nolen-Hoeksema, S. (2003). Rumination reconsidered: A psychometric analysis. Cognitive Therapy and Research,. *Cognitive Therapy and Research*, *27*(3), 247–259. https://doi.org/doi: 10.1023/A:1023910315561

Walker, H. E. K., & Trick, L. M. (2018). Mind-wandering while driving: The impact of fatigue, task length, and sustained attention abilities. *Transportation Research Part F: Traffic Psychology and Behaviour*, *59*, 81–97. https://doi.org/10.1016/j.trf.2018.08.009

Walker, H. E. K., & Trick, L. M. (2020). *Mind-Wandering and Driving: Comparing Thought Report and Individual Difference Measures*. *June*, 8–14. https://doi.org/10.17077/drivingassessment.1668

Wandtner, B., Schumacher, M., & Schmidt, E. A. (2016). The role of self-regulation in the context of driver distraction: A simulator study. *Traffic Injury Prevention*, *17*(5), 1–8. https://doi.org/10.1080/15389588.2015.1102231

Watkins, E. R. (2008). Constructive and unconstructive repetitive thought. *Psychological Bulletin*, *134*(2), 163–206. https://doi.org/10.1037/0033-2909.134.2.163

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063.

Whitmer, A. J., & Banich, M. T. (2007). Inhibition versus switching deficits in different forms of rumination. *Psychological Science*, *18*(6), 546–553. https://doi.org/10.1111/j.1467-9280.2007.01936.x

Winston, F. K., Puzino, K., & Romer, D. (2016). Precision prevention: Time to move beyond universal interventions. *Injury Prevention*, *22*(2), 87. https://doi.org/10.1136/injuryprev-2015-041691

World Health Organization. (2018). *Global status report on road safety 2018*. World Health Organization. https://www.who.int/publications/i/item/9789241565684

Wynne, R. A., Beanland, V., & Salmon, P. M. (2019). Systematic review of driving simulator validation studies. *Safety Science*, *117*(March), 138–151. https://doi.org/10.1016/j.ssci.2019.04.004

Yanko, M. R., & Spalek, T. M. (2014). Driving with the wandering mind: The effect that mind-wandering has on driving performance. *Human Factors: The Journal of the Human*

Factors and Ergonomics Society, *56*(2), 260–269. https://doi.org/10.1177/0018720813495280

Young, K. L., & Salmon, P. M. (2012). Examining the relationship between driver distraction and driving errors: A discussion of theory, studies and methods. *Safety Science*, *50*(2), 165–174. https://doi.org/10.1016/j.ssci.2011.07.008

Zatezalo, N., Erdogan, M., & Green, R. S. (2018). Road traffic injuries and fatalities among drivers distracted by mobile devices. *Journal of Emergencies, Trauma, and Shock*, *11*(3), 175–182. https://doi.org/10.4103/JETS.JETS_24_18

Zhang, Y., & Kumada, T. (2017). Relationship between workload and mind-wandering in simulated driving. *PLOS ONE*, *12*(5), e0176962. https://doi.org/10.1371/journal.pone.0176962

Zimasa, T., Jamson, S., & Henson, B. (2019). The influence of driver ' s mood on car following and glance behaviour: Using cognitive load as an intervention. *Transportation Research Part F: Psychology and Behaviour*, *66*, 87–100. https://doi.org/10.1016/j.trf.2019.08.019

Supplementary Material

Table S.1

Effects of Negative Mood on Mind Wandering (Hypothesis 1), Unsafe Driving During Mind Wandering (Hypothesis 2), and Heart Rate During Mind Wandering (Hypothesis 3)

H	Variable	Comparison			*d*(*B*)	*df*	*t*(*z*)	*p*
		Group	State	Time				
H1	MW	Neg - Neu	-	T2 - T1	(1.79)	-	(2.01)	.022
		Neu	-	T2 - T1	(0.99)	-	(-0.04)	ns
		Neg	-	T2 - T1	(1.70)	-	(2.81)	.005
H2	Mean Speed	Neg - Neu	MW - FD	T2 - T1	-0.47	37.0	-0.73	ns
	Speed Variability	Neg - Neu	MW - FD	T2 - T1	-0.40	35.6	-0.90	ns
	Mean Headway	Neg - Neu	MW - FD	T2 - T1	2.08	29.6	2.80	ns
	Headway Variability	Neg - Neu	MW - FD	T2 - T1	1.46	58.4	1.99	.026
		Neu	MW - FD	T2 - T1	-0.71	57.1	-1.41	ns
		Neg	MW - FD	T2 - T1	0.76	59.7	1.41	ns
	Steering Reversals	Neg - Neu	MW - FD	T2 - T1	(1.33)	-	(1.86)	.032
		Neu	MW - FD	T2 - T1	(0.91)	-	(-0.86)	ns
		Neg	MW - FD	T2 - T1	(1.20)	-	(1.83)	ns
	Overtaking	Neg - Neu	MW - FD	T2 - T1	(6.78)	-	(1.09)	ns
H3	Heart Rate	Neg - Neu	MW - FD	T2	-0.04	33.9	-0.08	ns

Note. $N = 40$. FD = focused driving (i.e., driving-related thoughts), H = hypothesis, MW = mind wandering (i.e., driving-unrelated thoughts), Neg = negative mood, Neu = neutral mood, ns = non-significant ($p \geq .05$), T1 = pre-manipulation, T2 = post-manipulation. Betas reflect odds ratios (*OR*), relating to changes in the likelihood of MW, or rate ratios (*RR*), relating to changes in rates of steering reversals or overtaking during MW. Change scores were calculated after modeling. Between-group comparisons are one-tailed. Within-group comparisons are two-tailed.

Table S.2

Moderation Effects of Trait Rumination and Inhibitory Control in Relationships Between Negative Mood, Mind Wandering, and Unsafe Driving During Mind Wandering (Hypothesis 4)

Moderator Variable	Outcome Variable	Comparison	*d*(*B*)	*df*	*t*(*z*)	*p*
Trait Rumination	MW	Neg - Neu	(2.11)	-	(2.96)	.002
		Neu	(0.98)	-	(-0.14)	ns
		Neg	(2.07)	-	(3.25)	.001
	Headway Variability	Neg - Neu	-0.74	19	-1.28	ns
	Steering Reversals	Neg - Neu	(1.25)	-	(1.36)	ns
Inhibitory Control	MW	Neg - Neu	(0.79)	-	(-1.09)	ns
	Headway Variability	Neg - Neu	-0.12	19	-0.26	ns
	Steering Reversals	Neg - Neu	(1.39)	-	(2.03)	ns

Note. $N = 40$. MW = mind wandering (i.e., driving-unrelated thoughts), Neg = negative mood, Neu = neutral mood, ns = non-significant ($p \geq .05$). Betas reflect odds ratios (*OR*), relating to changes in the likelihood of MW, or rate ratios (*RR*), relating to changes in steering reversal rates during MW. Between-group comparisons are one-tailed. Within-group comparisons are two-tailed.

Sample Size and Power for Detecting Small-to-Medium Effects

Power analyses, conducted with the SIMR package for R (Green & MacLeod, 2016), estimated sample sizes for future studies to detect small-to-medium effects ($d = 0.35$) of negative mood versus neutral mood on unsafe driving linked to MW. Sample sizes were calculated to achieve a desired power of .80 for one-tailed comparisons ($a = .05$) of estimated marginal means from LMMs and GLMMs. Results, based on driving behaviour data with intra-class correlation coefficients ranging from .51 to .85, revealed that a sample size of $N = 350$ ($n = 175$ per group) would adequately power analyses of most unsafe driving variables.

Preface to Study 2

In the previous section, Study 1 found support for a causal contribution of negative mood to MW and MW-related unsafe driving in young male drivers. Specifically, compared to neutral mood, negative mood led to more frequent MW while driving and more MW-related unsafe driving in terms of higher headway variability and steering reversals associated with MW. These findings align with the possibility that developmental factors, particularly in terms of emotional reactivity and limited emotional regulation, may contribute to dysregulation of MW in young drivers (while necessary, these findings are not sufficient to support this possibility, however).

Earlier, in the narrative review, evidence was found to suggest that young drivers may particularly benefit from techniques to enhance attention regulation, given the immaturity of their cognitive control systems. Mindfulness was hypothesized to mitigate MW in young drivers, given negative associations between trait mindfulness, driver distraction, including MW, and distraction-related unsafe driving (Burdett et al., 2016; Koppel et al., 2019; K. L. Young et al., 2019). Furthermore, MT has been found to increase cognitive control and decrease MW in non-driving contexts (Feruglio et al., 2021; Yakobi et al., 2021). Thus, MT may reduce MW while driving in young drivers. Additionally, some evidence was found linking meta-awareness of MW, a proposed mechanism of MT, to reduced unsafe driving associated with MW (Albert et al., 2018; Berthié et al., 2015; Cowley, 2013). Therefore, MT may reduce MW-related crash risk in young drivers by reducing MW and reducing unsafe driving by enhancing meta-awareness of MW.

The following section reports on Study 2, which aimed to test these hypotheses. Specifically, Study 2 tests whether, compared to an active control condition, MT: H1) increases meta-awareness; and H2) reduces the occurrence of MW while driving. Study 2 also explores the specificity of action of MT, changes in driving behaviour from MT and as a function of meta-awareness, as well as the feasibility of MT in young drivers.

A Randomized Controlled Pilot Trial of Brief Online Mindfulness Training in Young Drivers

Abstract

Objective

Driver distraction is a leading contributor to crashes in young drivers. Mind wandering (MW) is a covert form of distraction, involving task-unrelated thoughts, that is linked to unsafe driving and crashes. Brief online mindfulness training (MT) may reduce unsafe driving by enhancing recognition (meta-awareness) of MW and reducing its occurrence. This pilot trial tested these proposed mechanisms of MT and explored its specificity of action in terms of state mindfulness and motivation (interest/enjoyment of interventions). Driving behaviour in addition to online intervention adherence and acceptability in young drivers were also explored.

Methods

This pre-post (T1, T2), randomized, active placebo-controlled, double-blinded pilot trial, allocated 26 drivers aged 21–25 to either brief online MT (experimental) or progressive muscle relaxation (PMR, control), lasting 4–6 days (One lab session at T1, 2–4 remote sessions, and one lab session at T2). A custom website was used to blindly conduct randomization, deliver interventions, administer questionnaires (state mindfulness, acceptability, and motivation), and objectively track adherence. At T1 and T2, a simulator measured driving speed, headway distance, steering corrections, and overtaking. In simulation, participants indicated MW whenever they recognized it, to assess meta-awareness, and when prompted by a thought-probe, to assess overall MW.

Results

MT reduced MW while driving in simulation. The MT group reported higher state mindfulness following sessions. Motivation did not account for MW or mindfulness results. MT and meta-awareness were associated with more focus-related steering behaviour. Adherence and attrition did not differ significantly between interventions. No participants reached out about severe adverse effects, but MT participants reported greater difficulty following instructions.

Conclusion

Results support a plausible mechanism of MT for reducing MW-related crash risk (i.e., reduction of MW) in young drivers. This preliminary evidence, alongside encouraging online adherence and acceptability data, warrants definitive efficacy and effectiveness trials of online MT.

Keywords: mindfulness, mind wandering, unsafe driving behaviour, young drivers

Introduction

Young drivers, aged 16–25, are disproportionately represented in fatal crashes (World Health Organization, 2015). Driver distraction is a particularly prevalent contributor to crashes in this population (Guo et al., 2017). Laws prohibiting overt distraction, such as hand-held phone use, have proven effective in curbing these behaviours (Rudisill & Zhu, 2017). However, detection and enforcement challenges prevent this approach from addressing covert forms of driver distraction, such as mind wandering (Carpenter & Nguyen, 2015; Rudisill et al., 2018). Mind wandering (MW) involves engaging in task-unrelated thoughts and is a prevalent form of covert driver distraction (Lerner et al., 2015). MW constitutes up to 60% of waking thoughts (Seli et al., 2018) and is linked to unsafe driving behaviours, such as fast and variable driving speeds, short headway distances, and large steering corrections (Baldwin et al., 2017; Yanko & Spalek, 2014; Zhang & Kumada, 2017). Not surprisingly, MW is also linked to crashes (Gil-Jardiné et al., 2017; Yanko & Spalek, 2014). Hence, there is an urgent need to address this threat, but a dearth of research impedes the development of effective interventions.

Mounting evidence supports the efficacy of mindfulness training (MT) for reducing MW. Derived from traditional Buddhist practices, MT consists of meditation exercises that teach practitioners how to, "[pay] attention in a particular way: on purpose, in the present moment, and non-judgementally" (Kabat-Zinn, 1994, p. 4). Sustained non-distraction is an essential feature of state and trait mindfulness and represents a key outcome of training (M. D. Mrazek et al., 2014). MT typically takes place over multiple weeks, but brief interventions, consisting of one to five sessions, can reduce MW and enhance attention in tasks (M. D. Mrazek et al., 2012; Rahl et al., 2017). Trait mindfulness negatively predicts MW while driving (Burdett et al., 2016). Thus, brief

MT may represent a viable intervention strategy for reducing the contribution of MW to crashes in young drivers, but this possibility has yet to be tested.

Cultivating an ability to recognize distraction is a key mechanism of MT (Dunne et al., 2019), and may contribute to safer driving. Meta-awareness denotes the ability to monitor mental processes, which can facilitate the recognition and discontinuation of MW (Brandmeyer & Delorme, 2021). Spontaneous self-reports of MW are often compared to self-reports elicited by probes to distinguish between MW with meta-awareness (i.e., meta-aware MW) and MW without meta-awareness (i.e., meta-unaware MW), respectively (e.g., Sayette et al., 2009; Schooler et al., 2004). Task performance deficits linked to meta-aware MW are less pronounced than those linked to meta-unaware MW (Schooler et al., 2011; Smallwood et al., 2007). Similarly, driving studies suggest that meta-awareness may reduce the contribution of MW to unsafe driving (Albert et al., 2018; Cowley, 2013). Thus, meta-awareness represents a potential, yet unexplored, mechanism though which MT may contribute to safer driving.

Delivering MT online through web-platforms and mobile apps is now commonplace (Gál et al., 2021; Sevilla-Llewellyn-Jones et al., 2018). Online MT offers several clinical and experimental advantages. Clinically, It is relatively inexpensive and logistically simple to deploy (Andersson & Titov, 2014; Boggs et al., 2014)**.** It can also enhance accessibility by accommodating travel, scheduling, and, overcoming social distancing constraints in the age of COVID-19 (González-García et al., 2021; Stjernswärd & Hansson, 2017). Online MT may suffer from low acceptability, adherence, and retention, however (Baer et al., 2019; A. J. Mrazek et al., 2019; Spijkerman et al., 2016), but these essential aspects of intervention effectiveness have rarely been assessed. Therefore, preliminary exploration of acceptability, adherence, and retention in online MT in young drivers could inform the development of large-scale trials to evaluate its real-world effectiveness.

Experimentally, online MT can increase treatment fidelity by controlling common sources of confounding, including instructor experience and adherence to treatment guidelines (Crane & Hecht, 2018). Online delivery can also facilitate blinding in parallel-group designs by restricting access to allocation data (Xiao et al., 2013) and reducing participant-experimenter contact (Mathieu et al., 2013), though blinding is rare in MT studies. Many online MT RCTs also do not incorporate active controls (Davidson & Kaszniak, 2015; Goldberg et al., 2017). Online progressive muscle relaxation (PMR) may be a suitable active control condition due to its procedural similarity to MT (e.g., seated position, eyes closed, focus on bodily sensations), but online MT's specificity of action, to PMR's non-specificity of action, remains uncertain (J. B. Banks et al., 2015; Mander et al., 2019). State mindfulness mediates MT outcomes (Kiken et al., 2015), while intrinsic motivation can predict outcomes of cognitive training (Bryce et al., 2018) and MW in attention tasks (Seli et al., 2019). Therefore, measuring these process variables could clarify the contributions of specific (state mindfulness) and non-specific (motivation) factors to the effects of MT on MW in young drivers.

This pilot trial examined two proposed mechanisms of MT for reducing unsafe driving in young drivers. We hypothesized that, compared to PMR, MT: H1) increases meta-awareness; and H2) reduces the occurrence of MW while driving. This pilot also explored MT's specificity of action by testing whether MT elicited greater state mindfulness than PMR and whether meta-awareness, MW, or state mindfulness results were sensitive to variability in motivation. Driving behaviour linked to MW state (i.e., meta-aware MW, meta-unaware MW, and focused driving) and intervention assignment were also explored, in part, to recommend sample sizes for future definitive trials. Finally, this pilot trial clarified the feasibility of brief online MT, delivered via a custom-built website, in terms of adherence and acceptability in young drivers. Results may offer preliminary evidence of MT's proposed mechanisms and feasibility, which may support future definitive trials examining MT's efficacy for reducing MW-related crash risk in young drivers.

Materials and Methods

Study Design

The present study used a pre-post (T1, T2) randomized, parallel-group, active placebo-controlled design. Participant and experimenter were blind to condition assignments throughout computer-assisted data collection and analysis. T1 and T2 testing took place at the Addiction Research Program laboratory of the Douglas Hospital Research Centre, a McGill University-affiliated site in Montreal, Canada. A custom-built study website conducted randomization, delivered interventions, tracked adherence, and administered questionnaires. Participants were compensated $20 after T1 testing, and $40 after T2 testing. Study procedures were approved by the Douglas Mental Health University Institute Research Ethics Board (IUSMD-19-10).

Recruitment

Recruitment occurred through Facebook, Reddit, and university classified advertisements. Screening took place online. Eligibility was verified and other criteria assessed at the lab. Candidates were included if they self-reported the following: i) aged 21–25; ii) valid driving licence; iii) normal or corrected vision and hearing; iv) one or more years of independent driving. Candidates were excluded if they self-reported the following factors associated with non-normal

MW (Brown et al., 2016; Chen et al., 2019; Sayette et al., 2010; Smallwood, 2013): i) neurological or psychiatric diagnosis; ii) generalized anxiety symptoms (total scores > 10 on the Generalized Anxiety Disorders Questionnaire; Spitzer et al., 2006); iii) depression symptoms (total scores ≥ 14 on the Beck Depression Inventory II; Beck et al., 1996); iv) alcohol use disorder symptoms (total scores ≥ 2 on items 4 and 6 of the Alcohol Use Disorders Questionnaire; Saunders et al., 1993; Johnson et al., 2013); and v) substance use disorder symptoms (total scores ≥ 2 on items 6 and 8 of the Drug Use Disorders Questionnaire; Berman et al., 2003; Hildebrand, 2015); vi) previous charge of driving while impaired; vii) meditation practice ≥ once per week in the past 6 months. Candidates were also excluded if they self-reported the following factors associated with adverse effects from MT or PMR (Banks et al., 2015; Bernstein et al., 2007): viii) a family history of psychosis or schizophrenia; ix) prodromal symptoms (total scores ≥ 6 on the Prodromal Questionnaire; van der Gaag et al., 2012); x) propensity to hyperventilate; xi) psychological trauma, recent bereavement, or personal crisis. To prevent confounding by factors that may affect MW and driving behaviour: candidates presenting at the lab with detectable blood alcohol content (measured with an Alco-Sensor IV) or driving simulator sickness were also excluded.

Online Interventions

Figure 1 shows a timeline for the interventions and testing. Participants were assigned one intervention session per day over 4–6 days. Using the study website, participants completed one lab session at T1, 2–4 remote sessions between T1 and T2, and one lab session at T2. Varying remote session-days facilitated participant scheduling. Figure 2 shows the progression of one intervention session via the website. Each session involved 15-minutes of recorded audio instructions delivered by the same male voice. Introductory statements, including instructions to maintain an upright, seated position, were identical between interventions. The website administered a post-session questionnaire following each session.

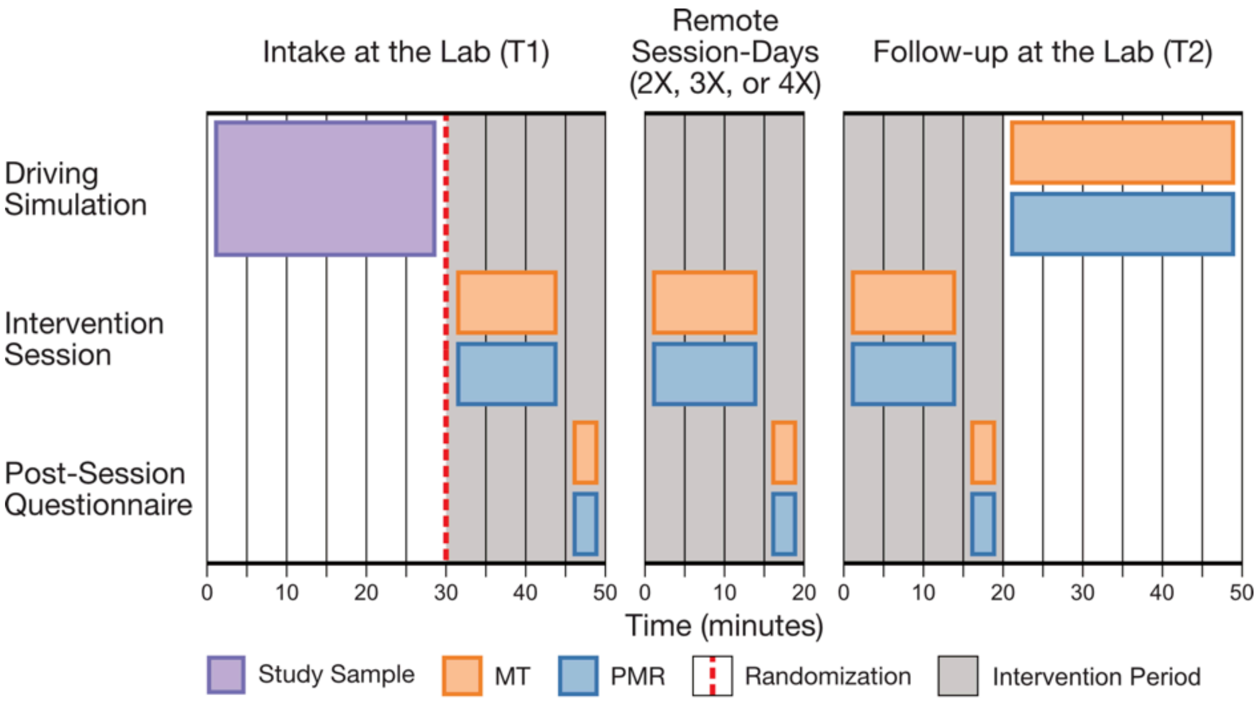


Figure 1. Timeline of Study Procedures. MT = Mindfulness Training, PMR = Progressive Muscle Relaxation. Remote session-days, between intake (T1) and follow-up (T2) lab visits, ranged from 2 to 4, based on participant scheduling. All intervention sessions and process questionnaires were completed through the study website.

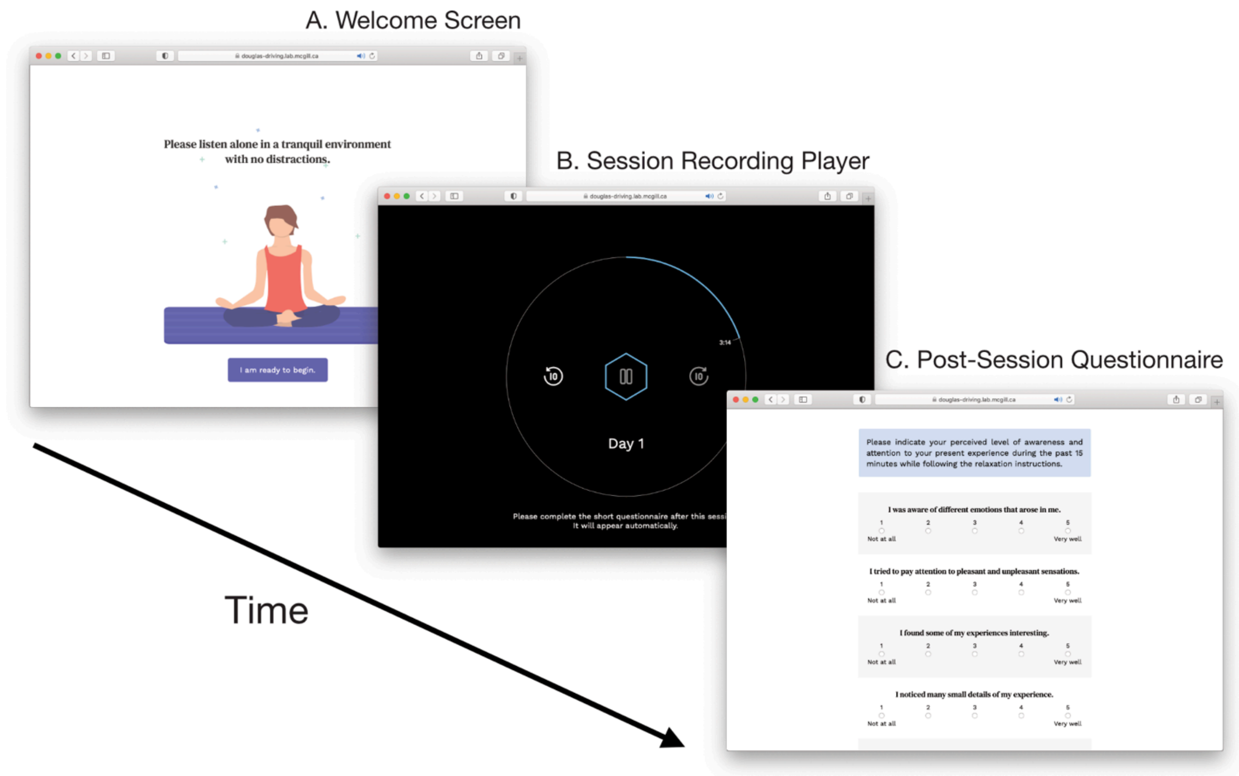


Figure 2. Progression of one online intervention session. A) participants were greeted with this screen when they followed the unique URL emailed to them. B) participants could play/pause, skip back and forward by 10 seconds (up to the last point they listened to before skipping back). C) the post-session questionnaire automatically appeared after each session recording.

There were four unique recordings for each intervention. The website allowed one full play-through of each day's recording. If participants missed one or more days of training, the website played the first un-played recording on their next visit. If participants completed all four unique recordings, the website randomly selected a previous recording for subsequent sessions.

Mindfulness Training

MT instructions were based on scripts from Rahl and colleagues (2017). In the first session, participants were instructed to fix their attention on the sensations of breathing. In the second and third sessions, they were instructed to direct attention to other body sensations and emotions. In the fourth session, participants were instructed to bring their attention back towards the breath. Whenever MW occurred, participants were told to silently label the thought as MW and disengage from it by redirecting attention. Participants were encouraged to maintain an accepting and non-judgemental attitude towards their experience.

Progressive Muscle Relaxation

Participants heard variations of instructions adapted from the PMR technique developed by Jacobson (1938) (Feldman et al., 2010). Participants were guided to establish a slow, even breath. Then, they were told to direct their attention to a particular muscle group (e.g., hands and arms), notice any tension, and release it completely. The recording guided participants once through the whole body (e.g., legs, back, chest) before leaving them in silence to cycle through each muscle group while counting from 1 to 10.

Randomization

The study website conducted randomization. Participants were allocated equally (1:1) to brief online MT (experimental) or PMR (control) using biased-coin minimization (Saghaei, 2011), which accounted for T1 MW (low: 0–0.38, medium: >0.38 & <0.66, high: 0.66–1) measured with thought-probes in driving simulation. Participant study codes and MW scores were entered into a password-protected webpage. The website randomly generated a unique URL that was emailed to participants and linked to their assigned intervention. The website stored intervention assignments and study codes in a non-user-accessible database.

Allocation Concealment and Blinding

Intervention assignments were generated at the moment of randomization and were not visible on the website or in the unique URL, thus concealing allocation from the experimenter. Participants accessed the interventions by themselves and were instructed not to discuss their experiences with the experimenter. Participant blinding was achieved by framing the study as an exploration of "relaxation training...for reducing the influence of [MW] on driving performance." The first recording of both interventions stated that participants would learn a relaxation technique. These statements encouraged all participants to think that their assigned intervention was experimental. To maintain experimenter blinding throughout data analysis, participant intervention assignments were masked by two randomly selected numbers. Blinding was broken following main hypothesis testing (H1 and H2).

Measures

Outcome Measures

Driving Simulation. A driving simulator developed at the University of Sherbrooke measured MW and driving behaviour at T1 and T2 (Brown et al., 2016; Ouimet et al., 2020). Participants sat in a vehicle seat in front of three 19-inch monitors (1920 x 1080 resolution) with stereo speakers. They interacted with the virtual driving environment using a Logitech GT Driving Force steering wheel, accelerator, and brake pedals. A virtual speedometer, at the bottom-right of the centre screen, indicated driving speed (km/h). Driving simulation can predict real-world driving (Wynne et al., 2019). The present simulator has been found to predict self-reported real-world driving (Brown et al., 2016; Ouimet et al., 2020) and traffic violations (Brown et al., 2017).

The drives at T1 and T2 were the same. They each lasted 30 minutes, were repetitive, and lacked variety to facilitate MW. They took place on a highway with a slight right curve, one ongoing lane, and one oncoming lane. The speed limit, visible at the start of each drive, was 90 km/h. Participants encountered intermittent oncoming vehicles and a series of 10 trucks traveling ahead at 65 km/h. The trucks and road curvature limited visibility of oncoming traffic. Participants were instructed to drive as they would normally, which could include passing other vehicles.

Mind Wandering. Thought-probes measured MW in T1 and T2 drives. Probe-tones prompted participants to classify their state as either MW (i.e., "thoughts unrelated to driving "; e.g., "plans for the weekend") or focused driving (i.e., "thoughts that are essential to performing the driving task") by pressing one of two buttons on the steering wheel. Thought-probes began after a five-minute delay, to provide time for MW to start. Thought-probes were delivered at random intervals ranging from 30–90 seconds, resulting in a median of 26 probes per drive. Probe-caught MW includes meta-unaware MW (Schooler et al., 2011). MW was operationalized as the proportion of MW responses to total thought-probes (Smallwood & Schooler, 2015).

Meta-Awareness. In the T1 and T2 drives, participants were also instructed to press the MW button on the steering wheel whenever they caught themselves MW. Self-caught MW reflects meta-aware MW. Self-caught MW rates, after statistically controlling for probe-caught MW, operationalized meta-awareness (Zanesco et al., 2016).

Driving Behaviour. Mean speed, speed variability, mean headway, headway variability, steering reversals, overtaking, and crashes operationalized driving behaviour for the T1 and T2 drives. Driving variables were derived from 10-second epochs prior to self-reported states of meta-aware MW, meta-unaware MW, and focused driving. Mean speed and speed variability (*SD*) were calculated from sampled driving velocities (km/h). Mean headway and headway variability were calculated from distances (m) between the front of the driver's vehicle and the rear of the nearest lead vehicle, within 100 meters (Biswas et al., 2021). Steering reversals, representing the per-epoch rate of clockwise to counter-clockwise (and vice versa) steering wheel rotations > 2°

(Markkula & Engstrom, 2006), were calculated from steering wheel position values ranging from 0–1 over 900° of full steering wheel rotation. Per-epoch rates of overtaking were calculated from instances in which headways crossed zero. Crashes were counted over each drive. Within-subject epochs that overlapped in time were removed. Driving variables were calculated for each MW state at T1, and for each drive (T1 and T2), irrespective of state.

Process Measures

State Mindfulness. The State Mindfulness Scale (SMS; Tanay & Bernstein, 2013) measured state mindfulness as part of the post-session questionnaire. The SMS contains two factors: SMS-Mind (15 items) and SMS-Body (6 items). Participants responded to statements (e.g., SMS-Mind: "I noticed thoughts come and go," SMS-Body: "I felt in contact with my body"), by indicating how well each described their experience using Likert scales (1 = "Not at All" to 5 = "Very Well"). The SMS shows good internal consistency with Cronbach's alphas ranging from .90 to .95 (Tanay & Bernstein, 2013). Means were calculated for T1, remote, and T2 sessions.

Motivation. The Intrinsic Motivation Inventory Interest/Enjoyment sub-scale (IMI-Enjoy; Ryan, 1982) measured motivation as part of the post-session questionnaire. Participants responded to seven statements (e.g., "I enjoyed this activity very much) by indicating how true each was for them using Likert scales (1 = "Not at all" to 7 = "Very true"). The IMI shows good internal consistency, with a Cronbach's alpha of .95 (Schutte et al., 2017). One mean was calculated from all of the intervention sessions.

Feasibility Measures

Adherence. Website-generated session playback logs objectively measured adherence. Proportions representing completed sessions over remote-session days were calculated for the full sample and each group to adjust for variation in remote session-days (based on scheduling). Means and standard deviations of absolute remote session exposure were also calculated.

Acceptability. Long-answer responses measured acceptability as part of the post-session questionnaire. Participants wrote about their experiences during the session, and whether each was positive, neutral, or negative. Qualitative theme analysis was used to synthesize common experiences by valence and group (Braun & Clarke, 2006). Per-session rates of positive, neutral, and negative experiences were also enumerated for each group.

Other Variables

Demographic Characteristics. A demographics questionnaire measured the following at T1: Date of birth, ethnicity (e.g., Caucasian, Arab, Asian), relationship status (e.g., single, married, divorced), children (yes, no), education level (e.g., high school, undergraduate or graduate university), annual income (i.e., ≤ $999 to ≥ $50,000), employment status (e.g., unemployed, caregiver, full-time/part-time studies and/or work). Grouped means and standard deviations or counts and percentages were calculated for continuous and ordinal responses, respectively.

Clinical Characteristics. Symptoms of generalized anxiety, depression, alcohol or substance use disorders, and prodrome psychosis, were assessed at T1. The Generalized Anxiety Disorders Questionnaire (GAD; Spitzer et al., 2006) assessed anxiety symptoms. Participants responded to seven items (e.g., "worrying too much about different things") by indicating how often they experienced each over the past two weeks using a Likert scale (0 = "Not at all" to 3 = "Nearly every day"). The Beck Depression Inventory II (BDI; Beck et al., 1996) assessed depression symptoms. Participants responded to 21 groups of four statements each (e.g., Sadness: 0 = "I do not feel sad" to 3 = "I am so sad or unhappy that I can't stand it") by indicating which best described their experience over the past two weeks. Item four and six of the Alcohol Use Disorders Questionnaire (AUDIT; Saunders et al., 1993) measured alcohol use disorder symptoms relating to the frequency of self-control failures over drinking and drinking in the morning, respectively. Participants responded using a Likert scale (0 = "Never" to 5 = "Daily or almost daily"). Items six and eight from the Drug Use Disorders Questionnaire (DUDIT; Berman et al., 2003) similarly assessed self-control failures over drug use and drug use in the morning with a Likert scale (0 = "Never" to 5 = "Daily or almost every day"). The Prodromal Questionnaire (PQ; van der Gaag et al., 2012) assessed prodrome psychosis. Participants responded to 16 statements (e.g., "I am confused at times whether something I experienced was real or imaginary") by indicating whether or not each applied to them (0 = "No", 1 = "Yes").

Procedures

The T1 lab visit lasted 1.5 hours. Study candidates' age and driving license were verified upon arrival. After informed consent, candidates underwent a breath alcohol test and completed a screening questionnaire. Eligible candidates completed a demographics questionnaire, they a 10-minute practice drive in the driving simulator. If they did not experience simulator sickness, participants performed a 30-minute drive, while reporting MW. Then, randomization took place. Using a tablet and headphones, participants accessed the study website with their unique URL to complete one intervention session and post-session questionnaire at the lab. Participants left the lab with instructions to complete one intervention session and post-session questionnaire daily until their scheduled T2 lab visit. T2 lasted one hour. Participants underwent a breath alcohol test. Then, they completed their last intervention session and post-session questionnaire. Participants then performed a 30-minute drive in the simulator while reporting MW. Participants then were debriefed.

Analytic strategy

Planned comparisons of estimated marginal means facilitated hypothesis and exploratory analyses. One-tailed comparisons of change ($\Delta T = T2-T1$) in MW and meta-awareness between groups (ΔT_{MT} vs. ΔT_{PMR}) assessed whether MT reduced MW (H1) and increased meta-awareness (H2) compared to PMR. One-tailed comparisons of state mindfulness between groups and sensitivity analyses with motivation as a covariate explored MT's specificity of action. Two-tailed Spearman's correlations explored relationships between driving variables within MW states at T1. Two-tailed planned comparisons with 95% CIs explored within-subject differences in driving behaviour between MW states at T1, as well as within-group and between-group changes in driving behaviour (T2-T1), irrespective of state.

Estimated marginal means for planned comparisons were generated from linear mixed models (LMM), in the case of continuous dependent variables, and general linear mixed models (GLMM) in the case of non-continuous variables. LMMs and GLMMs used restricted maximum likelihood estimation. Maximal random effects adjusted for repeated measures, since deltas were calculated post-modeling (Brauer & Curtin, 2018). Kenward-Roger degrees of freedom made use of all available data despite non-adherence and attrition, which is the least biased method of adjusting for missing data (Xi et al., 2018). Effect sizes were reported as standardized differences for continuous dependent variables (*d*), odds ratios (*OR*) for dichotomous variables (e.g., probe-caught MW), and rate ratios (*RR*) for rates (e.g, self-caught MW). Effect sizes for one-tailed tests are reported with 95% left-side or right-side intervals (e.g., left: $[X, +\infty]$, right: $[-\infty, X]$).

Rates, percentages, sub-sample sizes, and raw means with standard deviations, described feasibility measures. Two-tailed independent samples t-tests and Pearson's chi-squared independence tests with Monte Carlo resampling (n = 2000) explored between-group differences (Bradley & Cutcomb, 1977).

Model Diagnostics

Sensitivity analyses examined the influence of outliers (Cook's Distance > 0.3) and covariates on results of planned comparison hypothesis tests. Outliers were detected in models predicting positive experiences ($n_{MT} = 1$, $n_{PMR} = 2$) and negative experiences ($n_{MT} = 1$, $n_{PMR} = 1$), but had no impact on results. Singular random effects parameters were dropped from models predicting meta-awareness (random intercepts for time) and state mindfulness (random effects correlations). All other assumptions were met.

Sample Size and Power

Recruitment targeted 12–20 participants per study arm based on recommendations for pilot trials (Julious, 2005; Stallard, 2012). Over this range, two-tailed between-group comparisons (e.g., sample characteristics and feasibility) were powered ($\alpha = .05$, $1\text{-}\beta = .80$) to detect large effects (t-tests: $d \geq 1.20$ to $d \geq 0.91$, chi-square tests: $w \geq 0.57$ to $w \geq 0.44$). Assuming prior variances ($ICC_{LMM} = 0.49$, $ICC_{GLMM} = 0.34$), one-tailed planned comparisons could detect large effects for LMMs ($d \geq 1.05$ to $d \geq 0.80$) and medium effects for GLMMs ($OR \geq 2.40$ to $OR \geq 2.05$).

Power analyses, conducted with the SIMR package for R (Green & MacLeod, 2016), estimated sample sizes for future studies to detect small-to-medium effects (d = 0.35) of MT versus PMR on unsafe driving. Sample sizes were calculated to achieve a desired power of .80 for one-tailed comparisons (α = .05) of estimated marginal means from LMMs and GLMMs.

Results

Figure 3 depicts the flow of participants through the study over 21 weeks of recruitment from October 2019 to March 2020. Following an initial 6.43 weeks of slow recruitment (0.62 participants per week), adjustments were made to exclusion criteria regarding generalized anxiety symptoms (original: total scores > 2 on the GAD, adjusted: total scores > 10 on the GAD) and meditation experience (original: any prior meditation experience, adjusted: meditation ≥ once per week in the past 6 months). These criteria were selected on the basis that they accounted for approximately one third of all ineligibilities. Prior to the adjustment, 20.6% (14/68) of study candidates were eligible. Following the adjustment, 37.8% (28/74) of new candidates were eligible. Nineteen originally ineligible candidates were re-contacted and three were admitted to the study. Two participants were lost to follow-up due to seasonal illness, since they could not reschedule their T2 visit before more than four days from T1 had elapsed. Demographic and clinical characteristics of the sample are presented in Table 1 and Table 2, respectively.

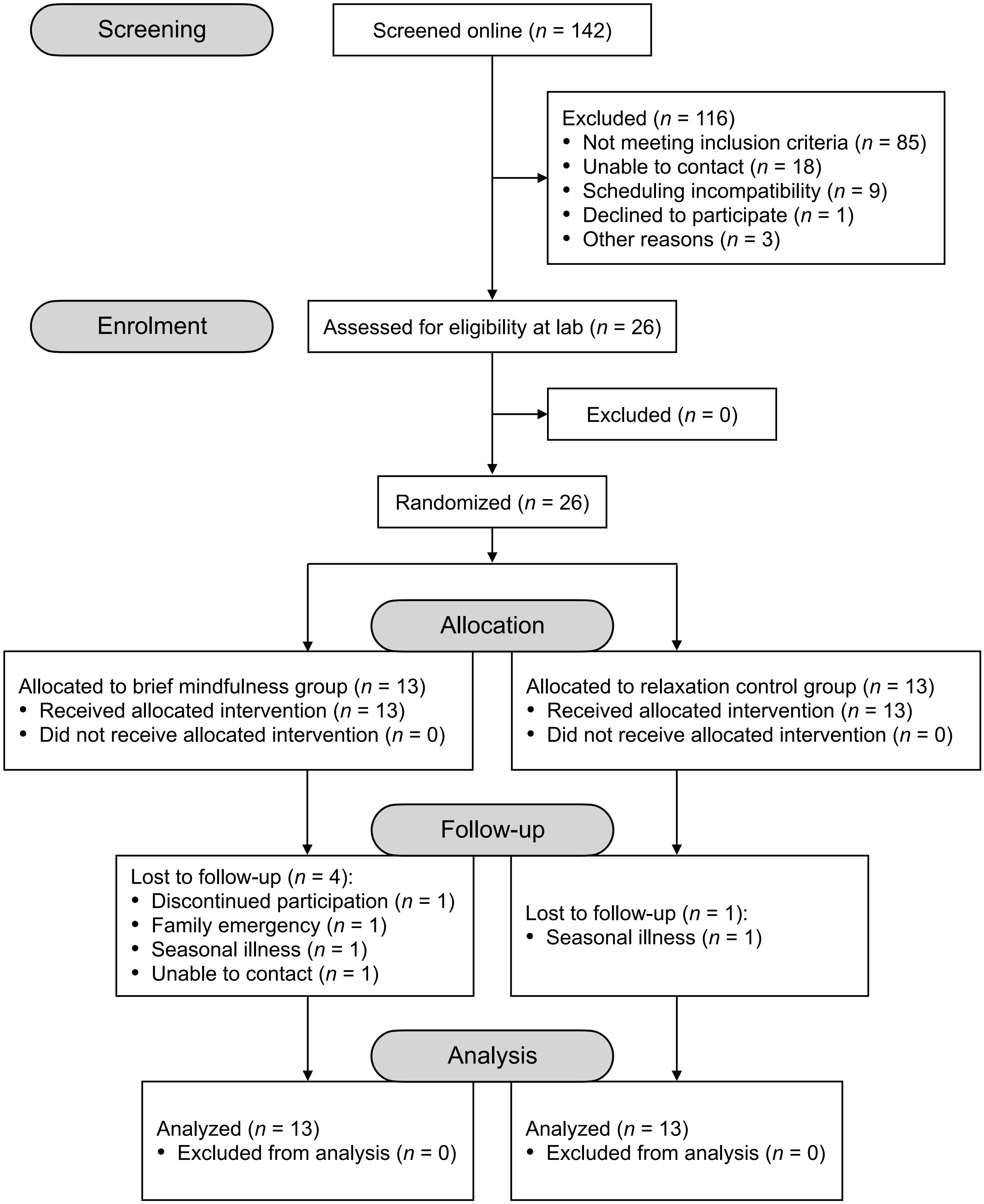


Figure 3. CONSORT flow diagram of participants through the study over 21 weeks of recruitment (October 2019 to March 2020).

Table 1

Demographic Characteristics of the Young Driver Sample

Variable	MT (*n* = 13)	PMR (*n* = 13)
Age, *M* (*SD*)	23.8 (1.27)	22.7 (1.01)
Sex, *n* male (%)	7 (53.9)	7 (53.9)
Ethnicity, *n* (%)		
Other	10 (76.9)	7 (53.8)
Caucasian	3 (23.1)	6 (46.2)
Education level, *n* (%)		
At least some university	8 (61.5)	10 (76.9)
High school or community college [a]	4 (30.8)	3 (23.1)
Missing	1 (7.70)	0 (0.00)
Annual income, *n* (%)		
$6,000 or more	7 (53.8)	8 (61.5)
$0 - $5,999	6 (46.2)	5 (38.5)
Employment status, *n* (%)		
Full-time studies and part-time work	7 (53.8)	5 (38.5)
Full-time work or full-time studies [b]	4 (30.8)	6 (46.1)
Other	2 (15.4)	2 (15.4)
License type, *n* probationary license (%)	13 (100)	11 (84.6)
Number of traffic violations, *n* (%)		
None	11 (84.6)	12 (92.3)
One within the past 2 years	2 (15.4)	1 (7.69)

Note. MT = Mindfulness Training, PMR = Progressive Muscle Relaxation.

a. Community college refers to *Collège d'enseignement général et professionnel* (CEGEP) in Quebec, Canada.

b. Full-time work ≥ 35 hours per week.

c. A probationary license can be obtained at ≥ 17 years old in Quebec (following 12 months with a learner's license, starting from 16 years of age). Drivers may obtain a full license after 2 years with a probationary license.

Table 2

Clinical Characteristics of the Young Driver Sample

Variable	MT		PMR	
	M	*SD*	*M*	*SD*
Beck Depression Inventory	1.38	2.06	3.00	3.19
Generalized Anxiety Disorder Questionnaire	1.38	2.14	1.31	1.60
Prodromal Questionnaire	0.23	0.44	0.15	0.38
Alcohol Use Disorder Identification Test	0.15	0.55	0.08	0.28
Drug Use Disorder Identification Test	0.00	0.00	0.00	0.00

Note. MT = Mindfulness Training, PMR = Progressive Muscle Relaxation.

Comparing ΔT MW between groups revealed a significant difference, $z = -2.36$, $p = .01$, *OR* = 0.35, 95% CI [-∞, 0.73]. The MT group reported a significant decrease in MW, $z = -2.33$, $p = .02$, *OR* = 0.45, *95% CI* [0.23, 0.88], whereas ΔT MW was non-significant in the PMR group, $z = 0.86$, $p = .39$, *OR* = 1.27, *95% CI* [0.74, 2.19]. Results remained significant after controlling for motivation, which did not differ significantly between groups, $t(24.0) = 0.22$, $p = .83$, $d = 0.28$, *95% CI* [-2.34, 2.90]. Comparing ΔT meta-awareness between groups revealed no significant difference, $z = 1.19$, $p = .12$, *RR* = 1.42, *95% CI* [0.87, +∞].

Figure 4 displays mean SMS-Mind and SMS-Body scores for each intervention group at T1, over remote sessions, and at T2. Comparing SMS scores between groups revealed a non-significant result, $t(23.9) = 1.58$, $p = .06$, $d = 0.89$, 95% CI [-0.08, +∞]. Results for SMS-Mind scores were significant, $t(23.9) = 1.94$, $p = .03$, $d = 1.03$, *95% CI* [0.11, +∞]. The MT group's mean response score on the SMS-Mind was 3.64, *95% CI* [3.32, 3.96], while the PMR group's was 3.22, *95% CI* [2.90, 3.54]. Results remained significant after controlling for motivation. Results for SMS-Body scores were non-significant, $t(24.0) = 0.52$, $p = .30$, $d = 0.31$, *95% CI* [-0.71, +∞].

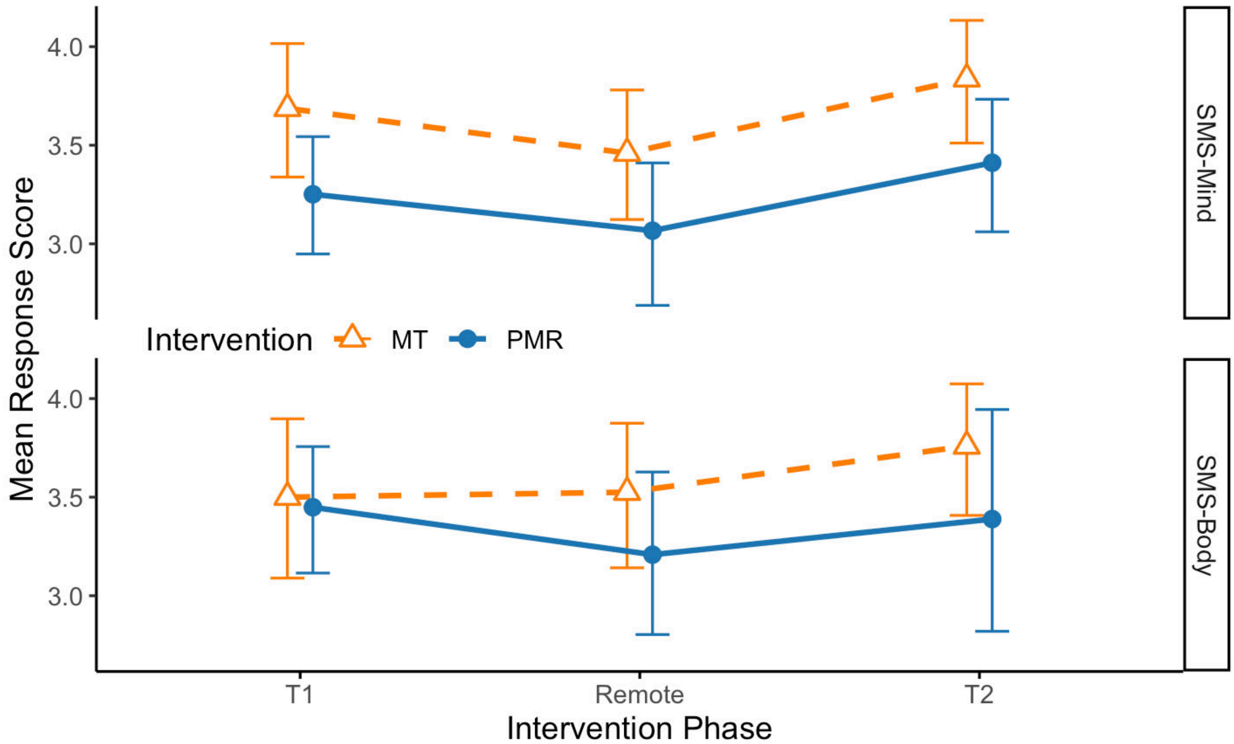


Figure 4. Mean response scores on the State Mindfulness Scale mind and body sub-scales by intervention group and intervention phase. MT = Mindfulness Training, PMR = Progressive Muscle Relaxation, T1 = Intake intervention session, Remote = Remote intervention sessions, T2 = Follow-up intervention session, SMS-Mind = State mindfulness of mind, SMS-Body = State mindfulness of body. Mean scores were derived from raw values and error bars represent bootstrapped 95% CIs.

Table 3 displays rank-order correlations between driving variables across MW states. Headway variability consistently correlated with overtaking across MW states. Steering reversals correlated with speed variability in focused driving and probe-caught MW. Headway variability correlated with mean speed in focused driving and self-caught MW.

Table 3

Correlations Between Driving Behaviour Variables by Driver State at T1

Variable	Focused Driving					
	1.	2.	3.	4.	5.	6.
1. Mean Speed	-					
2. Speed Variability	0.30	-				
3. Mean Headway	0.07	-0.53*	-			
4. Headway Variability	0.58**	0.23	0.29	-		
5. Steering Reversal	0.26	0.55**	-0.32	0.29	-	
6. Overtaking	0.11	0.26	0.11	0.81***	0.15	-
Variable	**Self-Caught Mind Wandering**					
	1.	2.	3.	4.	5.	6.
1. Mean Speed	-					
2. Speed Variability	-0.02	-				
3. Mean Headway	0.13	-0.39	-			
4. Headway Variability	0.55**	0.30	0.41*	-		
5. Steering Reversal	0.30	0.34	-0.20	0.27	-	
6. Overtaking	0.21	0.17	0.27	0.60**	0.01	-
Variable	**Probe-Caught Mind Wandering**					
	1.	2.	3.	4.	5.	6.
1. Mean Speed	-					
2. Speed Variability	-0.08	-				
3. Mean Headway	-0.25	-0.36	-			
4. Headway Variability	0.24	0.33	-0.22	-		
5. Steering Reversals	0.07	0.53**	-0.33	0.33	-	
6. Overtaking	-0.08	0.20	-0.18	0.66**	0.24	-

Note. T1 = Intake. Values represent Spearman rank-order correlation coefficients. Significance tests were two-tailed.

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Confidence intervals from exploratory comparisons of driving behaviour between MW states at T1 revealed that both self-caught and probe-caught MW predicted lower speed variability, headway variability, and overtaking compared to focused driving. In contrast, probe-caught MW predicted shorter headways compared to both focused driving and self-caught MW, which did not differ from one another. Similarly, only probe-caught MW predicted fewer steering reversals compared to focused driving, whereas self-caught MW did not differ from focused driving. Confidence intervals for mean speed did not reveal any differences between states. Full results can be found in Table S.1 of the supplementary material.

Confidence intervals from comparisons of ΔT driving behaviour, within and between groups, revealed a relative increase in steering reversals from MT versus PMR. Only PMR showed a decrease in steering reversals, however, whereas MT exhibited no discernable change. There were no discernable changes in mean speed, speed variability, mean headway, headway variability, overtaking, or crashes, within or between groups. Full results can be found in Table S.2 of the supplementary material. Power analyses, based on driving behaviour data with intra-class correlation coefficients ranging from .43 to .71, revealed that a sample size of N = 300 (n = 150 per group) would power future studies to detect small-to-medium effects of MT on unsafe driving.

Word clouds in Figure 5 display the relative frequency of keywords from each group's long-answer responses in the post-session questionnaires. Most participants that submitted long-answer responses indicated one or more positive (18/24) and neutral (18/24) experiences. A minority of participants (10/24) reported negative experiences. Per-session negative experience rates differed significantly between groups, z = 3.35, p = .001, RR = 5.16, 95% CI [1.98, 13.48]. There were 25 reports of negative experiences over a total of 31 post-session questionnaire responses in the MT group compared to 5 over 32 responses in the PMR group. Difficulty following instructions was a distinct theme in the MT group's negative experience reports. Rates of positive experiences did not differ significantly between groups, z = -0.07, p = 0.94, RR = 0.98, *95% CI* [0.64, 1.51]. No severe adverse effects from MT or PMR were reported.

MT PMR

Figure 5. Word-clouds representing keywords from each intervention group’s long-answer responses. MT = Mindfulness Training, PMR = Progressive Muscle Relaxation. Colour intensity and word-size correspond to relative frequency.

The full study sample completed 67.2% (43/64) of their assigned remote intervention sessions. On average, participants were exposed to 1.65 remote sessions, SD = 0.85. The MT group completed 58% (18/31) of their remote sessions while PMR participants completed 75.8% (25/33). Adherence did not differ significantly between groups, X^2 = 2.71, p = .10. On average, MT participants were exposed to 1.38 remote sessions, SD = 0.87, while PMR participants were exposed to 1.92 remote sessions, SD = 0.76. Remote session exposure did not differ significantly between groups, t(24.0) = -1.68, p = .11, d = 0.66, *95% CI* [-0.13, 1.45]. Overall, 19% (5/26) or participants were lost to follow-up (T2). Attrition was 30.8% (4/13) in the MT group and 7.69% (1/13) in the PMR group. Attrition did not differ significantly between groups, $X^2 = 1.00$, $p = .34$.

Discussion

The present study examined the mechanisms, specificity of action, and feasibility of brief online MT for reducing unsafe driving in young drivers. As hypothesized, MT reduced MW while driving. In previous work, online and in-person MT reduced MW in sustained attention tasks (Bennike et al., 2017; M. D. Mrazek et al., 2012; Rahl et al., 2017). In-person MT has also been shown to reduce MW in real-world settings (M. D. Mrazek et al., 2013; Zanesco et al., 2016). This study is the first to demonstrate a reduction in MW while driving following exposure to MT. This finding, in conjunction with recent evidence for fewer crashes in simulation following longer, in-person MT (Baltruschat et al., 2021), signals the promise of MT for reducing distraction and its consequences in real-world driving.

MT's effect on meta-awareness was inconclusive. Meta-awareness is predominantly conceptualized as intermittent, arising only when explicitly "taking stock" or reflecting on one's thoughts, and propositional, involving conscious judgements, sometimes in the form of thoughts such as, "My mind was just wandering!" (Schooler, 2002). In contrast, MT is proposed to cultivate a sustained and non-propositional form of meta-awareness, reflecting an ongoing process of monitoring thoughts and feelings (Dunne et al., 2019). The self-caught method of detecting MW may rely on propositional meta-awareness and therefore be insensitive to the type of meta-awareness cultivated by MT. Future research investigating alternative measures of meta-awareness may clarify its role in MT effects on driver attention and behaviour.

Exploratory analysis of driving behaviour revealed that steering reversals decreased following exposure to PMR, but not MT. Our study, and others (Baldwin et al., 2017), found fewer steering reversals linked to MW. Hence, the MT group's decrease in MW could explain its relative increase in steering reversals, although the PMR group's decrease in reversals did not coincide with an increase in MW. Future studies with larger samples may be able to clarify the relationships between MT and driving behaviour.

Curiously, steering reversals and headway distances were greater during meta-aware MW and focused driving compared to meta-unaware MW. For most other driving variables, behaviour associated with meta-aware and meta-unaware MW differed from focused driving. Meta-awareness has been associated with less pronounced task performance deficits associated with MW (Schooler et al., 2011). Therefore, this finding may reflect attenuation of MW-related changes in driving behaviour by meta-awareness. Future research using techniques known to elicit meta-awareness, such as offering incentives for self-caught MW (Zedelius et al., 2015), may elucidate its putative influence on unsafe driving linked to MW.

Overtaking was greater during focused driving compared to MW. This could explain why headway variability and speed variability were also greater during focused driving, which contradicts previous findings (Baldwin et al., 2017; Zhang & Kumada, 2017). Supporting this possibility, headway variability positively correlated with overtaking across states, as well as speed variability during focused driving. Drivers report using MW to cope with boredom in slow-moving traffic (Steinberger et al., 2016). While overtaking is risky, MW behind lead vehicles may also be risky given links to faster driving, shorter headway distances, and slower reaction times

(Yanko & Spalek, 2014). Future research may assess the relative risk of these possible boredom-management strategies.

Results supported online MT's specificity of action in young drivers. The MT group reported higher state mindfulness, following intervention sessions, compared to PMR. This finding supports online MT's specific capacity to induce a mindful state, which is integral to developing trait mindfulness (Kiken et al., 2015). This finding extends those from RCTs examining lab-based mindfulness inductions (Greif & Kaufman, 2021; Luberto & McLeish, 2018) and longer online MT interventions (Beshai et al., 2020; Noone & Hogan, 2018). Furthermore, MT's selective effect on present awareness of thoughts and feelings (i.e., mindfulness of mind) points to its involvement in MW and driving outcomes. Future research may examine relationships between pre-to-post-intervention changes in mindfulness of mind and MW while driving outcomes.

There was insufficient evidence to suggest that motivation differed between interventions or that variability in motivation explained MT effects on state mindfulness and MW. Motivation has been found to predict adherence (Alfonsson et al., 2016), outcomes of cognitive training (Bryce et al., 2018), and MW in attention tasks (Seli et al., 2019). Thus, future studies testing equivalency of motivation may support PMR as a suitable control for MT in young drivers.

MT and PMR differed in acceptability. While no severe adverse effects from MT or PMR were reported, the MT group reported more negative experiences. Difficultly following instructions was the only negative experience unique to MT. This theme included statements such as, "having to sit up with my eyes open was nearly impossible," and "I found it more difficult to...pay attention to the physical sensations in my body when there were longer periods of silence." MT participants may become frustrated or discouraged by frequent MW, since, unlike

PMR, the aim is to disengage from MW. This factor has been proposed to explain the higher attrition rates commonly found in MT relative to control conditions (Nam & Toneatto, 2016). Negative experiences did not predict adherence or attrition in the present study, however. Appraisal of MT-related experiences has been linked with adverse effects (Lindahl et al., 2021). Thus, future research may explore techniques to contextualize or normalize minor frustrations and difficulties associated with MT.

The interventions showed no detectable differences in adherence. In the present study, 57.7% of the sample completed all assigned remote sessions (ranging from 2–4). In contrast, Forbes and colleagues (2018) reported 73.5% adherence at 4 sessions (out of 10 assigned, each lasting 10 minutes, over 30 days). Although adherence did not differ significantly between studies, treatments with low intensity dosing schedules (e.g., shorter and less frequent sessions) generally have better adherence (Levensky et al., 2006). High intensity MT is generally more effective, however (Strohmaier, 2020). Future studies may assess the potential adherence costs and effectiveness benefits of different dosing schedules to optimize MT for young drivers.

Attrition did not differ significantly between interventions. While mixed modeling and other intent-to-treat methods adjust for attrition, large between-group differences can be signify blinding failure (Hróbjartsson et al., 2014), variation in treatment credibility (Alfonsson et al., 2016), and other confounds. Overall attrition in the present study was 19.2%, whereas the average among in-person MT RCTs is 29% (Nam & Toneatto, 2016). Future studies may determine whether the accessibility advantages of online MT contribute to lower attrition compared to in-person delivery in young drivers.

The present study faced early recruitment challenges. We initially set a low exclusion threshold for generalized anxiety symptoms, since MT and PMR can cause adverse effects, such as muscle tension and anxious thoughts, among anxiety-prone individuals (Baer et al., 2019; Bernstein et al., 2007). However, young drivers, and particularly students, may be exposed to situational stressors, such as high-stakes exams, that temporarily increase levels of non-pathological anxiety. Despite raising the exclusion threshold for anxiety, there were no reports of severe adverse effects. We also initially recruited only MT-naive individuals to avoid floor (MW) and ceiling (meta-awareness) effects. Many people have had at least some exposure to MT, especially given the increasing availability of MT-based apps and services (Gál et al., 2021). Future research may determine the best recruitment methods for obtaining a representative sample, while also outlining contraindications to mitigate risk of adverse effects.

Limitations

This pilot RCT employed rigorous experimental methods, aided by a custom intervention delivery and tracking website, to assess the promise of MT for reducing young driver crash risk. The study possesses certain limitations, however. Our small sample size limited detection of small and medium effects. We tried to increase sensitivity by using one-tailed planned comparisons. Preliminary results from this study provide compelling justification for future trials with larger and broader samples.

Our measures of MW may have altered driving behaviour. Self-caught and probe-caught measurement methods interrupt MW (Smallwood & Schooler, 2015), which can reduce its impact on driving (Walker & Trick, 2019). To control for this, we only sampled driving behaviour immediately prior to self-reports of MW. Self-catching MW also involves monitoring one's thoughts. This demands attention (Vannucci et al., 2019), and thus constitutes a secondary task that may interfere with driving. Future studies using multiple measures of MW, including retrospective self-reports, may corroborate the effects of MT on MW and driving.

Probe-caught MW does not only reflect meta-unaware MW. Unlike spontaneous self-reports of MW, thought probes can capture meta-unaware MW (Sayette et al., 2009; Schooler et al., 2004). However, participants may not always discontinue their MW after self-catching it. Thus, thought probes can capture both meta-aware and meta-unaware MW. One study measured self-caught and probe-caught MW, while also probing meta-awareness (e.g., Were you aware of your MW before the probe?). The study found that ≈ 60% of probe-caught MW (vs. 100% of self-caught) was meta-aware MW (Zanesco et al., 2016). Despite thought probes not purely reflecting meta-unaware MW, the present study found differences in driving behaviour between probe-caught and self-caught MW. Future studies may use other methods to measure meta-awareness, such as including three response-options for probes: meta-aware MW, meta-unaware MW, and focused driving (e.g., with separate buttons on the steering wheel).

Conclusion

The present study is the first to demonstrate a reduction in MW while driving from MT. This finding, and those pertaining to MT's specificity of action, support a plausible mechanism by which MT may reduce young driver distraction. Exploration of safe driving outcomes further hints at MT's potential for reducing MW-related crash risk. Overall, this pilot trial reveals MT to be a feasible and compelling candidate for future definitive trials.

References

Albert, D. A., Ouimet, M. C., Jarret, J., Cloutier, M.-S., Paquette, M., Badeau, N., & Brown, T. G. (2018). Linking mind wandering tendency to risky driving in young male drivers. *Accident Analysis & Prevention*, *111*, 125–132. https://doi.org/10.1016/j.aap.2017.11.019

Alfonsson, S., Olsson, E., & Hursti, T. (2016). Motivation and Treatment Credibility Predicts Dropout, Treatment Adherence, and Clinical Outcomes in an Internet-Based Cognitive Behavioral Relaxation Program: A Randomized Controlled Trial. *Journal of Medical Internet Research*, *18*(3), e5352. https://doi.org/10.2196/jmir.5352

Andersson, G., & Titov, N. (2014). Advantages and limitations of Internet-based interventions for common mental disorders. *World Psychiatry*, *13*(1), 4–11. https://doi.org/10.1002/wps.20083

Baer, R., Crane, C., Miller, E., & Kuyken, W. (2019). Doing no harm in mindfulness-based programs: Conceptual issues and empirical findings. *Clinical Psychology Review*, *March 2018*, 1–14. https://doi.org/10.1016/j.cpr.2019.01.001

Baldwin, C. L., Roberts, D. M., Barragan, D., Lee, J. D., Lerner, N., & Higgins, J. S. (2017). Detecting and quantifying mind wandering during simulated driving. *Frontiers in Human Neuroscience*, *11*, 406. https://doi.org/10.3389/fnhum.2017.00406

Baltruschat, S., Mas-Cuesta, L., Cándido, A., Maldonado, A., Verdejo-Lucas, C., Catena-Verdejo, E., & Catena, A. (2021). Repeat Traffic Offenders Improve Their Performance in Risky Driving Situations and Have Fewer Accidents Following a Mindfulness-Based Intervention. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.567278

Banks, J. B., Welhaf, M. S., & Srour, A. (2015). The protective effects of brief mindfulness meditation training. *Consciousness and Cognition*, *33*, 277–285. https://doi.org/10.1016/j.concog.2015.01.016

Banks, K., Newman, E., & Saleem, J. (2015). An Overview of the Research on Mindfulness-Based Interventions for Treating Symptoms of Posttraumatic Stress Disorder: A Systematic Review. *Journal of Clinical Psychology*, *71*(10), 935–963. https://doi.org/10.1002/jclp.22200

Beck, A. T., Steer, R. A., Brown, G. K., & others. (1996). Beck depression inventory-II. *San Antonio, TX: Psychological Corporation*, *78*(2), b9.

Bennike, I. H., Wieghorst, A., & Kirk, U. (2017). Online-based Mindfulness Training Reduces Behavioral Markers of Mind Wandering. *Journal of Cognitive Enhancement*, *1*(2), 172–181. https://doi.org/10.1007/s41465-017-0020-9

Berman, A. H., Bergman, H., Palmstierna, T., & Schlyter, F. (2003). *The Drug Use Disorders Identification Test: Manual*. 1–16.

Bernstein, D. A., Carlson, C. R., & Schmidt, J. E. (2007). Progressive relaxation. *Stress Management*, 88.

Berthié, G., Lemercier, C., Paubel, P.-V., Cour, M., Fort, A., Galéra, C., Lagarde, E., Gabaude, C., & Maury, B. (2015). The restless mind while driving: Drivers’ thoughts behind the wheel. *Accident Analysis & Prevention*, *76*, 159–165. https://doi.org/10.1016/j.aap.2015.01.005

Biswas, R. K., Friswell, R., Olivier, J., Williamson, A., & Senserrick, T. (2021). A systematic review of definitions of motor vehicle headways in driver behaviour and performance studies.

Transportation Research Part F: Traffic Psychology and Behaviour, *77*, 38–54. https://doi.org/10.1016/j.trf.2020.12.011

Boggs, J. M., Beck, A., Felder, J. N., Dimidjian, S., Metcalf, C. A., & Segal, Z. V. (2014). Web-Based Intervention in Mindfulness Meditation for Reducing Residual Depressive Symptoms and Relapse Prophylaxis: A Qualitative Study. *Journal of Medical Internet Research*, *16*(3), e87. https://doi.org/10.2196/jmir.3129

Bradley, D. R., & Cutcomb, S. (1977). Monte Carlo simulations and the chi-square test of independence. *Behavior Research Methods & Instrumentation*, *9*(2), 193–201. https://doi.org/10.3758/BF03214499

Brandmeyer, T., & Delorme, A. (2021). Meditation and the Wandering Mind: A Theoretical Framework of Underlying Neurocognitive Mechanisms. *Perspectives on Psychological Science*, *16*(1), 39–66. https://doi.org/10.1177/1745691620917340

Brauer, M., & Curtin, J. J. (2018). Linear mixed-effects models and the analysis of nonindependent data: A unified framework to analyze categorical and continuous independent variables that vary within-subjects and/or within-items. *Psychological Methods*, *23*(3), 389–411. https://doi.org/10.1037/met0000159

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, Executive Control, and Neurobiological Characteristics Associated with Different Forms of Risky Driving. *PLOS ONE*, *11*(2), e0150227. https://doi.org/10.1371/journal.pone.0150227

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2017). The effect of age on the personality and cognitive characteristics of three distinct risky driving offender groups. *Personality and Individual Differences*, *113*, 48–56. https://doi.org/10.1016/j.paid.2017.03.007

Bryce, S. D., Lee, S. J., Ponsford, J. L., Lawrence, R. J., Tan, E. J., & Rossell, S. L. (2018). The impact of intrinsic motivation on session attendance and reliable cognitive improvement in cognitive remediation in schizophrenia. *Schizophrenia Research*, *202*, 354–360. https://doi.org/10.1016/j.schres.2018.06.028

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 and Prevention*, *95*, 1–7. https://doi.org/10.1016/j.aap.2016.06.012

Carpenter, C. S., & Nguyen, H. V. (2015). Effects of a Driver Cellphone Ban on Overall, Handheld, and Hands-Free Cellphone Use While Driving: New Evidence from Canada: Effects of a Cellphone Ban on Handheld and Hands-Free Cellphone Use. *Health Economics*, *24*(11), 1452–1467. https://doi.org/10.1002/hec.3098

Chen, T., Qin, X., Cui, J., Li, Y., Liu, L., Wang, P., Tao, S., Shum, D. H. K., Wang, Y., & Chan, R. C. K. (2019). Mind wandering in schizophrenia: A thought-sampling study. *Consciousness and Cognition*, *74*, 102774. https://doi.org/10.1016/j.concog.2019.102774

Cowley, J. A. (2013). Off Task Thinking Types and Performance Decrements During Simulated Automobile Driving. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *57*(1), 1214–1218. https://doi.org/10.1177/1541931213571270

Crane, R. S., & Hecht, F. M. (2018). Intervention Integrity in Mindfulness-Based Research. *Mindfulness*, *9*(5), 1370–1380. https://doi.org/10.1007/s12671-018-0886-3

Davidson, R. J., & Kaszniak, A. W. (2015). Conceptual and Methodological Issues in Research on Mindfulness and Meditation. *The American Psychologist*, *70*(7), 581–592. https://doi.org/10.1037/a0039512

Dunne, J. D., Thompson, E., & Schooler, J. (2019). Mindful meta-awareness: Sustained and non-propositional. *Current Opinion in Psychology*, *28*, 307–311. https://doi.org/10.1016/j.copsyc.2019.07.003

Feldman, G., Greeson, J., & Senville, J. (2010). Differential effects of mindful breathing, progressive muscle relaxation, and loving-kindness meditation on decentering and negative reactions to repetitive thoughts. *Behaviour Research and Therapy*, *48*(10), 1002–1011. https://doi.org/10.1016/j.brat.2010.06.006

Feruglio, S., Matiz, A., Pagnoni, G., Fabbro, F., & Crescentini, C. (2021). The Impact of Mindfulness Meditation on the Wandering Mind: A Systematic Review. *Neuroscience & Biobehavioral Reviews*, *131*, 313–330. https://doi.org/10.1016/j.neubiorev.2021.09.032

Forbes, L., Gutierrez, D., & Johnson, S. K. (2018). Investigating Adherence to an Online Introductory Mindfulness Program. *Mindfulness*, *9*(1), 271–282. https://doi.org/10.1007/s12671-017-0772-4

Gál, É., Ștefan, S., & Cristea, I. A. (2021). The efficacy of mindfulness meditation apps in enhancing users' well-being and mental health related outcomes: A meta-analysis of randomized controlled trials. *Journal of Affective Disorders*, *279*, 131–142. https://doi.org/10.1016/j.jad.2020.09.134

Gil-Jardiné, C., Née, M., Lagarde, E., Schooler, J., Contrand, B., Orriols, L., & Galera, C. (2017). The distracted mind on the wheel: Overall propensity to mind wandering is associated with road crash responsibility. *PLoS ONE*, *12*(8), 1–10. https://doi.org/10.1371/journal.pone.0181327

Goldberg, S. B., Tucker, R. P., Greene, P. A., Simpson, T. L., Kearney, D. J., & Davidson, R. J. (2017). Is mindfulness research methodology improving over time? A systematic review. *PLoS ONE*, *12*(10), 1–16. https://doi.org/10.1371/journal.pone.0187298

González-García, M., Álvarez, J. C., Pérez, E. Z., Fernandez-Carriba, S., & López, J. G. (2021). Feasibility of a Brief Online Mindfulness and Compassion-Based Intervention to Promote Mental Health Among University Students During the COVID-19 Pandemic. *Mindfulness*, *12*(7), 1685–1695. https://doi.org/10.1007/s12671-021-01632-6

Guo, F., Klauer, S. G., Fang, Y., Hankey, J. M., Antin, J. F., Perez, M. A., Lee, S. E., & Dingus, T. A. (2017). The effects of age on crash risk associated with driver distraction. *International Journal of Epidemiology*, *46*(1), 258–265. https://doi.org/10.1093/ije/dyw234

Hildebrand, M. (2015). The Psychometric Properties of the Drug Use Disorders Identification Test (DUDIT): A Review of Recent Research. *Journal of Substance Abuse Treatment*, *53*, 52–59. https://doi.org/10.1016/j.jsat.2015.01.008

Hróbjartsson, A., Emanuelsson, F., Skou Thomsen, A. S., Hilden, J., & Brorson, S. (2014). Bias due to lack of patient blinding in clinical trials. A systematic review of trials randomizing patients to blind and nonblind sub-studies. *International Journal of Epidemiology*, *43*(4), 1272–1283. https://doi.org/10.1093/ije/dyu115

Jacobson, E. (1938). *Progressive relaxation ; a physiological and clinical investigation of muscular states and their significance in psychology and medical practice*. The University of Chicago press. //catalog.hathitrust.org/Record/001554317

Johnson, J. A., Lee, A., Vinson, D., & Seale, J. P. (2013). Use of AUDIT-based measures to identify unhealthy alcohol use and alcohol dependence in primary care: A validation study. *Alcoholism: Clinical and Experimental Research*, *37*(s1), E253–E259. https://doi.org/10.1111/j.1530-0277.2012.01898.x

Julious, S. A. (2005). Sample size of 12 per group rule of thumb for a pilot study. *Pharmaceutical Statistics*, *4*(4), 287–291. https://doi.org/10.1002/pst.185

Kabat-Zinn, J. (1994). *Wherever you go, there you are: Mindfulness meditation in everyday life*. Hyperion.

Kass, S. J., VanWormer, L. A., Mikulas, W. L., Legan, S., & Bumgarner, D. (2011). Effects of Mindfulness Training on Simulated Driving: Preliminary Results. *Mindfulness*, *2*(4), 236–241. https://doi.org/10.1007/s12671-011-0066-1

Kiken, L. G., Garland, E. L., Bluth, K., Palsson, O. S., & Gaylord, S. A. (2015). From a state to a trait: Trajectories of state mindfulness in meditation during intervention predict changes in trait mindfulness. *Personality and Individual Differences*, *81*, 41–46. https://doi.org/10.1016/j.paid.2014.12.044

Koppel, S., Bugeja, L., Hua, P., Osborne, R., Stephens, A. N., Young, K. L., Chambers, R., & Hassed, C. (2019). Do mindfulness interventions improve road safety? A systematic review. *Accident Analysis & Prevention*, *123*, 88–98. https://doi.org/10.1016/j.aap.2018.11.013

Lerner, N., Baldwin, C., Higgins, J. S., Lee, J., & Schooler, J. (2015). Mind Wandering While Driving. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *59*(1), 1686–1690. https://doi.org/10.1177/1541931215591364

Levensky, E. R., O'Donohue, W. T., & William, T. (2006). Patient adherence and nonadherence to treatments. *Promoting Treatment Adherence: A Practical Handbook for Health Care Providers*, 3–14.

Lindahl, J. R., Britton, W. B., Cooper, D. J., & Kirmayer, L. J. (2021). Challenging and Adverse Meditation Experiences: Toward a Person-Centered Approach. In M. Farias, D. Brazier, & M. Lalljee (Eds.), *The Oxford Handbook of Meditation* (pp. 839–864). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198808640.013.51

Mander, J., Blanck, P., Neubauer, A. B., Kröger, P., Flückiger, C., Lutz, W., Barnow, S., Bents, H., & Heidenreich, T. (2019). Mindfulness and progressive muscle relaxation as standardized session-introduction in individual therapy: A randomized controlled trial. *Journal of Clinical Psychology*, *75*(1), 21–45.

Markkula, G., & Engstrom, J. (2006). A steering wheel reversal rate metric for assessing effects of visual and cognitive secondary task load. *13th World Congress on Intelligent Transport Systems and Services*.

Mathieu, E., McGeechan, K., Barratt, A., & Herbert, R. (2013). Internet-based randomized controlled trials: A systematic review. *Journal of the American Medical Informatics Association : JAMIA*, *20*(3), 568–576. https://doi.org/10.1136/amiajnl-2012-001175

Mrazek, A. J., Mrazek, M. D., Cherolini, C. M., Cloughesy, J. N., Cynman, D. J., Gougis, L. J., Landry, A. P., Reese, J. V., & Schooler, J. W. (2019). The future of mindfulness training is digital, and the future is now. *Current Opinion in Psychology*, *28*, 81–86. https://doi.org/10.1016/j.copsyc.2018.11.012

Mrazek, M. D., Franklin, M. S., Phillips, D. T., Baird, B., & Schooler, J. W. (2013). Mindfulness Training Improves Working Memory Capacity and GRE Performance While Reducing Mind Wandering. *Psychological Science*, *24*(5), 776–781. https://doi.org/10.1177/0956797612459659

Mrazek, M. D., Mooneyham, B. W., & Schooler, J. W. (2014). Insights from quiet minds: The converging fields of mindfulness and mind-wandering. In *Meditation–Neuroscientific Approaches and Philosophical Implications* (pp. 227–241). Springer.

Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2012). Mindfulness and mind-wandering: Finding convergence through opposing constructs. *Emotion (Washington, D.C.)*, *12*(3), 442–448. https://doi.org/10.1037/a0026678

Nam, S., & Toneatto, T. (2016). The Influence of Attrition in Evaluating the Efficacy and Effectiveness of Mindfulness-Based Interventions. *International Journal of Mental Health and Addiction*, *14*(6), 969–981. https://doi.org/10.1007/s11469-016-9667-1

Ouimet, M. C., Brown, T. G., Corado, L., Paquette, M., & Robertson, R. D. (2020). The effects of alcohol dose, exposure to an in-vehicle alcohol feedback device, and subjective responses to alcohol on the decision to drink-drive in young drivers. *Accident Analysis & Prevention*, *139*, 105495. https://doi.org/10.1016/j.aap.2020.105495

Rahl, H. A., Lindsay, E. K., Pacilio, L. E., Brown, K. W., & Creswell, J. D. (2017). Brief mindfulness meditation training reduces mind wandering: The critical role of acceptance. *Emotion (Washington, D.C.)*, *17*(2), 224–230. https://doi.org/10.1037/emo0000250

Rudisill, T. M., Chu, H., & Zhu, M. (2018). Cell phone use while driving laws and motor vehicle driver fatalities: Differences in population subgroups and location. *Annals of Epidemiology*, *28*(10), 730–735. https://doi.org/10.1016/j.annepidem.2018.07.015

Rudisill, T. M., & Zhu, M. (2017). Hand-held cell phone use while driving legislation and observed driver behavior among population sub-groups in the United States. *BMC Public Health*, *17*(1), 437. https://doi.org/10.1186/s12889-017-4373-x

Ryan, R. M. (1982). Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory. *Journal of Personality and Social Psychology*, *43*(3), 450.

Saghaei, M. (2011). An overview of randomization and minimization programs for randomized clinical trials. *Journal of Medical Signals and Sensors*, *1*(1), 55.

Saunders, J. B., Aasland, O. G., Babor, T. F., De la Fuente, J. R., & Grant, M. (1993). Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption-II. *Addiction*, *88*(6), 791–804.

Sayette, M. A., Reichle, E. D., & Schooler, J. W. (2009). Lost in the sauce: The effects of alcohol on mind wandering. *Psychological Science*, *20*(6), 747–752. https://doi.org/10.1111/j.1467-9280.2009.02351.x

Sayette, M. A., Schooler, J. W., & Reichle, E. D. (2010). Out for a smoke: The impact of cigarette craving on zoning out during reading. *Psychological Science*, *21*(1), 26–30. https://doi.org/10.1177/0956797609354059

Schooler, J. W. (2002). Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in Cognitive Sciences*, *6*(8), 339–344. https://doi.org/10.1016/S1364-6613(02)01949-6

Schooler, J. W., Reichle, E. D., & Halpern, D. V. (2004). Zoning Out while Reading: Evidence for Dissociations between Experience and Metaconsciousness. *Thinking and Seeing: Visual Metacognition in Adults and Children.*, 203–226.

Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*, *15*(7), 319–326. https://doi.org/10.1016/j.tics.2011.05.006

Schutte, T., Tichelaar, J., Dekker, R. S., Thijs, A., De Vries, T. P. G. M., Kusurkar, R. A., Richir, M. C., & Van Agtmael, M. A. (2017). Motivation and competence of participants in a learner-centered student-run clinic: An exploratory pilot study. *BMC Medical Education*, *17*(1), 1–13. https://doi.org/10.1186/s12909-017-0856-9

Seli, P., Beaty, R. E., Cheyne, J. A., Smilek, D., Oakman, J., & Schacter, D. L. (2018). How pervasive is mind wandering, really?,. *Consciousness and Cognition*, *66*, 74–78. https://doi.org/10.1016/j.concog.2018.10.002

Seli, P., Schacter, D. L., Risko, E. F., & Smilek, D. (2019). Increasing participant motivation reduces rates of intentional and unintentional mind wandering. *Psychological Research*, *83*(5), 1057–1069. https://doi.org/10.1007/s00426-017-0914-2

Sevilla-Llewellyn-Jones, J., Santesteban-Echarri, O., Pryor, I., McGorry, P., & Alvarez-Jimenez, M. (2018). Web-Based Mindfulness Interventions for Mental Health Treatment: Systematic

Review and Meta-Analysis. *JMIR Mental Health*, *5*(3), e10278. https://doi.org/10.2196/10278

Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process–occurrence framework for self-generated mental activity. *Psychological Bulletin*, *139*(3), 519–535. https://doi.org/10.1037/a0030010

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review*, *14*(3), 527–533. https://doi.org/10.3758/BF03194102

Smallwood, J., & Schooler, J. W. (2015). The Science of Mind Wandering: Empirically Navigating the Stream of Consciousness. *Annual Review of Psychology*, *66*(1), 487–518. https://doi.org/10.1146/annurev-psych-010814-015331

Spijkerman, M. P. J., Pots, W. T. M., & Bohlmeijer, E. T. (2016). Effectiveness of online mindfulness-based interventions in improving mental health: A review and meta-analysis of randomised controlled trials. *Clinical Psychology Review*, *45*, 102–114. https://doi.org/10.1016/j.cpr.2016.03.009

Spitzer, R. L., Kroenke, K., Williams, J. B. W., & Löwe, B. (2006). A Brief Measure for Assessing Generalized Anxiety Disorder: The GAD-7. *Archives of Internal Medicine*, *166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Stallard, N. (2012). Optimal sample sizes for phase II clinical trials and pilot studies. *Statistics in Medicine*, *31*(11–12), 1031–1042. https://doi.org/10.1002/sim.4357

Steinberger, F., Moeller, A., & Schroeter, R. (2016). The antecedents, experience, and coping strategies of driver boredom in young adult males. *Journal of Safety Research*, *59*, 69–82. https://doi.org/10.1016/j.jsr.2016.10.007

Stjernswärd, S., & Hansson, L. (2017). Outcome of a web-based mindfulness intervention for families living with mental illness – A feasibility study. *Informatics for Health and Social Care*, *42*(1), 97–108. https://doi.org/10.1080/17538157.2016.1177533

Tanay, G., & Bernstein, A. (2013). State mindfulness scale (SMS): Development and initial validation. *Psychological Assessment*, *25*(4), 1286–1299. https://doi.org/10.1037/a0034044

van der Gaag, M., Klaassen, R. M. C., Linszen, D. H., Loewy, R. L., Ising, H. K., Veling, W., Rietdijk, J., Rietveld, M. W., Dragt, S., Nieman, D. H., & Wunderink, L. (2012). The Validity of the 16-Item Version of the Prodromal Questionnaire (PQ-16) to Screen for Ultra High Risk of Developing Psychosis in the General Help-Seeking Population. *Schizophrenia Bulletin*, *38*(6), 1288–1296. https://doi.org/10.1093/schbul/sbs068

Vannucci, M., Pelagatti, C., Hanczakowski, M., & Chiorri, C. (2019). Visual attentional load affects the frequency of involuntary autobiographical memories and their level of meta-awareness. *Memory & Cognition*, *47*(1), 117–129. https://doi.org/10.3758/s13421-018-0854-0

Walker, H. E. K., & Trick, L. M. (2019). Mind-Wandering and Driving: Comparing Thought Report and Individual Difference Measures. *Proceedings of the 10th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design: Driving Assessment 2019*, 8–14. https://doi.org/10.17077/drivingassessment.1668

Word Health Organization. (2015). Global status report on road safety 2015. In *Who*. World Health Organization.

Wynne, R. A., Beanland, V., & Salmon, P. M. (2019). Systematic review of driving simulator validation studies. *Safety Science*, *117*(March), 138–151. https://doi.org/10.1016/j.ssci.2019.04.004

Xi, W., Pennell, M. L., Andridge, R. R., & Paskett, E. D. (2018). Comparison of intent-to-treat analysis strategies for pre-post studies with loss to follow-up. *Contemporary Clinical Trials Communications*, *11*, 20–29. https://doi.org/10.1016/j.conctc.2018.05.008

Xiao, L., Huang, Q., Yank, V., & Ma, J. (2013). An Easily Accessible Web-Based Minimization Random Allocation System for Clinical Trials. *Journal of Medical Internet Research*, *15*(7), e139. https://doi.org/10.2196/jmir.2392

Yakobi, O., Smilek, D., & Danckert, J. (2021). The Effects of Mindfulness Meditation on Attention, Executive Control and Working Memory in Healthy Adults: A Meta-analysis of Randomized Controlled Trials. *Cognitive Therapy and Research*. https://doi.org/10.1007/s10608-020-10177-2

Yanko, M. R., & Spalek, T. M. (2014). Driving with the wandering mind: The effect that mind-wandering has on driving performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *56*(2), 260–269. https://doi.org/10.1177/0018720813495280

Young, K. L., Koppel, S., Stephens, A. N., Osborne, R., Chambers, R., & Hassed, C. (2019). Mindfulness Predicts Driver Engagement in Distracting Activities. *Mindfulness*, *10*(5), 913–922. https://doi.org/10.1007/s12671-018-1060-7

Zanesco, A. P., King, B. G., MacLean, K. A., Jacobs, T. L., Aichele, S. R., Wallace, B. A., Smallwood, J., Schooler, J. W., & Saron, C. D. (2016). Meditation training influences mind wandering and mindless reading. *Psychology of Consciousness: Theory, Research, and Practice*, *3*(1), 12–33. https://doi.org/10.1037/cns0000082

Zedelius, C. M., Broadway, J. M., & Schooler, J. W. (2015). Motivating meta-awareness of mind wandering: A way to catch the mind in flight? *Consciousness and Cognition*, *36*, 44–53. https://doi.org/10.1016/j.concog.2015.05.016

Zhang, Y., & Kumada, T. (2017). Relationship between workload and mind-wandering in simulated driving. *PLOS ONE*, *12*(5), e0176962. https://doi.org/10.1371/journal.pone.0176962

Supplementary Material

Table S.1

Driving Behaviour Linked to Probe-Caught MW, Self-Caught MW, and Focused Driving at T1

Variable	State	*M* (*SE*)	Planned Comparisons		
			Comparison	*B*	*95% CI*
Mean Speed,	FD	75.4 (2.02)	SMW - FD	-1.01	[-3.20, 1.17]
kilometers/hour	SMW	74.4 (2.02)	PMW - FD	0.72	[-1.50, 2.93]
	PMW	76.1 (2.03)	PMW - SMW	1.73	[-0.48, 3.95]
Speed Variability,	FD	3.71 (0.27)	SMW - FD	-0.81	[-1.34, -0.28]
kilometers/hour	SMW	2.90 (0.27)	PMW - FD	-0.89	[-1.43, -0.35]
	PMW	2.82 (0.27)	PMW - SMW	-0.08	[-0.62, 0.46]
Mean Headway,	FD	42.5 (2.88)	SMW - FD	1.75	[-3.00, 6.50]
meters	SMW	44.2 (2.82)	PMW - FD	-5.28	[-10.5, -0.09]
	PMW	37.2 (3.07)	PMW - SMW	-7.03	[-12.2, -1.86]
Headway Variability,	FD	8.88 (1.20)	SMW - FD	-3.26	[-6.10, -0.42]
meters	SMW	5.62 (1.15)	PMW - FD	-4.23	[-7.36, -1.11]
	PMW	4.65 (1.35)	PMW - SMW	-0.98	[-4.06, 2.11]
Steering Reversals,	FD	3.55 (0.38)	SMW / FD	0.97	[0.90, 1.05]
n/10 seconds	SMW	3.45 (0.37)	PMW / FD	0.89	[0.81, 0.98]
	PMW	3.17 (0.35)	PMW / SMW	0.92	[0.84, 1.00]
Overtaking,	FD	0.04 (0.01)	SMW / FD	0.32	[0.14, 0.72]
n/30 minute drive	SMW	0.01 (0.01)	PMW / FD	0.33	[0.12, 0.89]
	PMW	0.01 (0.01)	PMW / SMW	1.03	[0.36, 3.00]

Note. PMW = Probe-caught or meta-unaware mind wandering, SMW = Self-caught or meta-aware mind wandering, FD = Focused driving. There were no crashes within the 10-second samples for each state. Planned comparisons and 95% CIs were calculated with marginal means from linear and general linear mixed models. Planned comparisons were calculated as rate ratios for steering reversals and overtaking.

Table S.2

Changes in Driving Behaviour from T1 to T2 and Between Intervention Groups

Variable	Group	T1 *M* (*SE*)	T2 *M* (*SE*)	Planned Comparisons		
				Comparison	*B*	*95% CI*
Mean Speed,	MT	77.0 (3.03)	81.5 (3.37)	T2 - T1	4.54	[-1.30, 10.4]
kilometers/hour	PMR	73.4 (3.03)	76.3 (3.17)	T2 - T1	2.98	[-2.35, 8.32]
				$\Delta T_{MT} - \Delta T_{PMR}$	1.55	[-6.35, 9.46]
Speed Variability,	MT	3.42 (0.34)	3.79 (0.38)	T2 - T1	0.37	[-0.32, 1.06]
kilometers/hour	PMR	2.95 (0.34)	3.11 (0.35)	T2 - T1	0.16	[-0.47, 0.79]
				$\Delta T_{MT} - \Delta T_{PMR}$	0.21	[-0.72, 1.15]
Mean Headway,	MT	39.2 (3.36)	39.0 (4.12)	T2 - T1	-0.21	[-8.81, 8.39]
meters	PMR	45.6 (3.36)	44.8 (3.92)	T2 - T1	-0.72	[-8.91, 7.46]
				$\Delta T_{MT} - \Delta T_{PMR}$	0.51	[-11.4, 12.4]
Headway Variability,	MT	5.90 (1.21)	7.11 (1.74)	T2 - T1	1.21	[-1.91, 4.33]
meters	PMR	4.79 (0.99)	6.72 (1.58)	T2 - T1	1.93	[-0.80, 4.65]
				$\Delta T_{MT} - \Delta T_{PMR}$	-0.72	[-4.86, 3.43]
Steering Reversals,	MT	3.51 (0.49)	3.40 (0.49)	T2 / T1	0.97	[0.90, 1.05]
n/10 seconds	PMR	3.49 (0.49)	2.48 (0.35)	T2 / T1	0.71	[0.67, 0.76]
				$\Delta T_{MT} / \Delta T_{PMR}$	1.36	[1.23, 1.51]
Overtaking,	MT	0.03 (0.01)	0.02 (0.01)	T2 / T1	0.60	[0.25, 1.47]
n/30 minutes	PMR	0.02 (0.01)	0.02 (0.01)	T2 / T1	1.15	[0.55, 2.40]
				$\Delta T_{MT} / \Delta T_{PMR}$	0.52	[0.16, 1.67]
Crashes,	MT	0.39 (0.25)	0.08 (0.09)	T2 / T1	0.21	[0.02, 1.78]
n/30 minutes	PMR	0.05 (0.05)	0.15 (0.11)	T2 / T1	3.22	[0.33, 31.1]
				$\Delta T_{MT} / \Delta T_{PMR}$	0.07	[0.00, 1.47]

Note. MT = Mindfulness Training, PMR = Progressive Muscle Relaxation, T1 = Intake, T2 = Follow-up. ΔT = T2-T1. Crashes reflect any that occurred throughout simulation. Planned comparisons and 95% CIs were calculated with marginal means from linear and general linear mixed models. Planned comparisons were calculated as rate ratios for steering reversals, overtaking, and crashes.

General Discussion

Road traffic crashes continue to threaten the health and safety of young people everywhere. The present thesis aimed to address the contribution of MW to young driver crash risk by isolating negative mood as a potential cause and exploring mindfulness as a potential mitigator of MW while driving in this population. The present thesis included a narrative review and two manuscripts to accomplish these objectives. The narrative review, of evidence from the traffic safety and psychology literatures on MW, uncovered mechanisms by which negative mood and mindfulness may influence MW-related crash risk in young drivers. Study 1 reported on a randomized controlled experiment examining the effects of negative mood on MW and MW-related unsafe driving in young drivers. Study 2 reported on a pilot randomized controlled trial exploring the feasibility and preliminary efficacy of MT for reducing the contribution of MW to unsafe driving in young drivers. The following section summarizes, synthesizes, and explores the implications of the main findings of these studies, discusses the strengths and limitations of the present thesis, and suggests future directions for research in this area.

Summary of Main Findings

A Narrative Review of Potential Mechanisms Linking Mind Wandering to Young Driver Crashes

The narrative review addressed three questions. The first related to how MW may contribute to road traffic crashes. It was hypothesized that the relationship between MW and crashes is mediated by sensory-motor decoupling, a process whereby cognitive resources get diverted from sensory information processing and performance monitoring to self-generated thoughts. In support of this possibility, links were found between MW and poor hazard detection in the form of reduced visual scanning behaviour (e.g., He et al., 2011), attenuated cortical responses and slow reactions to road hazards (e.g., sudden braking by a lead vehicle; Pepin et al., 2020). MW was also linked to poor behaviour regulation in terms of unsafe changes in continuous driving behaviours (e.g., speeding, tailgating, drifting).

The second question addressed in the narrative review related to why young drivers are particularly prone to MW while driving. Developmental factors were proposed to contribute to more MW and poor regulation of MW while driving, in young compared to older drivers. The attention of young people was found to be biased towards exploration (broad, unfocused attention), which is associated with MW, versus exploitation (narrow, focussed attention), which is associated with task focus (Mata et al., 2013; Sripada, 2018). Evidence also suggested that two neurocognitive systems, which develop asymmetrically from adolescents to early adulthood (Shulman et al., 2016; Steinberg et al., 2008), contribute to the regulation of MW. In particular, the socioemotional system, which develops rapidly from the start of puberty and is involved in affective processes, reward-seeking, and social cognition, was found to overlaps with the salience network, which can contribute to emotion-related MW (Rosen et al., 2018; van Hoorn et al., 2019). The cognitive control system, which develops gradually into early adulthood and is involved in impulse control, was found to overlap with the cognitive control network, which can reduce MW to facilitate task focus (Christoff et al., 2016). The developmental asynchrony of these two systems was proposed to predispose young drivers to MW dysregulation.

The third question addressed by the narrative review relates to what factors may cause and mitigate MW in young drivers. Negative mood was hypothesized to cause MW and MW-related unsafe driving in young drivers. Evidence was found linking negative mood, MW, and crashes in young drivers. Depression symptoms, including negative mood and ruminative MW, were found to predict more crashes in young compared to older drivers (McDonald et al., 2014). Negative mood was also found to positively predict MW among young drivers in simulation (Walker & Trick, 2019). In the general population, negative mood was found to increase MW in non-driving contexts (Marcusson-Clavertz et al., 2020; Poerio et al., 2013; Smallwood, Fitzgerald, et al., 2009). Negative mood was also found to increase unsafe driving when drivers are unengaged in secondary tasks, and thus free to engage in MW (Steinhauser et al., 2018; Zimasa et al., 2019). Furthermore, evidence was found linking stressful life events to distraction-related driving errors and crash responsibility (Cunningham & Regan, 2016).

Mindfulness, a state and trait capacity for sustained non-distraction, was hypothesized to mitigate MW in young drivers. Greater trait mindfulness was found to predict less driver distraction and distraction-related unsafe driving (Koppel et al., 2019; K. L. Young et al., 2019). Lower trait mindfulness was also found to correlate with greater MW while driving in young compared to older drivers (Burdett et al., 2016). Substantial evidence was found linking MT, involving meditation practices for enhancing metacognitive awareness (i.e., meta-awareness) and disengagement from MW, to increased cognitive control and decreased MW in non-driving contexts (Feruglio et al., 2021; Yakobi et al., 2021). Preliminary evidence was also found linking MT to improved driver situational awareness (Kass et al., 2011), decreased risky driving, and decreased crashes in simulation (Baltruschat et al., 2021). Finally, evidence was found linking meta-awareness of MW to attenuated MW-related unsafe driving (Albert et al., 2018; Berthié et al., 2015; Cowley, 2013).

Negative Mood Mind Wandering and Unsafe Driving in Young Male Drivers

The first manuscript of the present thesis (Study 1) examined the effects of negative mood on MW and MW-related unsafe driving in a sample of young male drivers. It was hypothesized that, compared to neutral mood, negative mood would lead to more MW while driving, more unsafe driving linked to MW, and more emotionally arousing MW while driving. The study found that exposure to negative versus neutral mood led to more MW while driving in simulation. Negative mood also increased MW-related unsafe driving, specifically in terms of greater headway variability and steering reversals. It was also hypothesized that individual differences in trait rumination and inhibitory control would moderate the effects of negative mood. Results revealed a moderation effect of trait rumination on the relationship between negative mood and MW, such that higher trait rumination predicted greater increases in MW from negative mood.

A Randomized Controlled Pilot Trial of Brief Online Mindfulness Training in Young Drivers

The second manuscript of the present thesis (Study 2) explored the feasibility and preliminary efficacy of brief online MT for reducing MW and unsafe driving in a sample of young male and female drivers. It was hypothesized that, compared to an active control condition (PMR), exposure to 4–6 fifteen-minute sessions of MT via audio recordings would increase meta-awareness and reduce the occurrence of MW while driving. MT was found to reduce MW while driving in simulation. Results for meta-awareness were inconclusive. The specificity of action of MT was also explored by comparing state mindfulness following sessions of MT versus PMR, and by performing sensitivity analyses with interest/enjoyment (i.e., motivation) of the interventions as a covariate. MT was associated with greater state mindfulness following sessions. There was insufficient evidence to suggest that non-specific variability in motivation explained the effects of

MT on state mindfulness or MW. Driving behaviours associated with meta-awareness of MW, and from MT were also explored. Self-caught (i.e., meta-aware) MW was linked to longer headway distances compared to probe-caught (i.e., meta-unaware) MW, which was linked to shorter headway distances compared to focused driving. MT led to a relative increase in steering reversals compared to PMR. Finally, brief online MT feasibility, in terms of objective adherence and self-reported acceptability, was also explored. There was insufficient evidence for a difference in adherence between groups. No severe adverse effects were reported, but the MT group reported greater difficulty following intervention instructions compared to PMR.

Synthesis and Implications

Sensory-Motor Decoupling and Crashes Linked to Mind Wandering

Review evidence supported sensory-motor decoupling as a mechanism of MW-related crash risk. Evidence from driving simulation linking MW to reduced visual scanning (He et al., 2011), attenuated cortical responses, and slow reactions to road hazards (Pepin et al., 2020; Yanko & Spalek, 2014), aligns with evidence for sensory-motor decoupling in non-driving contexts. In particular, MW has been linked to a global attenuation of sensory information processing, evidenced by unresponsive eye movements (Smallwood et al., 2011), attenuated cortical responses, and slow reaction times to both task-relevant and irrelevant stimuli in attention tasks (Kam & Handy, 2013). Therefore, these findings suggest that sensory-motor decoupling generalizes to the driving context. MW-related sensory-motor decoupling may increase crash risk by preventing timely detection and reaction to road hazards. Sensory-motor decoupling may also account for MW-related unsafe driving, such as poor lane-keeping, which can lead to run-off-road crashes (Ghasemzadeh & Ahmed, 2017, 2018). Thus, sensory-motor decoupling may mediate the relationship between MW and crashes (Farouki et al., 2014; Galéra et al., 2012; Gil-Jardiné et al., 2017; Née et al., 2019). Understanding this to be a mechanism by which MW contributes to crashes may help target interventions. For instance, using machine-learning to detect changes in behaviour or physiology associated with sensory-motor decoupling could be combined with automation technologies to assist drivers when they become distracted (Beninger et al., 2021).

Young Driver Development of Attention Regulation

Review evidence linking neurocognitive development to attention regulation reveals certain ways in which young drivers may be particularly susceptible to crashes associated with MW. Evidence for a developmental bias of young people towards an exploratory mode of attention (Mata et al., 2013), which is proposed to include MW (Sripada, 2018), may explain why young drivers report more MW while driving compared to older drivers (Burdett et al., 2016). More frequent MW may increase the likelihood of a MW-related crash, possibly as a function of sensory-motor decoupling in situations where attention is needed to detect and quickly react to unexpected road hazards. The emotional reactivity of young drivers, coupled with their immature cognitive control capacities, may prevent them from effectively regulating MW while driving. Specifically, young drivers may have particular difficulty regulating negative mood-related MW, including rumination. Dysregulation of MW may be particularly dangerous when the demands of the driving task on attention are high, such as in complex driving scenarios (e.g., dense traffic, pedestrians, poor weather conditions, etc.)(Geden et al., 2018). Thus, greater MW and dysregulation of MW may contribute to young driver crash risk.

Negative Mood, Mindfulness, and Mind Wandering While Driving

Negative Mood Increases Mind Wandering

Study 1 demonstrated a causal link from negative mood to MW while driving in young drivers. Given review evidence for developmental limitations of young people in regulating emotion-related thoughts, a causal link from negative mood to MW in attention tasks, and a correlation between negative mood and MW in young drivers, it was hypothesized that negative mood may cause an increase the frequency, or extent, of MW while driving in young drivers. Young drivers exposed to a negative versus neutral mood induction in Study 1 reported more MW in response to thought probes during simulation than those in a neutral mood control condition. This finding generalizes previous findings from attention tasks to the context of driving. It also extends correlational evidence for negative mood-related MW among young drivers in simulation. Furthermore this finding aligns with review evidence suggesting that negative mood may represent a risk factor for MW and MW-related crashes in young drivers.

Study 1 also revealed a moderation effect of trait rumination in the relationship between negative mood and MW while driving. Specifically, high trait ruminators exhibited the greatest increases in MW following exposure to negative mood. This findings suggests that some young drivers are particularly susceptible to the effects of negative mood on MW while driving. Trait rumination may be suitable as a marker of young driver susceptibility to negative mood-related MW for the purpose of targeting interventions.

Mindfulness Training Decreases Mind Wandering

Study 2 found preliminary support for the efficacy of MT in reducing young driver MW in simulation. Specifically, young drivers reported MW to a smaller proportion of thought probes following exposure to MT versus an active control (PMR). This finding may explain previously observed improvements in situational awareness and safe driving in simulation following MT exposure. In particular, a small pilot study found that MT enhanced situational awareness, assessed via questions about the driving scenario (e.g., what is the speed limit? was there a pedestrian at the last intersection?) during a pause in the driving task (Kass et al., 2011). Another study found that MT reduced unsafe driving (e.g., high and variable driving speeds, higher steering variability, higher braking force) in risky driving scenarios, such as a pedestrian crossing the street or when there is an obstacle on the road (Baltruschat et al., 2021). Situational awareness and, by extension, adjustment of driving behaviour relies on sensory information (e.g., seeing the posted speed limit or the pedestrian). Thus, MT-related decreases in MW and MW-related sensory-motor decoupling may explain these previous findings. Together, these findings suggest that MT may reduce MW-related crash risk, by preventing sensory-motor decoupling from interfering with safe driving, particularly in the presence of road hazards.

The finding that MT reduced MW is bolstered by evidence supporting online MT's specificity of action. The observation of higher state mindfulness following sessions of MT compared to PMR suggests that online MT successfully induced a mindful state. Furthermore, there was insufficient evidence to suggest that motivation differed between interventions or that variability in motivation explained MT effects on state mindfulness and MW. Motivation positively predicts outcomes of cognitive training (Bryce et al., 2018) and negatively predicts MW in attention tasks and educational contexts (Seli et al., 2016, 2019). Thus, a significant association between motivation and MT outcomes could cast doubt on whether MT itself or some non-specific factor was responsible for its effects.

There was insufficient evidence for an increase in meta-awareness of MW while driving from MT. A previous study found a medium-sized increase in meta-awareness following intensive MT that took place over a month (Zanesco et al., 2016). Thus, Study 2 may have lacked sufficient power to detect this effect, or brief online MT may not be sufficient in dose or intensity to increase meta-awareness. At the same time, self-caught MW may not be a sensitive measure for the type of meta-awareness that is proposed to be cultivated in MT (Dunne et al., 2019).

Negative Mood, Mindfulness, and Unsafe Driving Linked to Mind Wandering

Negative Mood and Unsafe Driving Linked to Mind Wandering

Negative mood contributed to potentially unsafe changes in MW-related driving behaviour. Compared to neutral mood, negative mood increased headway variability linked to MW. In other words, compared to drivers in a neutral mood, those that were exposed to a negative mood maintained distances between themselves and lead vehicles that were less consistent during MW. A previous study found greater headway variability resulting from an angry mood (compared to calm and happy mood), but only in a driving scenario that placed little demands on driver attention (Steinhauser et al., 2018). Since MW is most frequent when demands on attention are low (Geden et al., 2018), the authors interpreted this finding to suggest that MW mediated the link between angry mood and unsafe driving. This finding from Study 1 thus extends this previous finding by directly examining the role of MW in negative mood-related unsafe driving. Greater headway variability is associated with driver distraction (Hosking et al., 2009; Regan & Hallett, 2011; K. L. Young & Salmon, 2012) and crashes (Hyun et al., 2019). Therefore, this finding suggests that negative mood may increase MW-related distraction and crash risk. At the same time, there was no significant change in headway variability from negative mood in isolation. Thus, additional research is needed to replicate and clarify this result.

Compared to neutral mood, negative mood also increased steering reversals linked to MW. Findings are mixed concerning the crash-risk implications of distraction-related increases in steering reversals. Some studies link more steering reversals to poor lane-keeping. For instance, more steering reversals have been linked to greater lane position variability, more lane excursions, reduced time-to-line crossing, and greater vehicle-to-road heading variability (Choudhary & Velaga, 2017; Kountouriotis et al., 2015, 2016; P. Li, Merat, et al., 2018; Z. Li et al., 2019; Pawar & Velaga, 2021). Other studies link more steering reversals to superior lane-keeping in terms of lower lane position variability (P. Li, Markkula, et al., 2018; Wang et al., 2019) and greater resistance to lateral movement from gusts of wind (He et al., 2014). These contradictory findings may reflect differences in minimum reversal size (e.g., 0.5° vs. 2° vs. 10°), driving scenario complexity, or distraction type. A previous study found fewer steering reversals (>2°) and lower lane position variability associated with MW compared to focused driving on straight roads in simulation (Baldwin et al., 2017). Another study found greater standard deviation of steering wheel angle, which increases with steering reversals (Choudhary & Velaga, 2017), and higher lane position variability associated with MW on curved roads (Zhang & Kumada, 2017). Since Study 1 incorporated curved roads, and a minimum reversal size of 2°, these findings suggest that the observed increase in steering reversals may be unsafe. As with headway variability, there was insufficient evidence for a significant change in steering reversals from negative mood in isolation, however. Thus, further research is needed to clarify the meaning and robustness of this finding.

Study 1 findings are unclear with respect to the precise mechanism by which negative mood contributes to MW-related unsafe driving. Study 1 did not replicate findings from other studies indicating main effects of negative mood on unsafe driving (Chan & Singhal, 2015; Du et al., 2020; Jallais et al., 2014; Jeon & Zhang, 2013). Furthermore, there was insufficient evidence for a mediation effect of MW frequency in relationships between negative mood and overall unsafe driving. This may relate to the use of thought-probes to measure MW in Study 1, which can limit unsafe driving linked to MW (Walker & Trick, 2019). Thus, results were inconclusive with respect to whether negative mood increases unsafe driving as a function of more frequent MW.

Results were inconclusive with respect to whether increases in MW-related unsafe driving from negative mood can be explained in terms of greater sensory-motor decoupling as a function of more emotionally arousing or salient MW. At the same time, steering reversals have been found to increase as a function of distraction-related cognitive load (Engström et al., 2017). Furthermore, in one study, both cognitive distraction and visual distraction increased small steering reversals (>0.5°), but only visual distraction increased larger steering reversals (>2.5°)(Kountouriotis et al., 2016). Since sensory-motor decoupling interferes with visual information processing (Pepin et al., 2020), the observed increase in MW-related steering reversals (>2°) from negative mood may reflect more sensory-motor decoupling related to high cognitive load MW. Thus, negative mood-related MW may be more cognitively demanding.

Various factors may explain the inconclusive results for the hypothesized increase in emotional arousal during negative mood-related MW. For instance, previously observed increases in heart rate during depressive rumination (Smallwood, O'Connor, et al., 2007) may not generalize to negative mood-related MW in healthy individuals. Alternatively, our mood manipulation may have selectively affected mood and MW valance, as distinct from arousal (Bliss-Moreau et al., 2020). Heart rate variability is linked to ruminative MW among depressed and healthy populations (Ottaviani et al., 2015). Heart rate increases have also been observed following self-reports of MW while driving, which may reflect drivers' cognitive effort to refocus attention (Pepin et al., 2018). Thus, future studies may assess whether heart rate variability during MW is positively associated with unsafe driving and heart rate after MW, which could implicate cognitive load in negative mood-related unsafe driving. Furthermore, using eye-tracking to measure drivers' visual scanning could further assess whether increased cognitive load associated with negative mood-related MW contributes to sensory-motor decoupling.

Mindfulness Training and Unsafe Driving Linked to Mind Wandering

In exploratory analysis, only one driving behaviour metric showed a discernable change between the MT and PMR groups. In particular, steering reversals decreased in PMR, but not MT. The meaning of this finding is unclear since the MT group exhibited a significant decrease in MW while there was insufficient evidence for a change in MW from PMR. Thus, it is unclear what could account for the PMR group's decrease in steering reversals.

Despite an inconclusive result for increased meta-awareness from MT, exploratory analyses of driving behaviour revealed safer driving, in terms of longer headway distances, associated with meta-aware compared to meta-unaware MW. There was no discernable difference between meta-aware MW and focused driving in terms of headway distance. Since shorter headways predict crashes (Hyun et al., 2019) this finding suggests that meta-aware MW may be less risky than meta-unaware MW. Previous studies similarly reveal safer driving linked to meta-awareness of MW. For instance, among a group of surveyed drivers, 55.1% of those who reported long delays before noticing MW also reported significant driving impairment associated with MW, versus only 12.3% of those who reported noticing MW immediately (Berthié et al., 2015). In another study, greater self-reported meta-awareness of MW predicted slower driving in simulation, whereas individual differences in meta-unaware MW, indexed behaviourally, predicted faster driving (Albert et al., 2018). Thus, trait and state meta-awareness may moderate links between MW and unsafe driving.

Negative Mood, Thought Suppression, and Unsafe Driving

Exploratory analyses of driving behaviour in Study 2 introduce additional interpretations of Study 1 findings. In Study 1, relative to neutral mood, negative mood caused increases in headway variability and steering reversals linked to MW. These changes were interpreted to reflect negative mood-related increases in the cognitive demands of MW, resulting in greater distraction (sensory-motor decoupling), or the intrusiveness of MW, resulting in engagement in MW at inopportune moments when it could impact driving behaviour. However, in Study 2, probe-caught MW was associated with lower headway variability and steering reversals compared to focused driving. This suggests that negative mood may have reduced differences in driving behaviour between MW and focused driving states. It may be that negative mood led to more frequent but less pronounced MW and sensory-motor decoupling. This explanation contradicts previous findings linking negative mood-related MW to greater performance deficits in attention tasks, however (Marcusson-Clavertz et al., 2020; Smallwood, Fitzgerald, et al., 2009). Alternatively, drivers may have tried to suppress negative MW, which manifested in driving behaviour resembling focused driving. This interpretation aligns with verbal reports from participants indicating attempts to distract themselves from their negative thoughts with the driving task. Furthermore, thought suppression can paradoxically increase unwanted thoughts (Abramowitz et al., 2001), which aligns with evidence for greater MW frequency in Study 1. Suppression of negative thoughts has been associated with poor working memory task performance (Banks et al., 2016; Banks & Boals, 2017). Thus, future research may investigate the potential impact of suppressing negative thoughts on unsafe driving and crash risk.

Mindfulness Training in Young Drivers

Feasibility of Brief Online Mindfulness Training

Promising preliminary evidence for the efficacy of brief online MT, in producing a mindful state and reducing MW while driving, warrants further investigation in future definitive trials. Feasibility findings from Study 2 may inform the development of such trials. Online MT offers various experimental and clinical advantages. Experimentally, online MT has the potential to reduce experimenter bias by minimizing access to allocation data (Xiao et al., 2013) and reducing participant-experimenter contact (Mathieu et al., 2013). Despite this, many studies are reported to have moderate to high risk of bias associated with poor allocation concealment or lack of personnel blinding (Victorson et al., 2020). Study 2 exploited the aforementioned advantages of online MT through the use of a custom website that automatically (i.e., without experimenter oversight) and blindly (i.e., hidden from view of the experimenter and participant) randomized participants to conditions, delivered assigned intervention recordings, and administered post-session questionnaires. Clinically, online MT is relatively inexpensive and logistically simple to deploy (Andersson & Titov, 2014; Boggs et al., 2014). Study 2 exemplified these advantages since very few personnel (i.e., one experimenter and one software developer) were required to set-up and run the study. Thus, future studies may reduce costs and potentially bias by implementing a similar system, although blinding integrity was not systematically tested in Study 2.

While online delivery of MT can reduce constraints related to travel, scheduling and, in the age of COVID-19, social distancing (González-García et al., 2021; A. J. Mrazek et al., 2019; Stjernswärd & Hansson, 2017), some evidence suggests that adherence can be impacted (Baer et al., 2019; A. J. Mrazek et al., 2019; Spijkerman et al., 2016). Adherence was objectively tracked by the study website, using intervention playback log data, which are more reliable than self-report (Flett et al., 2019), yet still underutilized in online interventions (Koneska et al., 2020). Overall adherence to the remote intervention sessions (i.e., when participants completed their intervention sessions at home) was comparable at 58% to other online MT studies ranging from 35 to 92% (Forbes et al., 2018; Sommers-Spijkerman et al., 2021) and in-person mindfulness at 76% (Ribeiro et al., 2018). Relatedly, at 19%, attrition in Study 2 was slightly below the level at which attrition bias starts to become a concern (i.e., 20%) and lower than rates typically observed for in-person, albeit longer, MT RCTs at 30% (Nam & Toneatto, 2016).

MT studies typically recruit only MT-naive participants. Many young drivers that registered for Study 2 had at least some MT experience, however. Study candidates with any previous MT experience were initially excluded, but this, along with the low generalized anxiety cut-off, contributed to slow recruitment. This criterion was later changed to admit candidates that had not practiced MT within the past 6 months. It is unclear whether this issue reflects the young drivers population as a whole, or was specific to the sample from Study 2. With the growing availability of mobile apps and services that offer MT (Gál et al., 2021; Nunes et al., 2020), it seems plausible that many people with access to technology, and especially tech-savvy young people, will have had some exposure to MT. At the same time, Study 2 relied on convenience sampling, which may have incidentally selected more candidates with MT experience.

Many young drivers that registered for the study were found to exhibit low-to-moderate generalized anxiety symptoms. Accordingly, initially excluding candidates with moderate-to-high anxiety symptoms contributed to slow recruitment. This exclusion criterion aimed to minimize risk of adverse effects, given the online/remote nature of the study. Despite increasing the anxiety exclusion threshold, which hastened recruitment, no severe adverse effects were reported, however. Nevertheless, mounting evidence suggests that MT can have short-term and, in some cases, long-term adverse effects (Aizik-Reebs et al., 2021; Britton et al., 2021). Future studies with larger samples may examine risk factors for adverse effects within the young driver population.

Acceptability data, collected via post-session questionnaires, revealed that MT was linked to greater difficulties following instructions. In particular, MT participants cited difficulties with sitting still and attending to their physical sensations. These difficulties may have related to the challenges of noticing and disengaging from MW in MT, while comparably little effort is needed for PMR. Reports of difficulties did not predict adherence or attrition, but future studies may assess methods of reframing these experiences to minimize discomfort (Lindahl et al., 2021).

Strengths and Limitations of the Present Thesis

Strengths

The narrative review combined evidence from multiple disciplines, including psychology, neuroscience, and traffic safety research, to form hypotheses about the ways in which MW could impact the safety of young drivers. The review was grounded in evidence derived from an extensive search for research articles on MW while driving in the traffic safety literature.

Importantly, the search terms and databases used to find the majority of cited studies on MW while driving were reported to bolster reproducibility.

Studies 1 and 2 in the present thesis employed rigorous randomized, controlled, and blinded experimental designs, representing an improvement on previous studies. Many mood-related driving studies and MT RCTs do not clearly control for non-specific factors (e.g., expectation, motivation, demand characteristics, etc.). Awareness of study objectives or experimental manipulations may encourage participants to modify their behaviour in accordance with their perception of the experimenter's wishes. Similarly, knowledge of one's condition assignment can influence expectancy or motivation. To circumvent these issues, deception was used: in Study 1 to convince participants that they were performing a bonified intelligence test, on which the negative mood group received poor performance feedback and; in Study 2 to misrepresent its aims such that both MT and PMR participants thought they were learning an experimental "relaxation technique." These methods were carefully implemented to isolate the effects of negative mood and MT on MW and MW-related unsafe driving.

Studies 1 and 2 leveraged thought sampling and driving simulation to both measure MW in situ and assess momentary changes in driving behaviour associated with MW as a function of the experimental manipulations (i.e., negative mood and MT). Study 1 is the first to use "online" thought sampling to measure mood-related changes in MW while driving in simulation. Similarly, Study 2 is the first to use thought sampling to measure reductions in MW while driving following exposure to MT. Compared to retrospective self-reports of MW, thought sampling minimizes measurement error linked to memory. Thought sampling also enables a fine-grained assessment of a manipulation's effects on MW-related driving behaviour, while controlling for variability associated with focused driving. This reduces the likelihood of conflating associations between driving behaviour and changes in MW frequency with changes in MW intensity. Moreover, combining both self-caught and probe-caught thought sampling techniques enabled the comparison of driving behaviour between meta-aware MW, meta-unaware MW, and focused driving, which represents another novel contribution of the present thesis.

Study 2 of the present thesis incorporated a custom-built study website that facilitated many of its rigorous experimental design features. In particular, randomization was conducted automatically and blindly through the study website. A randomly generated URL directed participants to their assigned intervention without revealing the assignment to them, or the experimenter. Condition assignments were stored by the website in a hidden database. The website also regulated intervention dosage, with participants only being able to listen once to each day's intervention recording. The study website also automatically tracked adherence via playback logs and administered post-intervention-session questionnaires to measure state mindfulness, interest/enjoyment (i.e., motivation), and acceptability. These features enhanced the experimental rigor of Study 2, while minimizing personnel or other resources requirements.

Limitations

Defining a reproducible search query capable of capturing all available literature on MW while driving, while not also returning thousands of irrelevant results, proved difficult. A diverse array of terms are used to address MW and related phenomena in the traffic safety literature, such as "internalized thought", "irrelevant thought", and "daydreaming" among others. Broad terms, such as "cognitive distraction" that are sometimes used to discuss MW can also encompass various other types of distraction (e.g., hands-free phone conversation). Thus, Google Scholar was sometimes used as a supplementary source for articles on MW while driving that were not returned through easily reproducible methods.

As preliminary investigations, Studies 1 and 2 recruited small samples. This may have impeded detection of small-to-medium effects. Certain statistical choices were made to enhance sensitivity, such as using mixed modeling to adjust for baseline variance and missing data, conducting directional hypothesis tests, and foregoing family-wise error control. The small sample sizes also prevented sex analyses. Males were recruited in Study 1 to reduce potential variability in outcomes associated with sex, especially given evidence that negative mood may impact young male and female drivers differently (Bogdan et al., 2016; Qu et al., 2015). While both males and females were recruited in Study 2, the sample was too small to meaningfully analyze sex. Included in the results of both studies, however, were power analyses to inform sample sizes in future studies to detect small-to-medium effects as well as larger sex differences.

Both studies employed robust Inclusion and exclusion criteria to control for factors that may mask effects, such as age, or reduce generalizability, such as depression symptoms. At the same time, study candidates were not screened based on their level of driving experience or driving frequency. These factors predict driving behaviour and MW. In particular, inexperienced drivers may find driving more difficult (Day et al., 2018) and perform worse than experienced drivers (Mueller & Trick, 2012; Z. Yang et al., 2021). Relatedly, driving difficulty negatively predicts MW (Geden et al., 2018) while driving frequency positively predicts MW (C. Lin et al., 2021). Our randomized, controlled study designs likely prevented these factors from confounding results, but futures studies should assess driving experience and frequency to examine their contributions to the effects of negative mood and MT on MW and unsafe driving.

The measures of MW used in Study 1 and Study 2 may have reduced effects of the experimental manipulations on driving behaviour. While enabling measurement of meta-awareness and acute changes in driving behaviour associated with MW, self-caught and probe-caught thought sampling techniques can interrupt MW (Smallwood & Schooler, 2015). This may reduce the impact of MW on driving (Walker & Trick, 2019). Furthermore, self-catching MW involves monitoring one's thoughts, which may place demands on attention (Vannucci et al., 2019) and thus interfere with normal driving. Future studies may replicate findings from Study 1 and Study 2 using different measures of MW, such as post-drive retrospective self-reports.

Using a more naturalistic driving scenario in Study 1 and Study 2 may have masked subtle effects of the manipulations on MW-related driving behaviour. The simulation scenario imposed few constraints on driving behaviour, allowing participants to change lanes and pass other vehicles. These maneuvers may have prevented detection of certain effects by increasing variability across states. Future studies using more constrained driving scenarios may uncover additional effects of negative mood or MW that reflect sensory-motor decoupling, or that can be more easily deciphered as a distinct process.

Future Directions

The compelling findings of the present thesis spark several hypotheses and questions for future research. One hypothesis is that the observed effects of negative mood and MT on MW and MW-related unsafe driving are greater in young compared to older drivers. If the dual-process framework applies to the regulation of MW while driving, as proposed in this thesis, then young drivers exposed to a negative mood should exhibit greater increases in MW and MW-related unsafe driving than older drivers, as a function of their emotional reactivity (Casey et al., 2008) and limited emotion-regulation capacities (K. Young et al., 2019). Similarly, young drivers may exhibit larger reductions in MW from MT compared to older drivers, due to their higher baseline MW and immature, but malleable cognitive control capacities (Amada & Shane, 2019; Godfrin & Van Heeringen, 2010) At the same time, individual differences, along with age, predict MW and MW-related unsafe driving (Albert et al., 2018; Burdett et al., 2016), but it is unclear how these factors may interact. For instance, while older adults engage in less MW than younger adults, they can suffer greater MW-related performance deficits when it occurs (Zavagnin et al., 2014). Thus, future studies may examine whether older drivers with a high tendency to engage in MW are at greater risk than their younger counterparts.

Future research may also test whether MT limits the impact of negative mood on MW and MW-related unsafe driving in young drivers. MT has been found to enhance emotion regulation (Tang et al., 2016; Teper et al., 2013) and cognitive control (Césedas et al., 2020; Gallant, 2016; Yakobi et al., 2021). It was proposed in the present thesis that negative mood may particularly increase MW while driving in young drivers due to their immature cognitive control capacities. Furthermore, it has also been suggested, in the present thesis, and by others (Amada & Shane, 2019; Broderick & Jennings, 2012; Eadeh et al., 2021), that MT may support the development of emotion regulation in young adults. By combining the methods presented in the Study 1 and Study 2, it may be possible to test whether MT is protective against increases in MW and MW-related unsafe driving from negative mood. This may further support MT as viable intervention strategy for reducing MW-related crash risk in young drivers.

A related hypothesis is that MT is particularly protective against negative mood-related MW in young drivers that are high in trait rumination. Mounting evidence suggests that MT can be equally effective in treating mood disorders, such as depression, compared to other standard treatments (Goldberg et al., 2018). High trait rumination is a risk factor for depression (Kuyken et al., 2006; Lo et al., 2008; Watkins, 2008), that MT specifically targets (Deyo et al., 2009; Heeren & Philippot, 2011; Jury & Jose, 2019). Thus, MT may be particularly protective against negative mood-related MW in young drivers with a high trait tendency to ruminate.

Future research may investigate the contributions of negative mood and mindfulness to real-world driving using a combination of methods from naturalistic distracted-driving studies and daily-life thought sampling studies. Instrumented vehicles have previously been used to detect high g-force events, such as crashes and near-crashes so that researchers can examine in-vehicle footage to determine the activities of the driver leading up to the event (Foss & Goodwin, 2014). Smartphones have been used in previous studies to deliver thought probes, inquiring about thoughts, feelings, and current activities, throughout a normal day (McVay et al., 2009; Poerio et al., 2013). These methods may be combined to explore associations between crashes, near-crashes, and drivers' thoughts, feelings, and degree of mindfulness at the time. Modern smartphones contain an array of sensors that could prevent probes from occurring before the end of a drive (Y. Li et al., 2016). Furthermore, these sensors may obviate the need for instrumented vehicles, as the phones themselves may be capable of distinguishing a crash or near-crash event.

Future research may also examine the implications of negative mood and MT for MW in the context of autonomous vehicles, especially as they gain widespread adoption. Automation increases MW in a variety of contexts (Gouraud et al., 2017), which may include driving (McWilliams & Ward, 2021). MW is considered the default state of human attention and occurs most frequently when individuals are unengaged in tasks (Thomson et al., 2015). Accordingly, automated driving is proposed to increase MW, since drivers are not actively engaged in the driving task (Gouraud et al., 2018). Given the current state of automation, however, drivers must be available to take control of the vehicle at any time. Thus, MW in this context appears to be unsafe. Future studies may investigate whether negative mood exacerbates the tendency to engage in MW while driving an autonomous vehicle and prohibits drivers from rapidly shifting attention to take control of the vehicle when necessary. Furthermore, MT may be investigated as a potential strategy for preventing MW and mitigating delays in shifting attention while driving an autonomous vehicle, especially given findings suggesting that MT enhances attentional flexibility (Sørensen et al., 2018).

The effects of MT found in Study 2 should be replicated and extended in larger, definitive trials. In particular, more evidence is needed concerning the safety, efficacy, and real-world effectiveness of MT for improving driving performance and reducing crashes in young drivers.. For instance, in terms of safety, MT can de-automatize learned behaviours (Choi et al., 2022), which may be detrimental to driver safety, since many aspects of safe driving are automatic and may be disrupted by conscious control (Engström et al., 2017). Relatedly, MT may cause drivers to become distracted by non-relevant aspects of their sensory experience (e.g., breathing) or the task of monitoring their thoughts (Vannucci et al., 2019). In terms of efficacy, different MT techniques, such as focused attention and open monitoring, have different effects on attention (Lippelt et al., 2014). Thus, certain techniques may be more be more effective for enhancing safe driving than others. In terms of effectiveness, research may investigate the minimum dose of MT required to affect long-term changes in driver attention and behaviour. Eight-week interventions of in-person MT, for example, have been found to increase trait mindfulness (Kiken et al., 2015), alter brain structure and function (Gotink et al., 2016), and affect long-term changes in personality (Spinhoven et al., 2017). At the same time, ongoing practice of MT is a predictor of its long-term mental health benefits (Mathew et al., 2010; Solhaug et al., 2019). Furthermore, long-term practitioners of MT exhibit less MW than those that practice irregularly (Brandmeyer & Delorme, 2018). Thus, it is unclear whether or how much regular practice may be needed to maintain the effects of MT, and furthermore, whether young drivers will continue practicing.

Conclusion

The present thesis aimed to address the contribution of MW to young driver crash risk by isolating negative mood as a potential cause and exploring mindfulness as a potential mitigator of MW while driving in this population. A review of the traffic safety literature on MW revealed that sensory-motor decoupling likely mediates the relationship between MW and crashes. Understanding the mechanism by which MW contributes to crashes may facilitate the development of technologies to detect and intervention to mitigate MW-related crashes. Review evidence also showed that developmental changes in young driver attention may predispose this population to MW-related crashes in certain circumstances. Specifically, it was hypothesized that negative mood could negatively impact attention regulation in young drivers, thus leading to more MW and MW-related unsafe driving. Conversely, it was hypothesized that MT may reduce the vulnerability of young drivers to MW when it is likely to negatively impact their safety. Study 1 found evidence to support the notion that young drivers are susceptible to negative mood-related MW. While this is not sufficient evidence for the proposition that young drivers are particularly susceptible to MW due to developmental factors, this finding supports future investigations into these possible age-related differences. Study 2 found preliminary support for the promise of MT as an intervention strategy to address MW-related crashes in young drivers. Study 2 also provides valuable feasibility data concerning the potential pitfalls and advantages of deploying online MT with this population. While results of the present thesis are preliminary, they provide compelling justification for future research into MW as a risk factor for crashes in the vulnerable young driver population.

References

Aarts, L., & van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis & Prevention*, *38*(2), 215–224. https://doi.org/10.1016/j.aap.2005.07.004

Abramowitz, J. S., Tolin, D. F., & Street, G. P. (2001). Paradoxical effects of thought suppression: A meta-analysis of controlled studies. *Clinical Psychology Review*, *21*(5), 683–703. https://doi.org/10.1016/S0272-7358(00)00057-X

Aduen, P. A., Kofler, M. J., Sarver, D. E., Wells, E. L., Soto, E. F., & Cox, D. J. (2018). ADHD, depression, and motor vehicle crashes: A prospective cohort study of continuously-monitored, real-world driving. *Journal of Psychiatric Research*, *101*, 42–49. https://doi.org/10.1016/j.jpsychires.2018.02.026

Aizik-Reebs, A., Shoham, A., & Bernstein, A. (2021). First, do no harm: An intensive experience sampling study of adverse effects to mindfulness training. *Behaviour Research and Therapy*, *145*, 103941. https://doi.org/10.1016/j.brat.2021.103941

Albert, D. A., Ouimet, M. C., Jarret, J., Cloutier, M.-S., Paquette, M., Badeau, N., & Brown, T. G. (2018). Linking mind wandering tendency to risky driving in young male drivers. *Accident Analysis & Prevention*, *111*, 125–132. https://doi.org/10.1016/j.aap.2017.11.019

Allen, R. W., Parseghian, Z., & Stein, A. C. (1996). *A driving simulator study of the performance effects of low blood alcohol concentration*. *40*(18), 943–946.

Almahasneh, H., Chooi, W.-T., Kamel, N., & Malik, A. S. (2014). Deep in thought while driving: An EEG study on drivers' cognitive distraction. *Transportation Research Part F: Traffic Psychology and Behaviour*, *26*, 218–226. https://doi.org/10.1016/j.trf.2014.08.001

Amada, N. M., & Shane, J. (2019). Mindfulness as a Promoter of Adaptive Development in Adolescence. *Adolescent Research Review*, *4*(1), 93–112. https://doi.org/10.1007/s40894-018-0096-1

Anālayo, B. (2019). Adding historical depth to definitions of mindfulness. *Current Opinion in Psychology*, *28*, 11–14. https://doi.org/10.1016/j.copsyc.2018.09.013

Andersson, G., & Titov, N. (2014). Advantages and limitations of Internet-based interventions for common mental disorders. *World Psychiatry*, *13*(1), 4–11. https://doi.org/10.1002/wps.20083

Baer, R., Crane, C., Miller, E., & Kuyken, W. (2019). Doing no harm in mindfulness-based programs: Conceptual issues and empirical findings. *Clinical Psychology Review*, *March 2018*, 1–14. https://doi.org/10.1016/j.cpr.2019.01.001

Baldwin, C. L., Roberts, D. M., Barragan, D., Lee, J. D., Lerner, N., & Higgins, J. S. (2017). Detecting and quantifying mind wandering during simulated driving. *Frontiers in Human Neuroscience*, *11*, 406. https://doi.org/10.3389/fnhum.2017.00406

Baltruschat, S., Mas-Cuesta, L., Cándido, A., Maldonado, A., Verdejo-Lucas, C., Catena-Verdejo, E., & Catena, A. (2021). Repeat Traffic Offenders Improve Their Performance in Risky Driving Situations and Have Fewer Accidents Following a Mindfulness-Based Intervention. *Frontiers in Psychology*, *11*. https://doi.org/10.3389/fpsyg.2020.567278

Baminiwatta, A., & Solangaarachchi, I. (2021). Trends and Developments in Mindfulness Research over 55 Years: A Bibliometric Analysis of Publications Indexed in Web of Science. *Mindfulness*, *12*(9), 2099–2116. https://doi.org/10.1007/s12671-021-01681-x

Banks, J. B., & Boals, A. (2017). Understanding the role of mind wandering in stress-related working memory impairments. *Cognition and Emotion*, *31*(5), 1023–1030. https://doi.org/10.1080/02699931.2016.1179174

Banks, J. B., Welhaf, M. S., Hood, A. V. B., Boals, A., & Tartar, J. L. (2016). Examining the role of emotional valence of mind wandering: All mind wandering is not equal. *Consciousness and Cognition*, *43*, 167–176. https://doi.org/10.1016/j.concog.2016.06.003

Barron, E., Riby, L. M., Greer, J., & Smallwood, J. (2011). Absorbed in Thought: The Effect of Mind Wandering on the Processing of Relevant and Irrelevant Events. *Psychological Science*, *22*(5), 596–601. https://doi.org/10.1177/0956797611404083

Bartholomew, M. E., Heller, W., & Miller, G. A. (2021). Inhibitory control of emotional processing: Theoretical and empirical considerations. *International Journal of Psychophysiology*, *163*, 5–10. https://doi.org/10.1016/j.ijpsycho.2019.03.015

Beesdo, K., Pine, D. S., Lieb, R., & Wittchen, H.-U. (2010). Incidence and Risk Patterns of Anxiety and Depressive Disorders and Categorization of Generalized Anxiety Disorder. *Archives of General Psychiatry*, *67*(1), 47–57. https://doi.org/10.1001/archgenpsychiatry.2009.177

Beninger, J., Hamilton-Wright, A., Walker, H. E. K., & Trick, L. M. (2021). Machine learning techniques to identify mind-wandering and predict hazard response time in fully immersive driving simulation. *Soft Computing*, *25*(2), 1239–1247. https://doi.org/10.1007/s00500-020-05217-8

Bernstein, A., Hadash, Y., & Fresco, D. M. (2019). Metacognitive processes model of decentering: Emerging methods and insights. *Current Opinion in Psychology*, *28*, 245–251. https://doi.org/10.1016/j.copsyc.2019.01.019

Berthié, G., Lemercier, C., Paubel, P.-V., Cour, M., Fort, A., Galéra, C., Lagarde, E., Gabaude, C., & Maury, B. (2015). The restless mind while driving: Drivers' thoughts behind the wheel. *Accident Analysis & Prevention*, *76*, 159–165. https://doi.org/10.1016/j.aap.2015.01.005

Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., Segal, Z. V., Abbey, S., Speca, M., Velting, D., & Devins, G. (2004). Mindfulness: A Proposed Operational Definition. *Clinical Psychology: Science and Practice*, *11*(3), 230–241. https://doi.org/10.1093/clipsy.bph077

Bliss-Moreau, E., Williams, L. A., & Santistevan, A. C. (2020). The immutability of valence and arousal in the foundation of emotion. *Emotion*, *20*(6), 993.

Bogdan, S. R., Măirean, C., & Havârneanu, C.-E. (2016). A meta-analysis of the association between anger and aggressive driving. *Advances in Driving Anger*, *42*, 350–364. https://doi.org/10.1016/j.trf.2016.05.009

Boggs, J. M., Beck, A., Felder, J. N., Dimidjian, S., Metcalf, C. A., & Segal, Z. V. (2014). Web-Based Intervention in Mindfulness Meditation for Reducing Residual Depressive Symptoms and Relapse Prophylaxis: A Qualitative Study. *Journal of Medical Internet Research*, *16*(3), e87. https://doi.org/10.2196/jmir.3129

Brandmeyer, T., & Delorme, A. (2018). Reduced mind wandering in experienced meditators and associated EEG correlates. *Experimental Brain Research*, *236*(9), 2519–2528. https://doi.org/10.1007/s00221-016-4811-5

Brandmeyer, T., & Delorme, A. (2021). Meditation and the Wandering Mind: A Theoretical Framework of Underlying Neurocognitive Mechanisms. *Perspectives on Psychological Science*, *16*(1), 39–66. https://doi.org/10.1177/1745691620917340

Britton, W. B., Lindahl, J. R., Cooper, D. J., Canby, N. K., & Palitsky, R. (2021). Defining and Measuring Meditation-Related Adverse Effects in Mindfulness-Based Programs. *Clinical Psychological Science*, *9*(6), 1185–1204. https://doi.org/10.1177/2167702621996340

Broderick, P. C., & Jennings, P. A. (2012). Mindfulness for adolescents: A promising approach to supporting emotion regulation and preventing risky behavior. *New Directions for Youth Development*, *2012*(136), 111–126. https://doi.org/10.1002/yd.20042

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2016). Personality, executive control, and neurobiological characteristics associated with different forms of risky driving. *PLOS ONE*, *11*(2), e0150227. https://doi.org/10.1371/journal.pone.0150227

Brown, T. G., Ouimet, M. C., Eldeb, M., Tremblay, J., Vingilis, E., Nadeau, L., Pruessner, J., & Bechara, A. (2017). The effect of age on the personality and cognitive characteristics of three distinct risky driving offender groups. *Personality and Individual Differences*, *113*, 48–56. https://doi.org/10.1016/j.paid.2017.03.007

Bryce, S. D., Lee, S. J., Ponsford, J. L., Lawrence, R. J., Tan, E. J., & Rossell, S. L. (2018). The impact of intrinsic motivation on session attendance and reliable cognitive improvement in cognitive remediation in schizophrenia. *Schizophrenia Research*, *202*, 354–360. https://doi.org/10.1016/j.schres.2018.06.028

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 and Prevention*, *95*, 1–7. https://doi.org/10.1016/j.aap.2016.06.012

Burdett, B. R. D., Charlton, S. G., & Starkey, N. J. (2019). Mind wandering during everyday driving: An on-road study. *Accident Analysis & Prevention*, *122*, 76–84. https://doi.org/10.1016/j.aap.2018.10.001

Caird, J. K., Simmons, S. M., Wiley, K., Johnston, K. A., & Horrey, W. J. (2018). Does Talking on a Cell Phone, With a Passenger, or Dialing Affect Driving Performance? An Updated Systematic Review and Meta-Analysis of Experimental Studies. *Human Factors*, *60*(1), 101–133. https://doi.org/10.1177/0018720817748145

Carpenter, C. S., & Nguyen, H. V. (2015). Effects of a Driver Cellphone Ban on Overall, Handheld, and Hands-Free Cellphone Use While Driving: New Evidence from Canada: Effects of a Cellphone Ban on Handheld and Hands-Free Cellphone Use. *Health Economics*, *24*(11), 1452–1467. https://doi.org/10.1002/hec.3098

Carver, C. S., & Johnson, S. L. (2018). Impulsive reactivity to emotion and vulnerability to psychopathology. *American Psychologist*, *73*(9), 1067–1078. https://doi.org/10.1037/amp0000387

Cásedas, L., Pirruccio, V., Vadillo, M. A., & Lupiáñez, J. (2020). Does Mindfulness Meditation Training Enhance Executive Control? A Systematic Review and Meta-Analysis of Randomized Controlled Trials in Adults. *Mindfulness*, *11*(2), 411–424. https://doi.org/10.1007/s12671-019-01279-4

Casey, B. J., Duhoux, S., & Cohen, M. M. (2010). Adolescence: What Do Transmission, Transition, and Translation Have to Do with It? *Neuron*, *67*(5), 749–760. https://doi.org/10.1016/j.neuron.2010.08.033

Casey, B. J., Getz, S., & Galvan, A. (2008). The adolescent brain. *Developmental Review*, *28*(1), 62–77. https://doi.org/10.1016/j.dr.2007.08.003

Chan, M., & Singhal, A. (2015). Emotion matters: Implications for distracted driving. *Safety Science*, *72*, 302–309. https://doi.org/10.1016/j.ssci.2014.10.002

Choi, E., Gruman, J. A., & Leonard, C. M. (2022). A balanced view of mindfulness at work. *Organizational Psychology Review*, *12*(1), 35–72. https://doi.org/10.1177/20413866211036930

Choudhary, P., & Velaga, N. R. (2017). Analysis of vehicle-based lateral performance measures during distracted driving due to phone use. *Transportation Research Part F: Traffic Psychology and Behaviour*, *44*, 120–133. https://doi.org/10.1016/j.trf.2016.11.002

Choudhary, P., & Velaga, N. R. (2018). Effects of phone use on driving performance: A comparative analysis of young and professional drivers. *Safety Science*, *October 2017*. https://doi.org/10.1016/j.ssci.2018.07.009

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences*, *106*(21), 8719–8724. https://doi.org/10.1073/pnas.0900234106

Christoff, K., Irving, Z. C., Fox, K. C. R., Spreng, R. N., & Andrews-Hanna, J. R. (2016). Mind-wandering as spontaneous thought: A dynamic framework. *Nature Reviews Neuroscience*, *17*(11), 718–731.

Cowley, J. A. (2013). Off Task Thinking Types and Performance Decrements During Simulated Automobile Driving. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *57*(1), 1214–1218. https://doi.org/10.1177/1541931213571270

Cunningham, M., & Regan, M. (2016). The impact of emotion, life stress and mental health issues on driving performance and safety. *Road and Transport Research*, *25*, 40–50.

Daly, N., Brogan, M., Kaneswaran, D., Deegan, C., Markham, C., & Commins, S. (2014). An exploratory study of the role played by sustained attention along a rural Irish route using a video-playback system. *Transportation Research Part F: Traffic Psychology and Behaviour*, *26*(PART A), 138–150. https://doi.org/10.1016/j.trf.2014.06.014

Davidson, R. J., & Kaszniak, A. W. (2015). Conceptual and Methodological Issues in Research on Mindfulness and Meditation. *The American Psychologist*, *70*(7), 581–592. https://doi.org/10.1037/a0039512

Day, M. R., Thompson, A. R., Poulter, D. R., Stride, C. B., & Rowe, R. (2018). Why do drivers become safer over the first three months of driving? A longitudinal qualitative study. *Accident Analysis & Prevention*, *117*, 225–231. https://doi.org/10.1016/j.aap.2018.04.007

Deyo, M., Wilson, K. A., Ong, J., & Koopman, C. (2009). Mindfulness and Rumination: Does Mindfulness Training Lead to Reductions in the Ruminative Thinking Associated With Depression? *EXPLORE*, *5*(5), 265–271. https://doi.org/10.1016/j.explore.2009.06.005

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Dias da Silva, M. R., & Postma, M. (2021). Straying Off Course: The Negative Impact of Mind Wandering on Fine Motor Movements. *Journal of Motor Behavior*, 1–17. https://doi.org/10.1080/00222895.2021.1937032

Dingus, T. A., Guo, F., Lee, S., Antin, J. F., Perez, M., Buchanan-King, M., & Hankey, J. (2016). Driver crash risk factors and prevalence evaluation using naturalistic driving data. *Proceedings of the National Academy of Sciences*, *113*(10), 2636–2641. https://doi.org/10.1073/pnas.1513271113

Du, N., Zhou, F., Pulver, E. M., Tilbury, D. M., Robert, L. P., Pradhan, A. K., & Yang, X. J. (2020). Examining the effects of emotional valence and arousal on takeover performance in conditionally automated driving. *Transportation Research Part C: Emerging Technologies*, *112*, 78–87. https://doi.org/10.1016/j.trc.2020.01.006

Dunne, J. D. (2015). Buddhist Styles of Mindfulness: A Heuristic Approach. In B. D. Ostafin, M. D. Robinson, & B. P. Meier (Eds.), *Handbook of Mindfulness and Self-Regulation* (pp. 251–270). Springer. https://doi.org/10.1007/978-1-4939-2263-5_18

Dunne, J. D., Thompson, E., & Schooler, J. (2019). Mindful meta-awareness: Sustained and non-propositional. *Current Opinion in Psychology*, *28*, 307–311. https://doi.org/10.1016/j.copsyc.2019.07.003

Eadeh, H.-M., Breaux, R., & Nikolas, M. A. (2021). A Meta-Analytic Review of Emotion Regulation Focused Psychosocial Interventions for Adolescents. *Clinical Child and Family Psychology Review*, *24*(4), 684–706. https://doi.org/10.1007/s10567-021-00362-4

Engström, J., Markkula, G., Victor, T., & Merat, N. (2017). Effects of cognitive load on driving performance: The cognitive control hypothesis. *Human Factors*, *59*(5), 734–764. https://doi.org/10.1177/0018720817690639

Farouki, K. E., Lagarde, E., Orriols, L., Bouvard, M.-P., Contrand, B., & Galéra, C. (2014). The Increased Risk of Road Crashes in Attention Deficit Hyperactivity Disorder (ADHD) Adult Drivers: Driven by Distraction? Results from a Responsibility Case-Control Study. *PLOS ONE*, *9*(12), e115002. https://doi.org/10.1371/journal.pone.0115002

Feldman, G., Greeson, J., Renna, M., & Robbins-Monteith, K. (2011). Mindfulness predicts less texting while driving among young adults: Examining attention- and emotion-regulation motives as potential mediators. *Personality and Individual Differences*, *51*(7), 856–861. https://doi.org/10.1016/j.paid.2011.07.020

Feruglio, S., Matiz, A., Pagnoni, G., Fabbro, F., & Crescentini, C. (2021). The Impact of Mindfulness Meditation on the Wandering Mind: A Systematic Review. *Neuroscience & Biobehavioral Reviews*, *131*, 313–330. https://doi.org/10.1016/j.neubiorev.2021.09.032

Fleming, S. M., & Dolan, R. J. (2012). The neural basis of metacognitive ability. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1594), 1338–1349. https://doi.org/10.1098/rstb.2011.0417

Flett, J. A. M., Fletcher, B. D., Riordan, B. C., Patterson, T., Hayne, H., & Conner, T. S. (2019). The peril of self-reported adherence in digital interventions: A brief example. *Internet Interventions*, *18*, 100267. https://doi.org/10.1016/j.invent.2019.100267

Fleur, D. S., Bredeweg, B., & van den Bos, W. (2021). Metacognition: Ideas and insights from neuro- and educational sciences. *Npj Science of Learning*, *6*(1), 1–11. https://doi.org/10.1038/s41539-021-00089-5

Fofanova, J., & Vollrath, M. (2012). Distraction in older drivers – A face-to-face interview study. *Safety Science*, *50*(3), 502–509. https://doi.org/10.1016/j.ssci.2011.10.017

Forbes, L., Gutierrez, D., & Johnson, S. K. (2018). Investigating Adherence to an Online Introductory Mindfulness Program. *Mindfulness*, *9*(1), 271–282. https://doi.org/10.1007/s12671-017-0772-4

Foss, R. D., & Goodwin, A. H. (2014). Distracted Driver Behaviors and Distracting Conditions Among Adolescent Drivers: Findings From a Naturalistic Driving Study. *Journal of Adolescent Health*, *54*(5, Supplement), S50–S60. https://doi.org/10.1016/j.jadohealth.2014.01.005

Fountain-Zaragoza, S., Puccetti, N. A., Whitmoyer, P., & Prakash, R. S. (2018). Aging and Attentional Control: Examining the Roles of Mind-Wandering Propensity and Dispositional Mindfulness. *Journal of the International Neuropsychological Society*, *24*(8), 876–888. https://doi.org/10.1017/S1355617718000553

Franklin, M. S., Broadway, J. M., Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2013). Window to the wandering mind: Pupillometry of spontaneous thought while reading. *Quarterly Journal of Experimental Psychology (2006)*, *66*(May 2015), 2289–2294. https://doi.org/10.1080/17470218.2013.858170

Franklin, M. S., Mrazek, M. D., Anderson, C. L., Smallwood, J., Kingstone, A., & Schooler, J. (2013). The silver lining of a mind in the clouds: Interesting musings are associated with positive mood while mind-wandering. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00583

Gál, É., Ștefan, S., & Cristea, I. A. (2021). The efficacy of mindfulness meditation apps in enhancing users' well-being and mental health related outcomes: A meta-analysis of randomized controlled trials. *Journal of Affective Disorders*, *279*, 131–142. https://doi.org/10.1016/j.jad.2020.09.134

Galéra, C., Orriols, L., M'Bailara, K., Laborey, M., Contrand, B., Ribéreau-Gayon, R., Masson, F., Bakiri, S., Gabaude, C., Fort, A., Maury, B., Lemercier, C., Cours, M., Bouvard, M.-P., & Lagarde, E. (2012). Mind wandering and driving: Responsibility case-control study. *BMJ : British Medical Journal*, *345*, e8105. https://doi.org/10.1136/bmj.e8105

Gallant, S. N. (2016). Mindfulness meditation practice and executive functioning: Breaking down the benefit. *Consciousness and Cognition*, *40*, 116–130. https://doi.org/10.1016/j.concog.2016.01.005

Gao, J., & Davis, G. A. (2017). Using naturalistic driving study data to investigate the impact of driver distraction on driver's brake reaction time in freeway rear-end events in car-following situation. *Journal of Safety Research*, *63*, 195–204. https://doi.org/10.1016/j.jsr.2017.10.012

Geden, M., Staicu, A.-M., & Feng, J. (2018). The impacts of perceptual load and driving duration on mind wandering in driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *57*, 75–83. https://doi.org/10.1016/j.trf.2017.07.004

Ghasemzadeh, A., & Ahmed, M. M. (2017). Drivers' Lane-Keeping Ability in Heavy Rain: Preliminary Investigation Using SHRP 2 Naturalistic Driving Study Data. *Transportation Research Record*, *2663*(1), 99–108. https://doi.org/10.3141/2663-13

Ghasemzadeh, A., & Ahmed, M. M. (2018). Utilizing naturalistic driving data for in-depth analysis of driver lane-keeping behavior in rain: Non-parametric MARS and parametric logistic regression modeling approaches. *Transportation Research Part C: Emerging Technologies*, *90*, 379–392. https://doi.org/10.1016/j.trc.2018.03.018

Gil-Jardiné, C., Née, M., Lagarde, E., Schooler, J., Contrand, B., Orriols, L., & Galera, C. (2017). The distracted mind on the wheel: Overall propensity to mind wandering is associated with road crash responsibility. *PLOS ONE*, *12*(8), e0181327. https://doi.org/10.1371/journal.pone.0181327

Godfrin, K. A., & Van Heeringen, C. (2010). The effects of mindfulness-based cognitive therapy on recurrence of depressive episodes, mental health and quality of life: A randomized controlled study. *Behaviour Research and Therapy*, *48*(8), 738–746.

Goldberg, S. B., Tucker, R. P., Greene, P. A., Davidson, R. J., Wampold, B. E., Kearney, D. J., & Simpson, T. L. (2018). Mindfulness-based interventions for psychiatric disorders: A systematic review and meta-analysis. *Clinical Psychology Review*, *59*, 52–60. https://doi.org/10.1016/j.cpr.2017.10.011

Goller, H., Banks, J. B., & Meier, M. E. (2020). An individual differences investigation of the relations among life event stress, working memory capacity, and mind wandering: A preregistered replication-extension study. *Memory & Cognition*, *48*(5), 759–771. https://doi.org/10.3758/s13421-020-01014-8

González-García, M., Álvarez, J. C., Pérez, E. Z., Fernandez-Carriba, S., & López, J. G. (2021). Feasibility of a Brief Online Mindfulness and Compassion-Based Intervention to Promote Mental Health Among University Students During the COVID-19 Pandemic. *Mindfulness*, *12*(7), 1685–1695. https://doi.org/10.1007/s12671-021-01632-6

Gotink, R. A., Meijboom, R., Vernooij, M. W., Smits, M., & Hunink, M. G. M. (2016). 8-week Mindfulness Based Stress Reduction induces brain changes similar to traditional long-term meditation practice – A systematic review. *Brain and Cognition*, *108*, 32–41. https://doi.org/10.1016/j.bandc.2016.07.001

Gouraud, J., Delorme, A., & Berberian, B. (2017). Autopilot, Mind Wandering, and the Out of the Loop Performance Problem. *Frontiers in Neuroscience*, *11*. https://doi.org/10.3389/fnins.2017.00541

Gouraud, J., Delorme, A., & Berberian, B. (2018). Out of the Loop, in Your Bubble: Mind Wandering Is Independent From Automation Reliability, but Influences Task Engagement. *Frontiers in Human Neuroscience*, *12*. https://www.frontiersin.org/article/10.3389/fnhum.2018.00383

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, *7*(4), 493–498. https://doi.org/10.1111/2041-210X.12504

Guo, F., Klauer, S. G., Fang, Y., Hankey, J. M., Antin, J. F., Perez, M. A., Lee, S. E., & Dingus, T. A. (2017). The effects of age on crash risk associated with driver distraction. *International Journal of Epidemiology*, *46*(1), 258–265. https://doi.org/10.1093/ije/dyw234

Hamzeie, R., Savolainen, P. T., & Gates, T. J. (2017). Driver speed selection and crash risk: Insights from the naturalistic driving study. *Journal of Safety Research*, *63*, 187–194. https://doi.org/10.1016/j.jsr.2017.10.007

Harden, K. P., & Tucker-Drob, E. M. (2011). Individual differences in the development of sensation seeking and impulsivity during adolescence: Further evidence for a dual systems model. *Developmental Psychology*, *47*(3), 739–746. https://doi.org/10.1037/a0023279

Hariton, E., & Locascio, J. J. (2018). Randomised controlled trials—The gold standard for effectiveness research. *BJOG: An International Journal of Obstetrics and Gynaecology*, *125*(13), 1716.

He, J., Becic, E., Lee, Y.-C., & McCarley, J. S. (2011). Mind wandering behind the wheel: Performance and oculomotor correlates. *Human Factors*, *53*(1), 13–21. https://doi.org/10.1177/0018720810391530

He, J., McCarley, J. S., & Kramer, A. F. (2014). Lane keeping under cognitive load: Performance changes and mechanisms. *Human Factors*, *56*(2), 414–426. https://doi.org/10.1177/0018720813485978

Heeren, A., & Philippot, P. (2011). Changes in Ruminative Thinking Mediate the Clinical Benefits of Mindfulness: Preliminary Findings. *Mindfulness*, *2*(1), 8–13. https://doi.org/10.1007/s12671-010-0037-y

Hill, L. L., Lauzon, V. L., Winbrock, E. L., Li, G., Chihuri, S., & Lee, K. C. (2017). Depression, antidepressants and driving safety. *Injury Epidemiology*, *4*(1), 10. https://doi.org/10.1186/s40621-017-0107-x

Hills, T. T., Todd, P. M., Lazer, D., Redish, A. D., & Couzin, I. D. (2015). Exploration versus exploitation in space, mind, and society. *Trends in Cognitive Sciences*, *19*(1), 46–54. https://doi.org/10.1016/j.tics.2014.10.004

Horrey, W. J., & Wickens, C. D. (2006). Examining the Impact of Cell Phone Conversations on Driving Using Meta-Analytic Techniques. *Human Factors*, *48*(1), 196–205. https://doi.org/10.1518/001872006776412135

Hosking, S. G., Young, K. L., & Regan, M. A. (2009). The Effects of Text Messaging on Young Drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *51*(4), 582–592. https://doi.org/10.1177/0018720809341575

Hu, N., He, S., & Xu, B. (2012). Different efficiencies of attentional orienting in different wandering minds. *Consciousness and Cognition*, *21*(1), 139–148. https://doi.org/10.1016/j.concog.2011.12.007

Huemer, A. K., Schumacher, M., Mennecke, M., & Vollrath, M. (2018). Systematic review of observational studies on secondary task engagement while driving. *Accident Analysis and Prevention*, *119*(December 2017), 225–236. https://doi.org/10.1016/j.aap.2018.07.017

Hwang, K., Velanova, K., & Luna, B. (2010). Strengthening of Top-Down Frontal Cognitive Control Networks Underlying the Development of Inhibitory Control: A Functional Magnetic Resonance Imaging Effective Connectivity Study. *Journal of Neuroscience*, *30*(46), 15535–15545. https://doi.org/10.1523/JNEUROSCI.2825-10.2010

Hyun, K. (Kate), Jeong, K., Tok, A., & Ritchie, S. G. (2019). Assessing crash risk considering vehicle interactions with trucks using point detector data. *Road Safety Data Considerations*, *130*, 75–83. https://doi.org/10.1016/j.aap.2018.03.002

Ivers, R., Senserrick, T., Boufous, S., Stevenson, M., Chen, H.-Y., Woodward, M., & Norton, R. (2009). Novice Drivers' Risky Driving Behavior, Risk Perception, and Crash Risk: Findings From the DRIVE Study. *American Journal of Public Health*, *99*(9), 1638–1644. https://doi.org/10.2105/AJPH.2008.150367

Jallais, C., Gabaude, C., & Paire-ficout, L. (2014). When emotions disturb the localization of road elements: Effects of anger and sadness. *Transportation Research Part F: Traffic Psychology and Behaviour*, *23*, 125–132. https://doi.org/10.1016/j.trf.2013.12.023

Jankowski, T., & Holas, P. (2014). Metacognitive model of mindfulness. *Consciousness and Cognition*, *28*(1), 64–80. https://doi.org/10.1016/j.concog.2014.06.005

Jeon, M., & Zhang, W. (2013). Sadder but wiser? Effects of negative emotions on risk perception, driving performance, and perceived workload. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *57*(1), 1849–1853. https://doi.org/10.1177/1541931213571413

Jonah, B. A., & Boase, P. (2016). Speeding and Other Risky Driving Behavior among Young Drivers. *Handbook of Teen and Novice Drivers: Research, Practice, Policy, and Directions*.

Jonkman, L. M., Markus, C. R., Franklin, M. S., & Dalfsen, J. H. van. (2017). Mind wandering during attention performance: Effects of ADHD-inattention symptomatology, negative mood, ruminative response style and working memory capacity. *PLOS ONE*, *12*(7), e0181213. https://doi.org/10.1371/journal.pone.0181213

Jordão, M., Ferreira-Santos, F., Pinho, M. S., & St. Jacques, P. L. (2019). Meta-analysis of aging effects in mind wandering: Methodological and sociodemographic factors. *Psychology and Aging*, *34*(4), 531–544. https://doi.org/10.1037/pag0000356

Ju, Y.-J., & Lien, Y.-W. (2018). Who is prone to wander and when? Examining an integrative effect of working memory capacity and mindfulness trait on mind wandering under different task loads. *Consciousness and Cognition*, *63*, 1–10. https://doi.org/10.1016/j.concog.2018.06.006

Jury, T. K., & Jose, P. E. (2019). Does Rumination Function as a Longitudinal Mediator Between Mindfulness and Depression? *Mindfulness*, *10*(6), 1091–1104. https://doi.org/10.1007/s12671-018-1031-z

Kabat-Zinn, J. (1994). *Wherever you go, there you are: Mindfulness meditation in everyday life*. Hyperion.

Kam, J. W. Y., Dao, E., Blinn, P., Krigolson, O., Boyd, L., & Handy, T. (2012). Mind wandering and motor control: Off-task thinking disrupts the online adjustment of behavior. *Frontiers in Human Neuroscience*, *6*, 329. https://doi.org/10.3389/fnhum.2012.00329

Kam, J. W. Y., Dao, E., Farley, J., Fitzpatrick, K., Smallwood, J., Schooler, J. W., & Handy, T. C. (2010). Slow Fluctuations in Attentional Control of Sensory Cortex. *Journal of Cognitive Neuroscience*, *23*(2), 460–470. http://dx.doi.org/10.1162/jocn.2010.21443

Kam, J. W. Y., Dao, E., Stanciulescu, M., Tildesley, H., & Handy, T. C. (2013). Mind Wandering and the Adaptive Control of Attentional Resources. *Journal of Cognitive Neuroscience*, *25*(6), 952–960. https://doi.org/10.1162/jocn_a_00375

Kam, J. W. Y., & Handy, T. C. (2013). The neurocognitive consequences of the wandering mind: A mechanistic account of sensory-motor decoupling. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00725

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science*, *18*(7), 614–621. https://doi.org/10.1111/j.1467-9280.2007.01948.x

Kass, S. J., Beede, K. E., & Vodanovich, S. J. (2010). Self-report measures of distractibility as correlates of simulated driving performance. *Accident Analysis & Prevention*, *42*(3), 874–880. https://doi.org/10.1016/j.aap.2009.04.012

Kass, S. J., VanWormer, L. A., Mikulas, W. L., Legan, S., & Bumgarner, D. (2011). Effects of Mindfulness Training on Simulated Driving: Preliminary Results. *Mindfulness*, *2*(4), 236–241. https://doi.org/10.1007/s12671-011-0066-1

Kiken, L. G., Garland, E. L., Bluth, K., Palsson, O. S., & Gaylord, S. A. (2015). From a state to a trait: Trajectories of state mindfulness in meditation during intervention predict changes in trait mindfulness. *Personality and Individual Differences*, *81*, 41–46. https://doi.org/10.1016/j.paid.2014.12.044

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science*, *330*(6006), 932–932.

King, J. S. (2020). Sad mood, emotion regulation, and response inhibition. *Journal of Cognitive Psychology*, *32*(5–6), 573–579. https://doi.org/10.1080/20445911.2020.1777418

Koneska, E., Appelbe, D., Williamson, P. R., & Dodd, S. (2020). Usage Metrics of Web-Based Interventions Evaluated in Randomized Controlled Trials: Systematic Review. *Journal of Medical Internet Research*, *22*(4), e15474. https://doi.org/10.2196/15474

Koppel, S., Bugeja, L., Hua, P., Osborne, R., Stephens, A. N., Young, K. L., Chambers, R., & Hassed, C. (2019). Do mindfulness interventions improve road safety? A systematic review. *Accident Analysis & Prevention*, *123*, 88–98. https://doi.org/10.1016/j.aap.2018.11.013

Körber, M., Cingel, A., Zimmermann, M., & Bengler, K. (2015). Vigilance Decrement and Passive Fatigue Caused by Monotony in Automated Driving. *Procedia Manufacturing*, *3*, 2403–2409. https://doi.org/10.1016/j.promfg.2015.07.499

Kountouriotis, G. K., Spyridakos, P., Carsten, O. M. J., & Merat, N. (2016). Identifying cognitive distraction using steering wheel reversal rates. *Accident Analysis & Prevention*, *96*, 39–45. https://doi.org/10.1016/j.aap.2016.07.032

Kountouriotis, G. K., Wilkie, R. M., Gardner, P. H., & Merat, N. (2015). Looking and thinking when driving: The impact of gaze and cognitive load on steering. *Transportation Research Part F: Traffic Psychology and Behaviour*, *34*, 108–121. https://doi.org/10.1016/j.trf.2015.07.012

Kuyken, W., Watkins, E., Holden, E., & Cook, W. (2006). Rumination in adolescents at risk for depression. *Journal of Affective Disorders*, *96*(1), 39–47. https://doi.org/10.1016/j.jad.2006.05.017

Lambert, A. E., Simons-Morton, B. G., Cain, S. A., Weisz, S., & Cox, D. J. (2014). Considerations of a dual-systems model of cognitive development and risky driving. *Journal of Research on Adolescence*, *24*(3), 541–550. https://doi.org/10.1111/jora.12126

Lee, F. S., Heimer, H., Giedd, J. N., Lein, E. S., Šestan, N., Weinberger, D. R., & Casey, B. J. (2014). Adolescent mental health—Opportunity and obligation. *Science*, *346*(6209), 547–549. https://doi.org/10.1126/science.1260497

Lemercier, C., Pêcher, C., Berthié, G., Valéry, B., Vidal, V., Paubel, P.-V., Cour, M., Fort, A., Galéra, C., Gabaude, C., Lagarde, E., & Maury, B. (2014). Inattention behind the wheel: How factual internal thoughts impact attentional control while driving. *Safety Science*, *62*, 279–285. https://doi.org/10.1016/j.ssci.2013.08.011

Li, P., Markkula, G., Li, Y., & Merat, N. (2018). Is improved lane keeping during cognitive load caused by increased physical arousal or gaze concentration toward the road center? *Accident Analysis & Prevention*, *117*, 65–74. https://doi.org/10.1016/j.aap.2018.03.034

Li, P., Merat, N., Zheng, Z., Markkula, G., Li, Y., & Wang, Y. (2018). Does cognitive distraction improve or degrade lane keeping performance? Analysis of time-to-line crossing safety margins. *Special Issue on Everyday Driving*, *57*, 48–58. https://doi.org/10.1016/j.trf.2017.10.002

Li, Y., Zhou, G., Li, Y., & Shen, D. (2016). Determining driver phone use leveraging smartphone sensors. *Multimedia Tools and Applications*, *75*(24), 16959–16981. https://doi.org/10.1007/s11042-015-2969-7

Li, Z., Li, X., Zhao, X., & Zhang, Q. (2019). Effects of Different Alcohol Dosages on Steering Behavior in Curve Driving. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *61*(1), 139–151. https://doi.org/10.1177/0018720818791850

Lin, C., Zhang, H., Gong, B., & Wu, D. (2021). Factors Identification and Prediction for Mind Wandering Driving Using Machine Learning. *Journal of Advanced Transportation*, *2021*, e4216215. https://doi.org/10.1155/2021/4216215

Lin, C.-T., Chuang, C.-H., Kerick, S., Mullen, T., Jung, T.-P., Ko, L.-W., Chen, S.-A., King, J.-T., & McDowell, K. (2016). Mind-Wandering Tends to Occur under Low Perceptual Demands during Driving. *Scientific Reports*, *6*(1), 21353. https://doi.org/10.1038/srep21353

Lindahl, J. R., Britton, W. B., Cooper, D. J., & Kirmayer, L. J. (2021). Challenging and Adverse Meditation Experiences: Toward a Person-Centered Approach. In M. Farias, D. Brazier, & M. Lalljee (Eds.), *The Oxford Handbook of Meditation* (pp. 839–864). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198808640.013.51

Lippelt, D. P., Hommel, B., & Colzato, L. S. (2014). Focused attention, open monitoring and loving kindness meditation: Effects on attention, conflict monitoring, and creativity – A review. *Frontiers in Psychology*, *5*. https://www.frontiersin.org/article/10.3389/fpsyg.2014.01083

Lo, C. S. L., Ho, S. M. Y., & Hollon, S. D. (2008). The effects of rumination and negative cognitive styles on depression: A mediation analysis. *Behaviour Research and Therapy*, *46*(4), 487–495. https://doi.org/10.1016/j.brat.2008.01.013

Luna, B., & Wright, C. (2016). Adolescent brain development: Implications for the juvenile criminal justice system. *APA Handbook of Psychology and Juvenile Justice.*, 91–116. https://doi.org/10.1037/14643-005

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences*, *12*(4), 163–169. https://doi.org/10.1016/j.tics.2008.01.005

Lyubomirsky, S., Kasri, F., & Zehm, K. (2003). Dysphoric Rumination Impairs Concentration on Academic Tasks. *Cognitive Therapy and Research*, *27*(3), 309–330. https://doi.org/10.1023/A:1023918517378

Maillet, D., Beaty, R. E., Jordano, M. L., Touron, D. R., Adnan, A., Silvia, P. J., Kwapil, T. R., Turner, G. R., Spreng, R. N., & Kane, M. J. (2018). Age-related differences in mind-wandering in daily life. *Psychology and Aging*, *33*(4), 643.

Marcusson-Clavertz, D., Kjell, O. N. E., Kim, J., Persson, S. D., & Cardeña, E. (2020). Sad mood and poor sleep are related to task-unrelated thoughts and experience of diminished cognitive control. *Scientific Reports*, *10*(1), 8940. https://doi.org/10.1038/s41598-020-65739-x

Mata, R., Wilke, A., & Czienskowski, U. (2013). Foraging across the life span: Is there a reduction in exploration with aging? *Frontiers in Neuroscience*, *7*, 53. https://doi.org/10.3389/fnins.2013.00053

Mathew, K., Whitford, H., Kenny, M., & Denson, L. (2010). The Long-Term Effects of Mindfulness-Based Cognitive Therapy as a Relapse Prevention Treatment for Major Depressive Disorder. *Behavioural and Cognitive Psychotherapy*, *38*, 561–576. https://doi.org/10.1017/S135246581000010X

Mathieu, E., McGeechan, K., Barratt, A., & Herbert, R. (2013). Internet-based randomized controlled trials: A systematic review. *Journal of the American Medical Informatics Association : JAMIA*, *20*(3), 568–576. https://doi.org/10.1136/amiajnl-2012-001175

McDonald, C. C., Sommers, M. S., & Fargo, J. D. (2014). Risky driving, mental health, and health-compromising behaviours: Risk clustering in late adolescents and adults. *Injury Prevention*, *20*(6), 365–372. https://doi.org/10.1136/injuryprev-2014-041150

McEvoy, S. P., Stevenson, M. R., & Woodward, M. (2006). The impact of driver distraction on road safety: Results from a representative survey in two Australian states. *Injury Prevention*, *12*(4), 242–247. https://doi.org/10.1136/ip.2006.012336

McKewen, M., Skippen, P., Cooper, P. S., Wong, A. S. W., Michie, P. T., Lenroot, R., & Karayanidis, F. (2019). Does cognitive control ability mediate the relationship between reward-related mechanisms, impulsivity, and maladaptive outcomes in adolescence and young adulthood? *Cognitive, Affective, & Behavioral Neuroscience*, *19*(3), 653–676. https://doi.org/10.3758/s13415-019-00722-2

McMillan, R. L., Kaufman, S. B., & Singer, J. L. (2013). Ode to positive constructive daydreaming. *Frontiers in Psychology*, *4*(SEP). https://doi.org/10.3389/fpsyg.2013.00626

McVay, J. C., & Kane, M. J. (2009). Conducting the train of thought: Working memory capacity, goal neglect, and mind wandering in an executive-control task. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *35*(1), 196–204. https://doi.org/10.1037/a0014104

McVay, J. C., & Kane, M. J. (2010). Does mind wandering reflect executive function or executive failure? Comment on Smallwood and Schooler (2006) and Watkins (2008). *Psychological Bulletin*, *136*(2), 188–197. https://doi.org/10.1037/a0018298

McVay, J. C., Kane, M. J., & Kwapil, T. R. (2009). Tracking the train of thought from the laboratory into everyday life: An experience-sampling study of mind wandering across controlled and ecological contexts. *Psychonomic Bulletin & Review*, *16*(5), 857–863. https://doi.org/10.3758/PBR.16.5.857

McVay, J. C., Meier, M. E., Touron, D. R., & Kane, M. J. (2013). Aging ebbs the flow of thought: Adult age differences in mind wandering, executive control, and self-evaluation. *Acta Psychologica*, *142*(1), 136–147. https://doi.org/10.1016/j.actpsy.2012.11.006

McWilliams, T., & Ward, N. (2021). Underload on the Road: Measuring Vigilance Decrements During Partially Automated Driving. *Frontiers in Psychology*, *12*, 1113. https://doi.org/10.3389/fpsyg.2021.631364

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, *24*, 167–202. https://doi.org/10.1146/annurev.neuro.24.1.167

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “Frontal Lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49–100. https://doi.org/10.1006/cogp.1999.0734

Mooneyham, B. W., & Schooler, J. W. (2013). The costs and benefits of mind-wandering: A review. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale*, *67*(1), 11–18. https://doi.org/10.1037/a0031569

Moore, M. M., & Brown, P. M. (2019). The association of self-regulation, habit, and mindfulness with texting while driving. *Accident Analysis & Prevention*, *123*, 20–28. https://doi.org/10.1016/j.aap.2018.10.013

Moran, C. N., McGovern, D. P., Warren, G., Grálaigh, R. Ó., Kenney, J. P., Smeaton, A., & Dockree, P. M. (2021). Young and restless, old and focused: Age-differences in mind-wandering frequency and phenomenology. *Psychology and Aging*.

Mrazek, A. J., Mrazek, M. D., Cherolini, C. M., Cloughesy, J. N., Cynman, D. J., Gougis, L. J., Landry, A. P., Reese, J. V., & Schooler, J. W. (2019). The future of mindfulness training is digital, and the future is now. *Current Opinion in Psychology*, *28*, 81–86. https://doi.org/10.1016/j.copsyc.2018.11.012

Mrazek, M. D., Chin, J. M., Schmader, T., Hartson, K. A., Smallwood, J., & Schooler, J. W. (2011). Threatened to distraction: Mind-wandering as a consequence of stereotype threat. *Journal of Experimental Social Psychology*, *47*(6), 1243–1248. https://doi.org/10.1016/j.jesp.2011.05.011

Mrazek, M. D., Mooneyham, B. W., & Schooler, J. W. (2014). Insights from quiet minds: The converging fields of mindfulness and mind-wandering. In *Meditation–Neuroscientific Approaches and Philosophical Implications* (pp. 227–241). Springer.

Mrazek, M. D., Smallwood, J., & Schooler, J. W. (2012). Mindfulness and mind-wandering: Finding convergence through opposing constructs. *Emotion (Washington, D.C.)*, *12*(3), 442–448. https://doi.org/10.1037/a0026678

Mueller, A. S., & Trick, L. M. (2012). Driving in fog: The effects of driving experience and visibility on speed compensation and hazard avoidance. *Accident Analysis & Prevention*, *48*, 472–479. https://doi.org/10.1016/j.aap.2012.03.003

Murphy, G., & Matvienko-Sikar, K. (2019). Trait mindfulness & self-reported driving behaviour. *Personality and Individual Differences*, *147*, 250–255. https://doi.org/10.1016/j.paid.2019.05.002

Murphy, L., & Murphy, G. (2018). Time to drive: Present vs. future orientation and self-reported driving behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour*, *56*, 1–13. https://doi.org/10.1016/j.trf.2018.03.026

Nam, S., & Toneatto, T. (2016). The Influence of Attrition in Evaluating the Efficacy and Effectiveness of Mindfulness-Based Interventions. *International Journal of Mental Health and Addiction*, *14*(6), 969–981. https://doi.org/10.1007/s11469-016-9667-1

Nayda, D. M., & Takarangi, M. K. T. (2021). The cost of being absent: Is meta-awareness of mind-wandering related to depression symptom severity, rumination tendencies and trauma intrusions? *Journal of Affective Disorders*, *292*, 131–138. https://doi.org/10.1016/j.jad.2021.05.053

Née, M., Contrand, B., Orriols, L., Gil-Jardiné, C., Galéra, C., & Lagarde, E. (2019). Road safety and distraction, results from a responsibility case-control study among a sample of road users interviewed at the emergency room. *Accident Analysis & Prevention*, *122*, 19–24. https://doi.org/10.1016/j.aap.2018.09.032

Nijboer, M., Borst, J. P., van Rijn, H., & Taatgen, N. A. (2016). Driving and Multitasking: The Good, the Bad, and the Dangerous. *Frontiers in Psychology*, *7*. https://doi.org/10.3389/fpsyg.2016.01718

Nolen-Hoeksema, S., Wisco, B. E., & Lyubomirsky, S. (2008). Rethinking rumination. *Perspectives on Psychological Science*, *3*(5), 400–424. https://doi.org/10.1111/j.1745-6924.2008.00088.x

Nowosielski, R. J., Trick, L. M., & Toxopeus, R. (2018). Good distractions: Testing the effects of listening to an audiobook on driving performance in simple and complex road environments. *Accident Analysis & Prevention*, *111*, 202–209. https://doi.org/10.1016/j.aap.2017.11.033

Nunes, A., Castro, S. L., & Limpo, T. (2020). A Review of Mindfulness-Based Apps for Children. *Mindfulness*, *11*(9), 2089–2101. https://doi.org/10.1007/s12671-020-01410-w

Ottaviani, C., Shahabi, L., Tarvainen, M., Cook, I., Abrams, M., & Shapiro, D. (2015). Cognitive, behavioral, and autonomic correlates of mind wandering and perseverative cognition in major depression. *Frontiers in Neuroscience*, *8*, 433. https://doi.org/10.3389/fnins.2014.00433

Ouimet, M. C., Brown, T. G., Corado, L., Paquette, M., & Robertson, R. D. (2020). The effects of alcohol dose, exposure to an in-vehicle alcohol feedback device, and subjective responses to alcohol on the decision to drink-drive in young drivers. *Accident Analysis & Prevention*, *139*, 105495. https://doi.org/10.1016/j.aap.2020.105495

Ouimet, M. C., Duffy, C. W., Simons-Morton, B. G., Brown, T. G., & Fisher, D. L. (2011). *Understanding and Changing the Younger Driver Problem: A Review of the Randomized Controlled Trials Conducted with Driving Simulation*.

Panek, E. T., Bayer, J. B., Dal Cin, S., & Campbell, S. W. (2015). Automaticity, mindfulness, and self-control as predictors of dangerous texting behavior. *Mobile Media & Communication*, *3*(3), 383–400. https://doi.org/10.1177/2050157915576046

Pawar, N. M., & Velaga, N. R. (2021). Effect of time pressure on steering control of the drivers in a car-following situation. *Transportation Research Part F: Traffic Psychology and Behaviour*, *80*, 218–236. https://doi.org/10.1016/j.trf.2021.04.007

Pepin, G., Fort, A., Jallais, C., Moreau, F., Ndiaye, D., Navarro, J., & Gabaude, C. (2020). Impact of mind-wandering on visual information processing while driving: An electrophysiological study. *Applied Cognitive Psychology*.

Pepin, G., Malin, S., Jallais, C., Moreau, F., Fort, A., Navarro, J., Ndiaye, D., & Gabaude, C. (2018). Do distinct mind wandering differently disrupt drivers? Interpretation of physiological and behavioral pattern with a data triangulation method. *Consciousness and Cognition*, *62*, 69–81. https://doi.org/10.1016/j.concog.2018.04.006

Poerio, G. L., Totterdell, P., & Miles, E. (2013). Mind-wandering and negative mood: Does one thing really lead to another? *Consciousness and Cognition*, *22*(4), 1412–1421. https://doi.org/10.1016/j.concog.2013.09.012

Pozuelos, J. P., Combita, L. M., Abundis, A., Paz-Alonso, P. M., Conejero, Á., Guerra, S., & Rueda, M. R. (2019). Metacognitive scaffolding boosts cognitive and neural benefits following executive attention training in children. *Developmental Science*, *22*(2), e12756. https://doi.org/10.1111/desc.12756

Prakash, R. S. (2021). Mindfulness Meditation: Impact on Attentional Control and Emotion Dysregulation. *Archives of Clinical Neuropsychology*, *36*(7), 1283–1290. https://doi.org/10.1093/arclin/acab053

Qin, L., Li, Z. (Richard), Chen, Z., Andi Bill, M. S., & Noyce, D. A. (2019). Understanding driver distractions in fatal crashes: An exploratory empirical analysis. *Journal of Safety Research*, *69*, 23–31. https://doi.org/10.1016/j.jsr.2019.01.004

Qu, W., Ge, Y., Xiong, Y., Carciofo, R., Zhao, W., & Zhang, K. (2015). The relationship between mind wandering and dangerous driving behavior among Chinese drivers. *Safety Science*, *78*, 41–48. https://doi.org/10.1016/j.ssci.2015.04.016

Quinn, P. D., & Harden, K. P. (2013). Differential changes in impulsivity and sensation seeking and the escalation of substance use from adolescence to early adulthood. *Development and Psychopathology*, *25*(1), 223–239. Cambridge Core. https://doi.org/10.1017/S0954579412000284

Rahl, H. A., Lindsay, E. K., Pacilio, L. E., Brown, K. W., & Creswell, J. D. (2017). Brief mindfulness meditation training reduces mind wandering: The critical role of acceptance. *Emotion (Washington, D.C.)*, *17*(2), 224–230. https://doi.org/10.1037/emo0000250

Rahman, M. A., Hossain, Md. M., Mitran, E., & Sun, X. (2021). Understanding the contributing factors to young driver crashes: A comparison of crash profiles of three age groups. *Transportation Engineering*, *5*, 100076. https://doi.org/10.1016/j.treng.2021.100076

Rajendran, M., & Balasubramanian, V. (2019). *Impact of Mind Wandering on Driving*. 224–232.

Regan, M. A., & Hallett, C. (2011). Driver distraction: Definition, mechanisms, effects, and mitigation. In B. E. Porter (Ed.), *Handbook of traffic psychology* (pp. 275–286). Academic Press. https://doi.org/10.1016/B978-0-12-381984-0.10020-7

Regan, M. A., Hallett, C., & Gordon, C. P. (2011). Driver distraction and driver inattention: Definition, relationship and taxonomy. *Accident Analysis & Prevention*, *43*(5), 1771–1781. https://doi.org/10.1016/j.aap.2011.04.008

Regan, M. A., & Strayer, D. L. (2014). Towards an understanding of driver inattention: Taxonomy and theory. *Annals of Advances in Automotive Medicine / Annual Scientific Conference ... Association for the Advancement of Automotive Medicine. Association for the Advancement of Automotive Medicine. Scientific Conference*, *58*, 5–14.

Ribeiro, L., Atchley, R. M., & Oken, B. S. (2018). Adherence to Practice of Mindfulness in Novice Meditators: Practices Chosen, Amount of Time Practiced, and Long-Term Effects Following a Mindfulness-Based Intervention. *Mindfulness*, *9*(2), 401–411. https://doi.org/10.1007/s12671-017-0781-3

Robison, M. K., Miller, A. L., & Unsworth, N. (2020). A multi-faceted approach to understanding individual differences in mind-wandering. *Cognition*, *198*, 104078. https://doi.org/10.1016/j.cognition.2019.104078

Roebers, C. M. (2017). Executive function and metacognition: Towards a unifying framework of cognitive self-regulation. *Developmental Review*, *45*, 31–51. https://doi.org/10.1016/j.dr.2017.04.001

Rolison, J. J., & Moutari, S. (2020). Combinations of factors contribute to young driver crashes. *Journal of Safety Research*, *73*, 171–177. https://doi.org/10.1016/j.jsr.2020.02.017

Romer, D., Lee, Y.-C., McDonald, C. C., & Winston, F. K. (2014). Adolescence, Attention Allocation, and Driving Safety. *Journal of Adolescent Health*, *54*(5), S6–S15. https://doi.org/10.1016/j.jadohealth.2013.10.202

Rosen, M. L., Sheridan, M. A., Sambrook, K. A., Dennison, M. J., Jenness, J. L., Askren, M. K., Meltzoff, A. N., & McLaughlin, K. A. (2018). Salience network response to changes in emotional expressions of others is heightened during early adolescence: Relevance for social functioning. *Developmental Science*, *21*(3), e12571. https://doi.org/10.1111/desc.12571

Rosner, A., Franke, T., Platten, F., & Attig, C. (2019). Eye Movements in Vehicle Control. In C. Klein & U. Ettinger (Eds.), *Eye Movement Research: An Introduction to its Scientific Foundations and Applications* (pp. 929–969). Springer International Publishing. https://doi.org/10.1007/978-3-030-20085-5_22

Ross, V., Jongen, E. M. M., Brijs, K., Brijs, T., & Wets, G. (2016). Investigating risky, distracting, and protective peer passenger effects in a dual process framework. *Accident Analysis & Prevention*, *93*, 217–225. https://doi.org/10.1016/j.aap.2016.05.007

Rudisill, T. M., Chu, H., & Zhu, M. (2018). Cell phone use while driving laws and motor vehicle driver fatalities: Differences in population subgroups and location. *Annals of Epidemiology*, *28*(10), 730–735. https://doi.org/10.1016/j.annepidem.2018.07.015

Rudisill, T. M., & Zhu, M. (2017). Hand-held cell phone use while driving legislation and observed driver behavior among population sub-groups in the United States. *BMC Public Health*, *17*(1), 437. https://doi.org/10.1186/s12889-017-4373-x

Sani, S. R. H., Tabibi, Z., Fadardi, J. S., & Stavrinos, D. (2017). Aggression, emotional self-regulation, attentional bias, and cognitive inhibition predict risky driving behavior. *Accident Analysis & Prevention*, *109*, 78–88. https://doi.org/10.1016/j.aap.2017.10.006

Santorelli, S. F. (2014). *Mindfulness-based stress reduction (MBSR): Standards of practice*. Center for Mindfulness in Medicine, Health Care & Society, University of ….

Santorelli, S. F., Kabat-Zinn, J., Blacker, M., Meleo-Meyer, F., & Koerbel, L. (2017). Mindfulness-based stress reduction (MBSR) authorized curriculum guide. *Center for Mindfulness in Medicine, Health Care, and Society (CFM). University of Massachusetts Medical School*.

Savage, S. W., Potter, D. D., & Tatler, B. W. (2020). The Effects of Cognitive Distraction on Behavioural, Oculomotor and Electrophysiological Metrics During a Driving Hazard Perception Task. *Accident Analysis & Prevention*, *138*, 105469.

Schaeffner, S., Chevalier, N., Kubota, M., & Karbach, J. (2021). Metacognitive Training. In T. Strobach & J. Karbach (Eds.), *Cognitive Training: An Overview of Features and Applications* (pp. 255–270). Springer International Publishing. https://doi.org/10.1007/978-3-030-39292-5_18

Schooler, J. W. (2002). Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in Cognitive Sciences*, *6*(8), 339–344. https://doi.org/10.1016/S1364-6613(02)01949-6

Schooler, J. W., & Smallwood, J. (2009). Metacognition. In *The Oxford Companion to Consciousness*. Oxford University Press. http://www.oxfordreference.com/view/10.1093/acref/9780198569510.001.0001/acref-9780198569510-e-214

Schooler, J. W., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences*, *15*(7), 319–326. https://doi.org/10.1016/j.tics.2011.05.006

Scott-Parker, B. (2017). Emotions, behaviour, and the adolescent driver: A literature review. *Transportation Research Part F: Traffic Psychology and Behaviour*, *50*, 1–37. https://doi.org/10.1016/j.trf.2017.06.019

Seli, P., Cheyne, J. A., & Smilek, D. (2013). Wandering minds and wavering rhythms: Linking mind wandering and behavioral variability. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(1), 1–5. https://doi.org/10.1037/a0030954

Seli, P., Kane, M. J., Smallwood, J., Schacter, D. L., Maillet, D., Schooler, J. W., & Smilek, D. (2018). Mind-wandering as a natural kind: A family-resemblances view. *Trends in Cognitive Sciences*, *22*(6), 479–490. https://doi.org/10.1016/j.tics.2018.03.010

Seli, P., O'Neill, K., Carriere, J. S. A., Smilek, D., Beaty, R. E., & Schacter, D. L. (2020). Mind-Wandering Across the Age Gap: Age-Related Differences in Mind-Wandering Are Partially Attributable to Age-Related Differences in Motivation. *The Journals of Gerontology: Series B*, gbaa031. https://doi.org/10.1093/geronb/gbaa031

Seli, P., Schacter, D. L., Risko, E. F., & Smilek, D. (2019). Increasing participant motivation reduces rates of intentional and unintentional mind wandering. *Psychological Research*, *83*(5), 1057–1069. https://doi.org/10.1007/s00426-017-0914-2

Seli, P., Wammes, J. D., Risko, E. F., & Smilek, D. (2016). On the relation between motivation and retention in educational contexts: The role of intentional and unintentional mind wandering. *Psychonomic Bulletin & Review*, *23*(4), 1280–1287. https://doi.org/10.3758/s13423-015-0979-0

Shulman, E. P., Harden, K. P., Chein, J. M., & Steinberg, L. (2015). Sex Differences in the Developmental Trajectories of Impulse Control and Sensation-Seeking from Early Adolescence to Early Adulthood. *Journal of Youth and Adolescence*, *44*(1), 1–17. https://doi.org/10.1007/s10964-014-0116-9

Shulman, E. P., Smith, A. R., Silva, K., Icenogle, G., Duell, N., Chein, J., & Steinberg, L. (2016). The dual systems model: Review, reappraisal, and reaffirmation. *Developmental Cognitive Neuroscience*, *17*, 103–117. https://doi.org/10.1016/j.dcn.2015.12.010

Smallwood, J. (2013). Distinguishing how from why the mind wanders: A process–occurrence framework for self-generated mental activity. *Psychological Bulletin*, *139*(3), 519–535. https://doi.org/10.1037/a0030010

Smallwood, J., & Andrews-Hanna, J. (2013). Not all minds that wander are lost: The importance of a balanced perspective on the mind-wandering state. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00441

Smallwood, J., Brown, K. S., Baird, B., Mrazek, M. D., Franklin, M. S., & Schooler, J. W. (2012). Insulation for Daydreams: A Role for Tonic Norepinephrine in the Facilitation of Internally Guided Thought. *PLOS ONE*, *7*(4), e33706. https://doi.org/10.1371/journal.pone.0033706

Smallwood, J., Brown, K. S., Tipper, C., Giesbrecht, B., Franklin, M. S., Mrazek, M. D., Carlson, J. M., & Schooler, J. W. (2011). Pupillometric evidence for the decoupling of attention from perceptual input during offline thought. *PLoS ONE*, *6*(3). https://doi.org/10.1371/journal.pone.0018298

Smallwood, J., Davies, J. B., Heim, D., Finnigan, F., Sudberry, M., O'Connor, R., & Obonsawin, M. (2004). Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Consciousness and Cognition*, *13*(4), 657–690. https://doi.org/10.1016/j.concog.2004.06.003

Smallwood, J., Fitzgerald, A., Miles, L. K., & Phillips, L. H. (2009). Shifting moods, wandering minds: Negative moods lead the mind to wander. *Emotion*, *9*(2), 271–276. https://doi.org/10.1037/a0014855

Smallwood, J., McSpadden, M., & Schooler, J. W. (2007). The lights are on but no one's home: Meta-awareness and the decoupling of attention when the mind wanders. *Psychonomic Bulletin & Review*, *14*(3), 527–533. https://doi.org/10.3758/BF03194102

Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory & Cognition*, *36*(6), 1144–1150. https://doi.org/10.3758/MC.36.6.1144

Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition*, *18*(1), 118–125. https://doi.org/10.1016/j.concog.2008.11.004

Smallwood, J., O'Connor, R. C., Sudbery, M. V., & Obonsawin, M. (2007). Mind-wandering and dysphoria. *Cognition and Emotion*, *21*(4), 816–842. https://doi.org/10.1080/02699930600911531

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*(6), 946–958. https://doi.org/10.1037/0033-2909.132.6.946

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology*, *66*(1), 487–518. https://doi.org/10.1146/annurev-psych-010814-015331

Smilek, D., Carriere, J. S. A., & Cheyne, J. A. (2010). Failures of sustained attention in life, lab, and brain: Ecological validity of the SART. *Neuropsychologia*, *48*(9), 2564–2570. https://doi.org/10.1016/j.neuropsychologia.2010.05.002

Solhaug, I., de Vibe, M., Friborg, O., Sørlie, T., Tyssen, R., Bjørndal, A., & Rosenvinge, J. H. (2019). Long-term Mental Health Effects of Mindfulness Training: A 4-Year Follow-up Study. *Mindfulness*, *10*(8), 1661–1672. https://doi.org/10.1007/s12671-019-01100-2

Sommers-Spijkerman, M., Austin, J., Bohlmeijer, E., & Pots, W. (2021). New Evidence in the Booming Field of Online Mindfulness: An Updated Meta-analysis of Randomized Controlled Trials. *JMIR Mental Health*, *8*(7), e28168. https://doi.org/10.2196/28168

Sørensen, L., Osnes, B., Visted, E., Svendsen, J. L., Adolfsdottir, S., Binder, P.-E., & Schanche, E. (2018). Dispositional Mindfulness and Attentional Control: The Specific Association Between the Mindfulness Facets of Non-judgment and Describing With Flexibility of Early Operating Orienting in Conflict Detection. *Frontiers in Psychology*, *9*, 2359. https://doi.org/10.3389/fpsyg.2018.02359

Spijkerman, M. P. J., Pots, W. T. M., & Bohlmeijer, E. T. (2016). Effectiveness of online mindfulness-based interventions in improving mental health: A review and meta-analysis of randomised controlled trials. *Clinical Psychology Review*, *45*, 102–114. https://doi.org/10.1016/j.cpr.2016.03.009

Spinhoven, P., Huijbers, M. J., Ormel, J., & Speckens, A. E. M. (2017). Improvement of mindfulness skills during Mindfulness-Based Cognitive Therapy predicts long-term reductions of neuroticism in persons with recurrent depression in remission. *Journal of Affective Disorders*, *213*, 112–117. https://doi.org/10.1016/j.jad.2017.02.011

Sripada, C. S. (2018). *An Exploration/Exploitation Trade-off Between Mind-Wandering and Goal-Directed Thinking* (K. Christoff & K. C. R. Fox, Eds.; Vol. 1). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190464745.013.28

Steinberg, L., Albert, D., Cauffman, E., Banich, M., Graham, S., & Woolard, J. (2008). Age differences in sensation seeking and impulsivity as indexed by behavior and self-report: Evidence for a dual systems model. *Developmental Psychology*, *44*(6), 1764–1778. https://doi.org/10.1037/a0012955

Steinhauser, K., Leist, F., Maier, K., Michel, V., Pärsch, N., Rigley, P., Wurm, F., & Steinhauser, M. (2018). Effects of emotions on driving behavior. *Transportation Research Part F: Traffic Psychology and Behaviour*, *59*, 150–163. https://doi.org/10.1016/j.trf.2018.08.012

Stjernswärd, S., & Hansson, L. (2017). Outcome of a web-based mindfulness intervention for families living with mental illness – A feasibility study. *Informatics for Health and Social Care*, *42*(1), 97–108. https://doi.org/10.1080/17538157.2016.1177533

Suhr, K. A. (2016). Mulling Over Anger: Indirect and Conditional Indirect Effects of Thought Content and Trait Rumination on Aggressive Driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *42, Part 2*, pp 276-285.

Suhr, K. A., & Dula, C. S. (2017). The dangers of rumination on the road: Predictors of risky driving. *Accident Analysis & Prevention*, *99*, 153–160. https://doi.org/10.1016/j.aap.2016.10.026

Suhr, K. A., & Nesbit, S. M. (2013). Dwelling on 'road rage': The effects of trait rumination on aggressive driving. *Transportation Research Part F: Traffic Psychology and Behaviour*, *21*, 207–218. https://doi.org/10.1016/j.trf.2013.10.001

Tang, Y.-Y., Ma, Y., Fan, Y., Feng, H., Wang, J., Feng, S., Lu, Q., Hu, B., Lin, Y., Li, J., Zhang, Y., Wang, Y., Zhou, L., & Fan, M. (2009). Central and autonomic nervous system interaction is altered by short-term meditation. *Proceedings of the National Academy of Sciences*, *106*(22), 8865–8870. https://doi.org/10.1073/pnas.0904031106

Tang, Y.-Y., Ma, Y., Wang, J., Fan, Y., Feng, S., Lu, Q., Yu, Q., Sui, D., Rothbart, M. K., Fan, M., & Posner, M. I. (2007). Short-term meditation training improves attention and self-regulation. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(43), 17152–17156. https://doi.org/10.1073/pnas.0707678104

Tang, Y.-Y., Tang, R., & Posner, M. I. (2016). Mindfulness meditation improves emotion regulation and reduces drug abuse. *Drug and Alcohol Dependence*, *163*, S13–S18. https://doi.org/10.1016/j.drugalcdep.2015.11.041

Techer, F., Jallais, C., Corson, Y., Moreau, F., Ndiaye, D., Piechnick, B., & Fort, A. (2017). Attention and driving performance modulations due to anger state: Contribution of electroencephalographic data. *ALS: New Molecular Mechanisms and Emerging Therapeutic Targets*, *636*, 134–139. https://doi.org/10.1016/j.neulet.2016.11.011

Teper, R., Segal, Z. V., & Inzlicht, M. (2013). Inside the Mindful Mind: How Mindfulness Enhances Emotion Regulation Through Improvements in Executive Control. *Current Directions in Psychological Science*, *22*(6), 449–454. https://doi.org/10.1177/0963721413495869

Terry, C. P., & Terry, D. L. (2015). Cell Phone-Related Near Accidents Among Young Drivers: Associations With Mindfulness. *The Journal of Psychology*, *149*(7), 665–683. https://doi.org/10.1080/00223980.2014.964166

Thomson, D. R., Besner, D., & Smilek, D. (2015). A Resource-Control Account of Sustained Attention: Evidence From Mind-Wandering and Vigilance Paradigms. *Perspectives on Psychological Science*, *10*(1), 82–96. https://doi.org/10.1177/1745691614556681

Transport Canada. (2020). *Canadian motor vehicle traffic collision statistics: 2018*. https://tc.canada.ca/en/road-transportation/motor-vehicle-safety/canadian-motor-vehicle-traffic-collision-statistics-2018

Turnbull, A., Wang, H.-T., Schooler, J. W., Jefferies, E., Margulies, D. S., & Smallwood, J. (2019). The ebb and flow of attention: Between-subject variation in intrinsic connectivity and cognition associated with the dynamics of ongoing experience. *NeuroImage*, *185*, 286–299. https://doi.org/10.1016/j.neuroimage.2018.09.069

van Belle, J., Vink, M., Durston, S., & Zandbelt, B. B. (2014). Common and unique neural networks for proactive and reactive response inhibition revealed by independent component analysis of functional MRI data. *NeuroImage*, *103*, 65–74. https://doi.org/10.1016/j.neuroimage.2014.09.014

Van Dam, N. T., van Vugt, M. K., Vago, D. R., Schmalzl, L., Saron, C. D., Olendzki, A., Meissner, T., Lazar, S. W., Kerr, C. E., Gorchov, J., Fox, K. C. R. R., Field, B. A., Britton, W. B., Brefczynski-

Lewis, J. A., & Meyer, D. E. (2018). Mind the Hype: A Critical Evaluation and Prescriptive Agenda for Research on Mindfulness and Meditation. *Perspectives on Psychological Science*, *13*(1), 36–61. https://doi.org/10.1177/1745691617709589

van Hoorn, J., Shablack, H., Lindquist, K. A., & Telzer, E. H. (2019). Incorporating the social context into neurocognitive models of adolescent decision-making: A neuroimaging meta-analysis. *Neuroscience & Biobehavioral Reviews*, *101*, 129–142. https://doi.org/10.1016/j.neubiorev.2018.12.024

van Vugt, M. K., van der Velde, M., & Investigators, E.-M. (2018). How Does Rumination Impact Cognition? A First Mechanistic Model. *Topics in Cognitive Science*, *10*(1), 175–191. https://doi.org/10.1111/tops.12318

Vannucci, M., & Chiorri, C. (2018). Individual differences in self-consciousness and mind wandering: Further evidence for a dissociation between spontaneous and deliberate mind wandering. *Personality and Individual Differences*, *121*, 57–61. https://doi.org/10.1016/j.paid.2017.09.022

Vannucci, M., Pelagatti, C., Hanczakowski, M., & Chiorri, C. (2019). Visual attentional load affects the frequency of involuntary autobiographical memories and their level of meta-awareness. *Memory & Cognition*, *47*(1), 117–129. https://doi.org/10.3758/s13421-018-0854-0

Verhaeghen, P. (2021). Mindfulness as Attention Training: Meta-Analyses on the Links Between Attention Performance and Mindfulness Interventions, Long-Term Meditation Practice, and Trait Mindfulness. *Mindfulness*, *12*(3), 564–581. https://doi.org/10.1007/s12671-020-01532-1

Victorson, D. E., Sauer, C. M., Wolters, L., Maletich, C., Lukoff, K., & Sufrin, N. (2020). Meta-analysis of Technology-Enabled Mindfulness-Based Programs for Negative Affect and Mindful Awareness. *Mindfulness*, *11*(8), 1884–1899. https://doi.org/10.1007/s12671-020-01373-y

Walker, H. E. K., & Trick, L. M. (2018). Mind-wandering while driving: The impact of fatigue, task length, and sustained attention abilities. *Transportation Research Part F: Traffic Psychology and Behaviour*, *59*, 81–97. https://doi.org/10.1016/j.trf.2018.08.009

Walker, H. E. K., & Trick, L. M. (2019). Mind-Wandering and Driving: Comparing Thought Report and Individual Difference Measures. *Proceedings of the 10th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design: Driving Assessment 2019*, 8–14. https://doi.org/10.17077/drivingassessment.1668

Wang, C., Li, Z., Fu, R., Guo, Y., & Yuan, W. (2019). What is the difference in driver's lateral control ability during naturalistic distracted driving and normal driving? A case study on a real highway. *Accident Analysis & Prevention*, *125*, 98–105. https://doi.org/10.1016/j.aap.2019.01.030

Watkins, E. R. (2008). Constructive and unconstructive repetitive thought. *Psychological Bulletin*, *134*(2), 163–206. https://doi.org/10.1037/0033-2909.134.2.163

Weil, L. G., Fleming, S. M., Dumontheil, I., Kilford, E. J., Weil, R. S., Rees, G., Dolan, R. J., & Blakemore, S.-J. (2013). The development of metacognitive ability in adolescence. *Consciousness and Cognition*, *22*(1), 264–271. https://doi.org/10.1016/j.concog.2013.01.004

Wielgosz, J., Goldberg, S. B., Kral, T. R. A., Dunne, J. D., & Davidson, R. J. (2019). Mindfulness Meditation and Psychopathology. *Annual Review of Clinical Psychology*, *15*(1), 285–316. https://doi.org/10.1146/annurev-clinpsy-021815-093423

World Health Organization. (2015). *Global status report on road safety 2015*. World Health Organization; WHO IRIS. https://apps.who.int/iris/handle/10665/189242

World Health Organization. (2018). *Global status report on road safety 2018*. World Health Organization. https://www.who.int/publications/i/item/9789241565684

Wynne, R. A., Beanland, V., & Salmon, P. M. (2019). Systematic review of driving simulator validation studies. *Safety Science*, *117*, 138–151. https://doi.org/10.1016/j.ssci.2019.04.004

Xiao, L., Huang, Q., Yank, V., & Ma, J. (2013). An Easily Accessible Web-Based Minimization Random Allocation System for Clinical Trials. *Journal of Medical Internet Research*, *15*(7), e139. https://doi.org/10.2196/jmir.2392

Yakobi, O., Smilek, D., & Danckert, J. (2021). The Effects of Mindfulness Meditation on Attention, Executive Control and Working Memory in Healthy Adults: A Meta-analysis of Randomized Controlled Trials. *Cognitive Therapy and Research*. https://doi.org/10.1007/s10608-020-10177-2

Yang, Y., Cao, S., Shields, G. S., Teng, Z., & Liu, Y. (2017). The relationships between rumination and core executive functions: A meta-analysis. *Depression and Anxiety*, *34*(1), 37–50. https://doi.org/10.1002/da.22539

Yang, Z., Yu, Q., Zhang, W., & Shen, H. (2021). A comparison of experienced and novice drivers' rear-end collision avoidance maneuvers under urgent decelerating events.

Transportation Research Part F: Traffic Psychology and Behaviour, *76*, 353–368. https://doi.org/10.1016/j.trf.2020.12.009

Yanko, M. R., & Spalek, T. M. (2014). Driving with the wandering mind: The effect that mind-wandering has on driving performance. *Human Factors*, *56*(2), 260–269. https://doi.org/10.1177/0018720813495280

Young, K. L., Koppel, S., Stephens, A. N., Osborne, R., Chambers, R., & Hassed, C. (2019). Mindfulness Predicts Driver Engagement in Distracting Activities. *Mindfulness*, *10*(5), 913–922. https://doi.org/10.1007/s12671-018-1060-7

Young, K. L., & Salmon, P. M. (2012). Examining the relationship between driver distraction and driving errors: A discussion of theory, studies and methods. *Safety Science*, *50*(2), 165–174. https://doi.org/10.1016/j.ssci.2011.07.008

Young, K., Sandman, C., & Craske, M. (2019). Positive and Negative Emotion Regulation in Adolescence: Links to Anxiety and Depression. *Brain Sciences*, *9*(4), 76. https://doi.org/10.3390/brainsci9040076

Zanesco, A. P., King, B. G., MacLean, K. A., Jacobs, T. L., Aichele, S. R., Wallace, B. A., Smallwood, J., Schooler, J. W., & Saron, C. D. (2016). Meditation training influences mind wandering and mindless reading. *Psychology of Consciousness: Theory, Research, and Practice*, *3*(1), 12–33. https://doi.org/10.1037/cns0000082

Zavagnin, M., Borella, E., & De Beni, R. (2014). When the mind wanders: Age-related differences between young and older adults. *Acta Psychologica*, *145*, 54–64. https://doi.org/10.1016/j.actpsy.2013.10.016

Zeidan, F., Johnson, S. K., Diamond, B. J., David, Z., & Goolkasian, P. (2010). Mindfulness meditation improves cognition: Evidence of brief mental training. *Consciousness and Cognition*, *19*(2), 597–605. https://doi.org/10.1016/j.concog.2010.03.014

Zetsche, U., Bürkner, P.-C., & Schulze, L. (2018). Shedding light on the association between repetitive negative thinking and deficits in cognitive control – A meta-analysis. *Clinical Psychology Review*, *63*, 56–65. https://doi.org/10.1016/j.cpr.2018.06.001

Zhang, Y., & Kumada, T. (2017). Relationship between workload and mind-wandering in simulated driving. *PLOS ONE*, *12*(5), e0176962. https://doi.org/10.1371/journal.pone.0176962

Zimasa, T., Jamson, S., & Henson, B. (2019). The influence of driver's mood on car following and glance behaviour: Using cognitive load as an intervention. *Transportation Research Part F: Traffic Psychology and Behaviour*, *66*, 87–100. https://doi.org/10.1016/j.trf.2019.08.019

Appendix A

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Date: September 29, 2021 at 7:37 PM
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Co-Authors: Derek A. Albert; Marie Claude Ouimet, PhD
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