Mindless Driving: Linking Trait Absentmindedness to Risky Driving Behaviour

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Abstract

Background

Risky driving is an important factor associated with road traffic crashes, which is the leading cause of death among young people. An internal form of distraction, known as mind wandering (i.e., shifting attention from the immediate environment and ongoing tasks to unrelated thoughts and feelings), is associated with a reduction in driver visual attention, impairments in driving performance, and increased likelihood of being responsible for a crash. Individuals who show a propensity for mind wandering (i.e., trait absentmindedness) also experience more routine task errors, but whether trait absentmindedness also predicts risky driving behaviour is unknown. Moreover, mind wandering interferes with sensory information processing, but whether driver visual attention mediates the relationship between trait absentmindedness and risky driving has yet to be determined. Finally, executive control (i.e., the system responsible for deliberate and effortful goal-oriented cognition) is thought to facilitate and regulate mind wandering. It is currently unclear, however, whether it moderates the association between trait absentmindedness and behaviour.

Objective

The present study examines the relationships between trait absentmindedness, executive control capacity, driver visual attention, and risky driving behaviour in young male drivers.

Hypotheses

We hypothesized that: H1) greater trait absentmindedness is associated with higher risky driving behaviour; H2) greater trait absentmindedness is associated with less

driver visual attention; H3) visual attention mediates the relationship between trait absentmindedness and risky driving; and H4) executive control capacity moderates the relationship between trait absentmindedness and risky driving behaviour.

Methods

A sample (*N* = 30) of young male drivers aged 18-21 years was administered the Sustained Attention to Response Task, the Daydreaming Frequency Scale, and the Dundee Stress State Questionnaire to measure trait absentmindedness, as well as the Color-Word Interference Test for executive control capacity. Mean driving speed in a simulator was used to measure risky driving, and eye tracking was used to quantify visual attention.

Results

Results showed that greater trait absentmindedness is significantly associated with higher risky driving, with trait absentmindedness explaining 32% of the variance in mean driving speed (i.e., H1). Greater executive control capacity was significantly associated with higher risky driving as a function of trait absentmindedness, with executive control explaining an additional 16% of the variance in mean driving speed (i.e., H4). The expected association between trait absentmindedness and driver visual attention (i.e., H2 and H3) was not detected. Exploratory analyses hinted that explicit awareness of mind wandering may be associated with reduced risky driving, and that greater trait absentmindedness may be associated with higher mean vertical gaze position.

Discussion

Trait absentmindedness is a significant marker of risky driving among young male drivers in a simulator. Moreover, executive control moderates this relationship,

while meta-awareness may lessen the impact of mind wandering on driving. These preliminary findings suggest avenues for the development of detection and intervention programs designed to mitigate risky driving behaviour linked to trait absentmindedness.

Résumé

Contexte

La conduite à risque est un facteur important associé aux collisions routières qui représentent la première cause de décès chez les jeunes. La pensée errante est une forme de distraction interne qui consiste à déplacer son attention de l'environnement immédiat et d'une tâche courante vers des pensées et des émotions non liées à la tâche. Elle est associée à une réduction de l'attention visuelle du conducteur, une diminution de la performance de conduite et à une augmentation de la probabilité d'être reconnu responsable d'une collision. Les individus qui présentent une propension à la pensée errante (appelée ici le trait d'inattention) commettent aussi plus d'erreurs lors de l'exécution de tâches routinières. Toutefois, aucune étude ne s'est penchée sur la relation entre le trait d'inattention et la conduite à risque. De plus, la pensée errante interfère avec le traitement sensoriel de l'information, mais l'influence de l'attention visuelle du conducteur sur le lien entre le trait d'inattention et la conduite à risque n'a pas été étudiée. Enfin, le contrôle exécutif (c.-à-d., le système responsable de l'activité mentale délibérée et orientée vers un but) semble faciliter et réguler la pensée errante. Cependant, l'influence du contrôle exécutif sur l'association entre le trait d'inattention et le comportement reste à déterminer.

Objectif

La présente étude examine les liens entre le trait d'inattention, la capacité de contrôle exécutif, l'attention visuelle du conducteur et la conduite à risque chez les jeunes conducteurs masculins.

Hypothèses

Les hypothèses suivantes sont proposées : H1) un trait d'inattention plus élevé est associé à une plus grande manifestation de conduite à risque; H2) un trait d'inattention plus élevé est associé à une moins grande attention visuelle chez le conducteur; H3) l'attention visuelle influence le lien entre le trait d'inattention et la conduite à risque; et H4) la capacité de contrôle exécutif modère le lien entre le trait d'inattention et la conduite à risque.

Méthode

Un échantillon ($N = 30$) de jeunes conducteurs masculins âgés de 18 à 21 ans ont complété plusieurs tâches et questionnaires : une tâche d'attention soutenue à une réponse (*Sustained Attention to Response Task*); une échelle de fréquence de la rêverie (*Daydreaming Frequency Scale*); un questionnaire sur le trait d'inattention (*Dundee Stress State Questionnaire*) et un questionnaire pour mesurer la capacité de contrôle exécutif (*Color-Word Interference Test*). La conduite à risque est mesurée par la vitesse moyenne de conduite dans un simulateur et l'attention visuelle est calculée à l'aide d'un système de suivi oculaire.

Résultats

Les résultats indiquent qu'un trait d'inattention plus élevé est significativement associé à une vitesse plus élevée ; le trait d'inattention expliquant 32 % de la variance de la vitesse moyenne (c.-à-d., H1). De plus, une capacité de contrôle exécutif plus importante est significativement liée à une vitesse moyenne plus élevée en fonction du trait d'inattention ; la capacité de contrôle exécutif expliquant 16 % additionnel de la variance de la vitesse moyenne (c.-à-d., H4). Aucun lien significatif n'a été démontré entre le trait d'inattention et l'attention visuelle (c.-à-d., H2 et H3). Des analyses exploratoires suggèrent que la prise de conscience de la pensée errante pourrait être associée à une diminution de la conduite à risque et qu'un trait d'inattention plus élevé est significativement associé à une variation plus importante de la position verticale du regard.

Discussion

Le trait d'inattention est significativement associé à la conduite à risque chez les jeunes conducteurs masculins dans une situation de simulation. De plus, le contrôle exécutif modère ce lien, alors que la méta-conscience pourrait réduire l'impact de la pensée errante sur la conduite. Ces résultats préliminaires suggèrent des pistes pour le développement de programmes de détection et d'intervention visant à atténuer la conduite à risque liée au trait d'inattention.

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Author Contributions

I designed the study in collaboration with Dr. Brown and Dr. Ouimet. I brought the initial idea to Dr. Brown, who then assisted me in constructing the theoretical model that informed our testable hypotheses. Since the present study relied on data that were collected in the context of Dr. Ouimet's larger study, she helped me determine what measures could be added and where.

Dr. Brown and I formulated the analysis strategy, whereas I conducted the analysis independently. He also worked with me on the introduction, mainly suggesting things to add in order to address conceptual gaps, as well as the discussion and conclusion, mainly suggesting things to remove in order to stay focussed on point. Dr. Brown also provided editorial support for greater clarity and concision.

Dr. Ouimet assisted mainly with ensuring the accuracy and clarity of the methods section, since she and her team knew the inclusion/exclusion criteria, procedures, and apparatus inside and out. She also provided translation and editorial support in preparation for final thesis submission.

Glossary

- CFQ — Cognitive Failures Questionnaire
- CHUS — *Centre hospitalier universitaire de Sherbrooke*
- CI — confidence interval
- CV — criterion variable
- CWIT — Color-Word Interference Test
- DDFS — Daydreaming Frequency Scale
- DSSQ — Dundee Stress State Questionnaire
- EEG — electroencephalography
- IRB — Institutional Review Board
- Km/h — kilometers per hour
- OLS — ordinary least squares
- PV — predictor variable
- RAM — random access memory
- SART — Sustained Attention to Response Task

Introduction

The Young Driver Problem and Risky Driving Behaviour

Human factors are estimated to account for 90% of all road traffic crashes (Peden et al., 2004). More troublingly, injuries from road traffic crashes are the number one cause of death in young people, aged 15-29, worldwide (World Health Organization, 2015). The "young driver problem" refers to consistent overrepresentation of young drivers in road traffic crashes (Mayhew, Simpson, & Singhal, 2005). Constituting only 12.6% of all drivers in Canada, 16-24 year olds represented nearly 21% of fatalities and 20% of those seriously injured from crashes in 2013 (Transport Canada, 2014).

While novice drivers of all ages are particularly vulnerable to crashes due in part to their lack of experience (Mayhew, Simpson, & Pak, 2003), developmental factors may also contribute to their heightened crash risk. For example, teenage drivers still show significantly greater crash risk than drivers over the age of 25 irrespective of length of licensure or driving exposure (McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009). Developmental trends in certain aspects of personality and cognition correspond to a decline in various risk-taking behaviours between adolescence and middle adulthood (Steinberg et al., 2008). These age-related behavioural differences are reflected in the tendency of young drivers, especially males, to engage in risky driving behaviours such as speeding, tailgating, and driving while impaired (Fergusson, Swain-Campbell, & Horwood, 2003; Turner & McClure, 2003). At the same time, there is substantial within-group variability in the degree to which individuals are prone to engage in risky driving (Fergusson et al., 2003; Jessor, 1987).

Research into why some are more inclined than others to take risks on the road has focused on individual differences in dispositional traits, such as sensation seeking (see Jonah, 1997 for a review), and cognitive capacities like executive control (Mäntylä, Karlsson, & Marklund, 2009; Ross et al., 2015). More recently, research has investigated the driving decrements and crash risk associated with states of external distraction brought about by cell phones, in-vehicle entertainment systems, and other captivating stimuli in the environment (Klauer et al., 2014). Less research attention has been dedicated, however, to the investigation of individual differences in dispositional traits and cognitive capacities that might influence one's susceptibility to distraction. Moreover, only recently have states of internal distraction, due to thoughts and feelings that are unrelated to the immediate environment or ongoing tasks, been considered in the context of traffic safety (Galéra et al., 2012; He, Becic, Lee, & McCarley, 2011; Yanko & Spalek, 2013). No studies to date have addressed the potential influence of individual differences for this driving risk factor, however.

Overall, multiple factors likely interact to produce risky driving in young drivers. The aim of the present study is to clarify whether a dispositional trait (i.e., trait absentmindedness) and a cognitive capacity (i.e., executive control) associated with internal distraction are linked to risky driving behaviour among young male drivers — the most at-risk driver subgroup (Ivers et al., 2009; Turner & McClure, 2003). Furthermore, driver visual attention as a possible mediating factor is also explored. The following sections review these components and their relationships. A better understanding of how individual differences related to internal distraction predict variability in risky driving could lead to advancements in the detection of those who are most at risk within this vulnerable subgroup. It could also inform future investigations looking at between-group differences in risky driving across sex/gender, experience, and development. Finally, uncovering the possible underpinnings of risky driving behaviour among young male drivers may aid the development of interventions and preventative strategies aimed at curbing the young driver problem.

Driver Distraction

Drivers are known to engage in a variety of nonessential activities while operating their vehicles. Driver distraction is defined as, "the diversion of attention away from activities critical for safe driving towards a competing activity" (World Health Organization & National Highway Traffic Safety Administration, 2011, p. 7). In Canada between 2003 and 2007, driver distraction was estimated to account for approximately 11% of crashes resulting in injury or death (Transport Canada, 2007). Moreover, a study that used instrumented vehicles to observe the behaviour of drivers found that driver distraction from various sources contributed to approximately 22% of all risky road events, including crashes and near-crashes (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006).

Drivers are susceptible to multiple sources of distraction both inside and outside of the vehicle. As of 2001, the most prevalent sources of distraction associated with crashes included people, objects and events outside the vehicle, in-vehicle entertainment systems, and passengers (Stutts, 2001). The proliferation of cell phones and other mobile devices in recent years has made them increasingly relevant to traffic safety, however. As a result, contemporary driver distraction research has primarily focussed on in-vehicle cell phone use (Caird, Johnston, Willness, Asbridge, & Steel, 2014; Caird, Willness, Steel, & Scialfa, 2008; McCartt, Hellinga, & Bratiman, 2006). The data suggest that cell phones are now the second most prevalent crash risk factor. Drivers use their phones approximately 6.4% of the time while driving, which is associated with a 360% increase in the odds of being involved in a crash (Dingus et al., 2016). Therefore, cell phones may serve as a useful example for understanding the general behavioural and cognitive characteristics of driver distraction and its potential for increasing crash risk.

Distraction that impairs driving performance often results from engaging in inessential activities (i.e., secondary tasks) performed concurrently alongside the primary task of driving. This impairment may occur through multiple mechanisms. In the case of cell phones, manual texting and dialling require drivers to glance away from the road (i.e., visual distraction) and physically remove a hand from the steering wheel (i.e., biomechanical distraction) in order to use the mobile device, which in turn can interfere with timely detection (i.e., hazard perception) and response to traffic events (Hosking, Young, & Regan, 2009). In-vehicle entertainment and information systems that require manual input operate similarly (Sodhi, Reimer, & Llamazares, 2002). Longer response times to traffic events are observed even when drivers are using hands-free cellular systems (Strayer, Drews, & Johnston, 2003) and voice-operated interfaces (Ranney, Harbluk, & Noy, 2005). While drivers tend to reduce their speed when using hand-held mobile devices or engaging in other secondary tasks, they appear to compensate less while using hands-free systems, possibly because a phone-in-hand reminds drivers that their attention is divided (Caird et al., 2008; Horberry, Anderson, Regan, Triggs, & Brown, 2006). Thus, diminished awareness of performance decrements accompanying engagement in a secondary task may also contribute to crash risk (Horrey, Lesch, & Garabet, 2008; Sanbonmatsu, Strayer, Biondi, Behrends, & Moore, 2015).

In addition to overt visual and biomechanical factors, covert cognitive processes underlie many of the decrements associated with driver distraction (i.e., cognitive distraction). Even though there is no need to glance away from the road while conversing on a cell phone, drivers nevertheless exhibit reduced visual attention. Two effects on visual attention have been observed: i) visual tunnelling, which is a reduction in peripheral awareness due to a spatially narrowed spread of gaze fixations, with longer fixations closer to the center of the visual field (Briggs, Hole, & Land, 2011); and ii) inattention blindness, which is a failure to notice changes in the environment or take note of important aspects of the roadway (Strayer & Drews, 2007). Driver distraction is also associated with an elevation in the frequency of driving errors, or inappropriate responses to driving situations, such as pressing the accelerator instead of the brake, misjudging the speed of an oncoming vehicle, or unintentionally exceeding the speed limit (Young & Salmon, 2012). Furthermore, experiments in which participants performed mental tasks that were designed to be cognitively but not visually or biomechanically demanding (e.g., mental arithmetic) produce driving deficits comparable to those seen with distraction observed in naturalistic settings (Drews, Pasupathi, & Strayer, 2008; Harbluk, Noy, & Eizenman, 2002; Reimer, 2009).

Distraction in which attention is diverted to stimuli external to the driver (i.e., external distraction), as in the case of cell phones, may be informative for thinking about another form of distraction and its potential implications for driving. Internal distraction describes when attention is diverted from task performance to internal stimuli, such as daydreams, extraneous task-related thoughts, or task-unrelated thoughts and feelings. Previous research neglected the salience of internal stimuli by attributing driver distraction only to external sources and distinguishing driver inattention as the absence of sufficient focus on driving with no competing activity or compelling reason (Caird & Dewar, 2007; Lee, Young, & Regan, 2008; Treat, 1980). Recent work has addressed this issue by accounting for variants of *internalised thought* as subtypes of driver distraction (Regan, Hallett, & Gordon, 2011). While difficult to observe and experimentally control, internal distraction contributes significantly to crash risk. In their review, Young and Salmon (2012) found that the proportion of distraction-related crashes linked to internal distraction (i.e., daydreaming/lost in thought) ranged from 2.8% to 11.2%. These estimates rival those reported for cell phone use, which ranged from 2.1% to 8.8% (see Table 1 of Young & Salmon, 2012, for complete data). These findings suggest that, despite the ubiquity of cell phones and the extensive research focus on external driver distraction, internal distraction demands greater research attention.

Mind Wandering

Mind wandering is an integral part of human experience. It is also linked to individual differences in personality and cognitive capacities. While it is adaptive in many ways, it can also be considered a distraction from the present moment. The mind escapes the here and now by engaging in thoughts and feelings that are not directly related to sensory input from the immediate environment (i.e., self-generated thought; Smallwood & Schooler, 2015). The study of daydreaming and fantasy presaged modern interest in mind wandering. Singer and Antrobus (1963) conducted a factor analysis on their comprehensive imaginal processes inventory (Singer & Antrobus, 1966) that distinguished three main types of daydreaming (Giambra, 1980a, 1989): i) positive constructive daydreaming, characterized by purposeful thoughts and imaginings of wish fulfillment; ii) guilty-dysphoric daydreaming encompassing compulsive worrying and depressive rumination; and iii) poor attentional control, which describes a dissociation from both internal thoughts and the external environment. It was later found that these three daydreaming styles were linked to the Big Five personality dimensions of openness, neuroticism, and conscientiousness, respectively (Zhiyan & Singer, 1997). Singer and Antrobus (1963) also identified many adaptive functions of daydreaming in the context of planning, learning, and creativity (for a review please see McMillan, Kaufman, & Singer, 2013).

Contemporary investigations into mind wandering have focussed largely on how it enables mental time-travel, during which one reflects on past experiences and simulates future possibilities. These transient departures from the present moment leverage self-referential, autobiographical information to construct a coherent personal narrative that facilitates future-oriented thought (Smallwood et al., 2011). Autobiographical planning describes a process where individuals "plan and anticipate personally relevant future goals" (Baird, Smallwood, & Schooler, 2011, p. 1604). Autobiographical planning can also in turn, contribute to a sense of identity (D'Argembeau, Lardi, & Van der Linden, 2012). It is estimated that individuals on average spend nearly half of their waking lives engaged in mind wandering (Killingsworth & Gilbert, 2010), especially about the future (i.e., prospection) (Ruby, Smallwood, Sackur, & Singer, 2013; Song, Wang, & Krueger, 2012; Stawarczyk, Majerus, Maj, Van der Linden, & D'Argembeau, 2011). Prospection can be beneficial for decision making; engaging in mind wandering is associated with reduced delayed reward discounting, which manifests as a preference for instant gratification over the prospect of a larger future reward (Smallwood, Ruby, & Singer, 2013). Finally, mind wandering appears to be helpful in problem solving by facilitating creative incubation, where attention is diverted from a difficult task to allow for unconscious processing (Baird et al., 2012; Ritter & Dijksterhuis, 2014).

Mind wandering can also be disadvantageous in certain circumstances. Similar to external distraction, mind wandering has a detrimental impact on performance of various laboratory tasks, such as those designed to test attention, memory, and executive control (Smallwood & Schooler, 2006). Mind wandering can also impact daily life activities such as reading a book or writing an exam (McVay, Kane, & Kwapil, 2009; Mooneyham & Schooler, 2013). It is often unintentional, occurring spontaneously amidst other activities (e.g., zoning out while reading), which, like external distraction, is akin to engaging in a secondary task at the expense of attention to goal-relevant stimuli in the environment. As distinct from external distraction, mind wandering reflects an internally oriented process (i.e., internal distraction) that entails a diversion or decoupling of attention from the external environment. For example, self-generated thought is associated with a reduction in the automatic orienting of attention to external cues (Hu, He, & Xu, 2012). Neuroimaging evidence shows reduced cortical responses to sensory input during mind wandering (Kam et al., 2010; Smallwood, Beach, Schooler, & Handy, 2007) and robust associations between self-generated thought and brain regions that are most active at rest and least active during periods of focussed task engagement (Andrews-Hanna, Smallwood, & Spreng, 2014; Christoff, Gordon, Smallwood, Smith, & Schooler, 2009; Mason et al., 2007).

Relevant to the focus of this thesis, recent research has demonstrated the negative impact of mind wandering while driving. Individuals drive faster, are slower to respond to road hazards (Yanko & Spalek, 2013), and exhibit reduced visual scanning while engaged in mind wandering (He et al., 2011). Drivers who retrospectively reported having experienced mind wandering shortly before a crash were also more likely to have been responsible for it (Galéra et al., 2012). Furthermore, individual differences in the susceptibility to external distraction and mind wandering tendency are both correlated with certain aspects of executive control, such as working memory capacity. This finding suggests that external and internal distraction may arise through related mechanisms (Forster & Lavie, 2014; Unsworth & McMillan, 2014). Thus, a thorough examination of the cognitive processes governing attention and behaviour will be beneficial for understanding the occurrence and mechanisms underlying driver distraction and its associated crash risk (Trick, Enns, Mills, & Vavrik, 2004).

Executive Control

The cognitive mechanisms governing attention are relevant for understanding how and why drivers become distracted. Executive control is a collection of effortful mental processes that guide the spotlight of the mind (i.e., attention) in favour of goal-oriented responding to external and internal stimuli. Attention describes the allocation of finite information processing resources to effectively guide behaviour in a given situation. It involves the selection and modulation of information (i.e., stimuli) from both external and internal sources (e.g., sensory perception, thoughts, feelings, and actions). Selection determines what information gets processed, while modulation follows and encompasses the speed, accuracy and extent to which information gets processed (Chun, Golomb, & Turk-Browne, 2011). Selection and modulation can be exogenous, initiated by stimulus characteristics, such as the loudness of a noise, or they can be endogenous, initiated by current or previously held goals, such as reading this text. These processes often occur quickly and automatically, without explicit awareness or effort, but they can also be purposefully guided under conscious supervision (Awh, Belopolsky, & Theeuwes, 2012; Trick et al., 2004). Thus, executive control overrides automatic selection and modulation processes. Limitations of this system are thought to account for the occurrence of distraction and its negative impact on task performance. Executive control incorporates three main components, inhibition, working memory, and cognitive flexibility (Diamond, 2013), which are now considered in more detail.

Inhibition. The suppression of automatic stimulus selection and modulation, which is necessary for volitional control of attention and behaviour, is achieved through inhibition. Poor inhibition can lead to distraction by failing to prevent interference from non-relevant information. Selective attention encompasses the ways in which executive control orients attention in space, and filters information from the environment through the inhibition of non-relevant information (Gazzaley & Nobre, 2012). Selective attention is manifested in overt orienting behaviours like head and eye movements, but covert orienting also occurs automatically before executive control exerts its influence. For example, when participants gaze at the center of a screen where cues (i.e., fixation crosses) appear on one side or the other followed by a target, participants direct their gaze to the target faster when the preceding cue and subsequent target locations are congruent. Thus, performance on the task is influenced by the cue triggering covert orienting to select that area of the screen by neglecting or inhibiting the rest (Chica, Martín-Arévalo, Botta, & Lupiánez, 2014). While exogenously salient stimuli (e.g., a suddenly appearing cue) can capture attention despite the inhibitory influence of executive control, inhibition facilitates the endogenous disengagement and re-orientation of attention (Theeuwes, 2010).

Inhibition also enables the suppression of automatic cognitive processing tendencies. Selective attention inhibits the processing of non-relevant characteristics belonging to particular stimuli in the environment. For example, in the Color-Word Interference Test, participants are presented with colour words that are written in coloured ink. When stimulus characteristics are incongruent, inhibition suppresses the automatic tendency to read the text and thus increases the ability to correctly report the ink colour (Banich et al., 2000; Cohen, Dunbar, & McClelland, 1990; Milham, Banich, Claus, & Cohen, 2003). Performance on this task has often been used to measure executive control capacity (Hilbert, Nakagawa, Bindl, & Bühner, 2014). Inhibition also occurs when attention is directed inward to thoughts and feelings as opposed to external stimuli, which suggests a global suppression of environmental information processing (Handy & Kam, 2015). Thus, in situations where attention to information from the environment is important, inhibition is necessary to suppress unwanted or irrelevant thoughts and memories (Anderson & Levy, 2009).

Finally, inhibition exerts direct influence on behaviour. In addition to filtering environmental information, and suppressing irrelevant thoughts and memories, inhibition contributes to the selection of behavioural responses (Wager et al., 2005). Resisting temptations (Houben & Jansen, 2011), persisting at a difficult task (Munakata et al., 2011), delaying gratification (Metcalfe & Mischel, 1999), and regulating emotion to prevent an outburst (Carlson & Wang, 2007) are examples of circumstances where inhibition enhances self-control of behaviour to prevent impulsive mistakes. Taken together, this component of executive control is important for minimizing the intrusion of goal-irrelevant information and behaviours making it essential for preventing distraction.

Working memory. Information is temporarily stored and manipulated in working memory. It is also where goals, plans, and cognitive strategies (i.e., repeating a phone number to remember it) are represented, enacted, and maintained. This aspect of executive control, which is limited in capacity, supports three essential cognitive abilities: i) comprehension, or the creation of mental models by relating events and organizing pieces of information unfolding over time (Gathercole & Baddeley, 2014); ii) planning, or the synthesis and modification of action plans based on ideas, instructions, and information from the environment (Logie, 2014); and iii) reasoning, or the formation of abstract concepts from available information and making inferences based on those concepts (Feeney & Thompson, 2014). Distraction occurs when secondary task information gets activated and interferes with goal-relevant information in working memory. Inhibition plays a key role in permitting only the most relevant pieces of information, from either external or internal sources, into working memory (Kane & Engle, 2002). Thus, failures of cognitive inhibition can lead to interference that contributes to goal neglect, task performance errors, and/or behavioural regulation failures (McVay & Kane, 2009). Therefore, if inhibition fails to prevent goal-irrelevant information from interfering with goal maintenance in working memory, then distraction will compromise primary task performance.

Cognitive flexibility. This component constitutes the ability to quickly and effectively adapt behaviour to changing circumstances. It is important for switching between tasks and adopting new rules within tasks (Dajani & Uddin, 2015). Thus, cognitive flexibility may protect against the negative impact of distraction on task performance by minimizing switching costs (i.e., the time it takes to switch from one task to another). It also facilitates the consideration of multiple spatial or interpersonal perspectives in a given situation, and the ability to reframe a problem in order to generate new creative solutions.

This aspect of executive control is arguably the most sophisticated, as it builds upon both inhibition and working memory. For example, a previously held frame of reference must be inhibited to allow for the emergence of another in working memory (Diamond, 2013). Moreover, noticing and adjusting to important changes in the environment requires the ability to efficiently replace obsolete thought and action schemas. Cognitive flexibility facilitates overriding or modifying current, automatized cognitive processes and behavioural responses in order to dynamically initiate more suitable alternatives (Canas, Quesada, Antolí, & Fajardo, 2003). Thus, cognitive flexibility has important implications for the efficiency of attention, especially when environmental circumstances suddenly demand cognitive resources that are being recruited for task-unrelated processes (Handy & Kam, 2015). Overall, executive control has a major influence on attention via multiple cognitive processes. Accounting for the functioning of this system advances our understanding of driver distraction and the potential forms it can take.

Executive Control and Mind Wandering

The executive control system appears to both support and regulate mind wandering. Smallwood and Schooler (2006) first proposed that mind wandering recruits executive control resources, thus competing with other processes for space in working memory. Evidence suggests that as a task becomes more familiar and demands less executive resources (i.e., becomes automatized), mind wandering increases (Antrobus, 1968; Cunningham, Scerbo, & Freeman, 2000; Giambra, 1995; Smallwood et al., 2004; Smallwood, Obonsawin, & Heim, 2003). Moreover, performance decreases when mind wandering occurs during a task requiring a high level of executive control (Mrazek, Smallwood, Franklin, et al., 2012), but not when executive control is less necessary (Ruby et al., 2013; Teasdale et al., 1995). Thus, the context regulation hypothesis (Smallwood & Schooler, 2015) posits that mind wandering is adaptive only when deployed in situations that do not require high levels of sustained attention and thus, executive control resources.

Mind wandering may interfere with the adaptive recruitment of executive control in the context of driving. While many driving behaviours quickly become automatized during the first few months of practice, executive control is necessary in circumstances that demand sustained or focussed attention. For example, staying alert on a monotonous highway route or navigating a busy intersection, both require effortful executive recruitment. Inexperienced young drivers are more reliant on executive control in complex driving situations than experienced drivers (Paxion, Galy, & Berthelon, 2014), which may be problematic for those with a high tendency to mind wander. Furthermore, mind wandering is associated with spontaneous and involuntary behaviours, such as fidgeting (Carriere, Seli, & Smilek, 2013). This may indicate reduced behavioural inhibition by the executive control system, which is characteristic of impulsivity (Gay, Schmidt, & Van der Linden, 2011), and could contribute to speeding and other risky driving behaviours. Thus, diminished executive control resources from mind wandering while driving could plausibly impact traffic safety.

Executive control may make distinct contributions to the occurrence and process of mind wandering (Smallwood, 2013). Some authors have suggested that mind wandering represents a failure of executive control, especially when self-generated thought interferes with task performance (Kane & McVay, 2012; McVay et al., 2009). For example, when task demands are high, those low in working memory capacity report more mind wandering than those high in working memory capacity (Kane et al., 2007). When task demands are low, however, the inverse relationship is observed (Levinson, Smallwood, & Davidson, 2012), which suggests that executive control may be involved in adaptively regulating the occurrence of mind wandering (Rummel & Boywitt, 2014). At the same time, evidence suggests that executive control insulates self-generated thought processes from disruption by external perceptual interference. One study found that participants neglected both task-relevant and novel distractor stimuli while mind wandering during a task (Barron, Riby, Greer, & Smallwood, 2011). Taken together, these findings suggest that individual differences in executive control may predict both how well mind wandering is inhibited when inappropriate and how well it is sustained once initiated.

Current methodological limitations make it difficult to establish a causal link between mind wandering and executive control. Mind wandering is typically measured using experience sampling, where participants are periodically asked to report on the contents of their thoughts (Smallwood et al., 2004). Experience sampling does not reveal the precise moments at which a mind wandering episode begins and ends. Thus, it is unclear what events or processes trigger mind wandering (Smallwood, 2013). Furthermore, self-reporting mind wandering during a task, either spontaneously (i.e., self-caught) or when prompted (e.g., probe-caught), can disrupt the mind wandering process under observation. It has been suggested that explicit awareness of mental states (i.e., metacognitive awareness or meta-awareness) may be a mechanism by which executive control regulates self-generated thought processes (Schooler et al., 2011). Finally, while there are preliminary methods for manipulating mind wandering (Mrazek et al., 2011), the causal direction of its relationship to executive control has been difficult to establish experimentally. It is currently unclear whether individual differences in executive control explain the occurrence of mind wandering, or alternatively, whether individual differences in mind wandering tendency influence performance on measures of executive control (Smallwood & Schooler, 2015). Regardless, accounting for both mind wandering tendency and executive control capacity will likely better predict task performance.

Findings from a recent study using transcranial direct current stimulation support the involvement of executive control in negotiating between self-generated thought and task performance. The left dorsal lateral prefrontal cortex is known to play a central role in executive control processes, including working memory (Kane & Engle, 2002). Researchers observed an increase in self-reported mind wandering from stimulating the left dorsal lateral prefrontal cortex with transcranial direct current stimulation while participants performed an attention task. This increase in mind wandering had no impact on task performance, however. Accordingly, the authors posited that a temporary increase in working memory capacity from the stimulation allowed participants to engage in more self-generated thought without sacrificing performance (Axelrod, Rees, Lavidor, & Bar, 2015).

Given that transcranial direct current stimulation has poor spatial resolution, these findings do not clarify the role of executive control in regulating and/or supporting mind wandering. The stimulation may have activated anterior regions of the prefrontal cortex, which increased participants' meta-awareness of their mind wandering. Meta-awareness has been shown to reduce the negative impact of mind wandering on task performance (Schooler et al., 2011). It may have also activated parts of the default mode network, which is associated with self-generated thought processes (Broadway, Zedelius, Mooneyham, Mrazek, & Schooler, 2015; Christoff et al., 2009). Nevertheless, this study hints that executive control has a role in moderating the relationship between mind wandering and task performance. Whether greater executive control capacity helps or hinders driving performance as a function of individual differences in mind wandering tendency is unclear, however.

Trait Absentmindedness and Mind Wandering

Trait absentmindedness describes the stable tendency to make errors during daily activities as a result of mind wandering. Individuals who score high on measures of trait absentmindedness report frequently experiencing cognitive failures (i.e., common mistakes, errors, or faulty actions during routine activities) such as having to re-read a section in a book, putting things in unintended locations (e.g., the milk in the pantry), or failing to see an object that is in plain view (e.g., "It was right in front of my eyes this whole time!”). Reason (1977, 1979, 1984) conducted research on absentmindedness by asking participants to record their faulty actions in a journal as they went about their daily activities. These errors were then categorized as either planning miscalculations or mistakes that occurred during execution. The first denotes a misunderstanding or lack of knowledge about the situation or task, while the second represents a misapplication or neglect of the rules governing appropriate behaviour for that situation or task. The author (Reason, 1984) posited that faulty actions, belonging to the second category, result from lapses of attention in conjunction with automatization.

Studies using self-report measures support the notion that absentmindedness is a trait dimension that affects everyday functioning, including driving. Broadbent, Cooper, FitzGerald, and Parkes (1982) developed the Cognitive Failures Questionnaire (CFQ) to determine the frequency with which individuals experience cognitive failures. Individuals differ in the tendency to experience such errors, which remains fairly consistent over time (Vom Hofe, Mainemarre, & Vannier, 1998). Spousal ratings have corroborated self-reports of cognitive failures (Broadbent et al., 1982). High scores on the CFQ significantly predicted real-world outcomes including vehicle crashes, injuries and hospitalizations (Larson & Alderton, 1997; Larson & Merritt, 1991). Thus, individual differences in the tendency to experience cognitive failures are relevant to traffic safety.

Behavioural data also reveal a link between cognitive failures and trait mind wandering. The Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) measures fluctuations and lapses of attention. Essentially a go/no go paradigm, participants are instructed to press a button (e.g., the space bar on a keyboard) for each number from 1 to 9 that appears on a screen, except for the number 3, which is presented 11% of the time. Short response times preceding an error of commission (i.e., incorrectly pressing the spacebar in response to the number 3), which is considered a response inhibition failure, are posited to reflect a transition to automatic responding. An inappropriate behavioural response gets triggered when attention drifts away from the task. SART performance has not only predicted self-reported cognitive failures, specifically those most related to attention, but has also been linked to trait mind wandering (Manly, Robertson, Galloway, & Hawkins, 1999; Smilek, Carriere, & Cheyne, 2010a).

Errors on the SART are associated with episodes of mind wandering measured using experience sampling. Notably, only self-generated thoughts that go unnoticed (i.e., lacking meta-awareness) until participants are prompted to reflect by an experience sampling probe, have predicted response inhibition failures on the SART (Smallwood, McSpadden, & Schooler, 2007). Using experience sampling on mobile devices, researchers have established links between mind wandering in the lab and its impact on daily life task performance (McVay et al., 2009; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012). Overall, trait absentmindedness appears to reflect one's tendency to make errors due to mind wandering, which could be relevant to driving behaviour.

Driver Visual Attention and Mind Wandering

Many common driving situations require the coordination of multiple pieces of visual information. When approaching a yellow light, for example, observation of the precise moment the light changes, distance from the intersection, and speed of approach, is crucial for accurate risk appraisal (Konecni, Ebbeson, & Konecni, 1976). Active visual attention is also necessary for responsive and safe driving, especially in the face of unexpected events (Marple-Horvat et al., 2005; Strayer et al., 2003; Wilson, Chattington, & Marple-Horvat, 2008). Reduced visual attention due to excessive mind wandering may impede perceptual processing and hazard detection, thus contributing to risky driving behaviour. Nevertheless, no study to date has linked trait absentmindedness with deficits in driver visual attention. Moreover, it is unclear as to whether reduced visual attention associated with trait absentmindedness contributes to risky driving behaviour.

Mind wandering appears to disrupt perceptual processing. Performance deficits associated with mind wandering have largely been attributed to perceptual decoupling (Smallwood, 2013), a process by which attention gets redirected from external perception towards self-generated (i.e., stimulus-independent) thought. This may have serious implications for driving performance. The “looked but failed to see” phenomenon for example, describes when drivers directed their gaze to the appropriate location in the environment, but did not properly process or respond to the visual information (I. D. Brown & Great Britain, 2005; Hills, 1980; Kass, Cole, & Stanny, 2007; Koustanaï, Boloix, Van Elslande, & Bastien, 2008). This phenomenon can result in delayed hazard detection (Rumar, 2011) and may be a consequence of perceptual decoupling due to mind wandering (Rensink, O'Regan, & Clark, 1997).

The impact of mind wandering on perception is also apparent in eye movements. Detailed perceptual processing only occurs for visual information received via the fovea of the eye (i.e., a small cluster of colour-sensitive cells near the center of the retina). Thus, shifting gaze is necessary to inspect multiple aspects of a scene. Furthermore, changes in pupil size and blinking behaviour have been linked to shifts in mental state. Consequently, eye movements can be used to quantify visual attention (Holmqvist, Nyström, & Mulvey, 2012). In one study, participants showed eye movements indicative of reduced visual attention when exposed to verbal and spatial imagery tasks meant to induce cognitive distraction during a driving task (Recarte & Nunes, 2000). These findings agree with those reported by He et al. (2011) indicating that visual attention behaviour decreases during mind wandering episodes. Mind wandering has also been shown to temporarily increase eye-blink frequency (Smilek, Carriere, & Cheyne, 2010b), which could lead to a failure in detecting changes in the visual field (O'Regan, Deubel, Clark, & Rensink, 2000). Given that visual perception is essential for driving and that mind wandering has a negative impact on visual attention, the influence of trait absentmindedness on driving behaviour may be mediated by visual attention.

Summary

Young drivers are overrepresented among those involved in road traffic crashes. Young males are especially prone to engage in risky driving behaviours that endanger themselves and others on the road. Driver distraction, due to cell phone use for example, is another known contributor to crash risk. Recent research indicates that states of internal distraction due to mind wandering also increase risky driving and impair performance, possibly through interactions with visual attention and executive control capacity. Some individuals are more prone to mind wandering and related errors, suggesting that trait absentmindedness may represent a distinct and stable individual risk factor. Whether trait absentmindedness predicts risky driving behaviours comparable to those observed during mind wandering states has not been investigated, however. Studying the relationships between trait absentmindedness, executive control capacity, driver visual attention, and risky driving behaviour may help identify novel approaches to preventing young driver crashes. More pragmatically, a better understanding of how trait absentmindedness relates to risky driving behaviour may help to: i) identify a subset of young drivers who are prone to risky driving due to this stable characteristic; and ii) design personalized interventions that could disrupt the impact of trait absentmindedness on driving behaviour and mitigate this vulnerable population's heightened crash risk.

Aims and Hypotheses

The present study examined relationships between trait absentmindedness, executive control capacity, driver visual attention, and risky driving behaviour in young male drivers. Figure 1 depicts a model of how these factors were posited to interact to increase risky driving behaviour. To test this model, we hypothesized that: H1) higher trait absentmindedness is associated with increased risky driving behaviour; H2) higher trait absentmindedness is associated with reduced driver visual attention; H3) driver visual attention mediates the relationship between trait absentmindedness and risky driving behaviour; and H4) executive control capacity moderates the association between trait absentmindedness and risky driving.

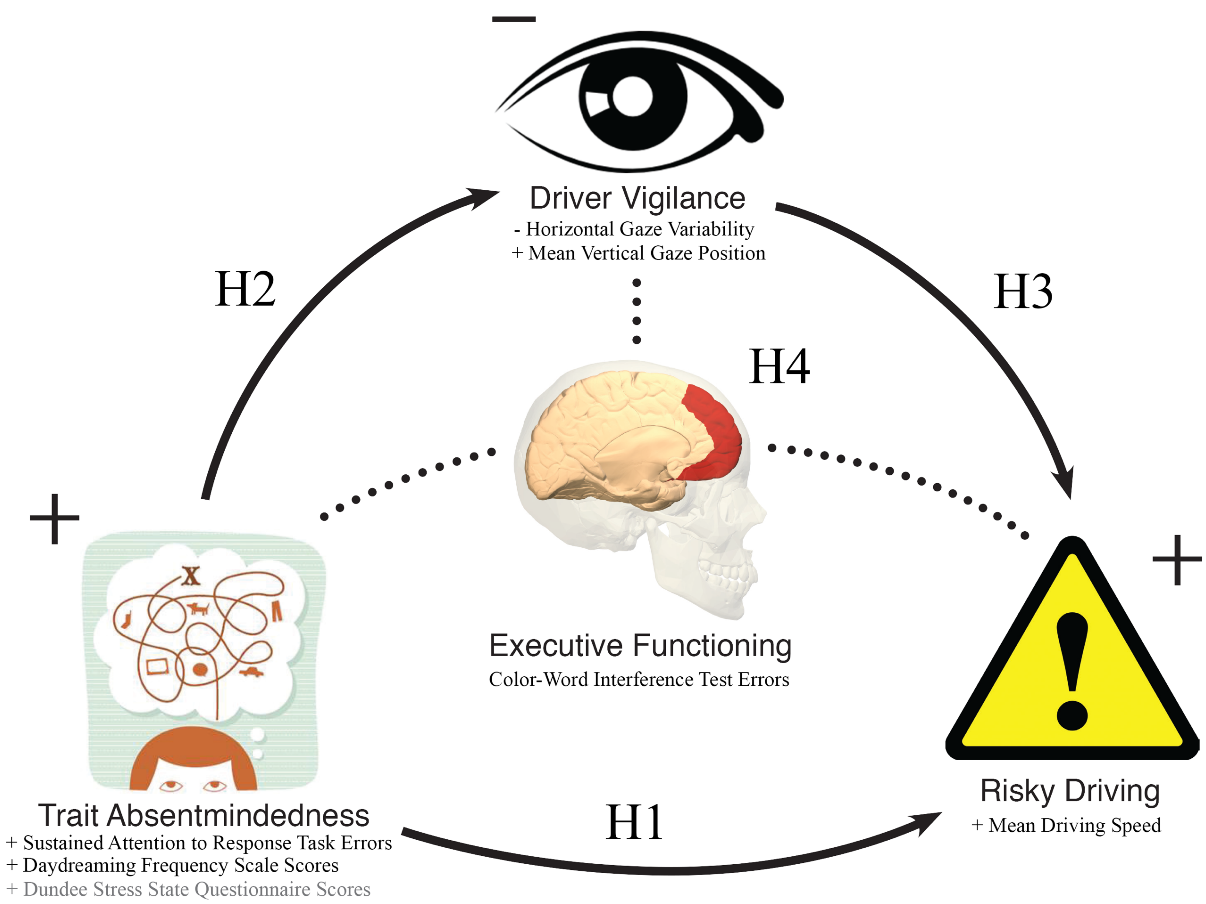

Figure 1. The proposed model linking trait absentmindedness to risky driving behaviour with driver visual attention mediating and executive control moderating the relationship. Also included are the measures used to quantify each construct along with their hypothesized directions.

Methods

The present study is a secondary analysis of data from a *ministère des Transports du Québec*-funded project entitled, *Compréhension du rôle de l'environnement routier et bâti dans les accidents impliquant les jeunes conducteurs* (Ouimet et al., 2015), investigating the effects of environmental risk factors on young drivers. The *Centre hospitalier universitaire de Sherbrooke* Research Ethics Board approved Dr. Ouimet's study (CHUS #12-140-M2) with the inclusion of measures specific to the present study's hypotheses. All of the participants gave informed consent for the study. They also gave consent to have their data linked from Dr. Ouimet's previous studies, of which they were a part, to the present study. Data collection took place at Dr. Ouimet's simulation laboratory at the *Université de Sherbrooke* campus in Longueil, Quebec. Permission to use an anonymized subset of this study's data to test the above hypotheses was obtained from Dr. Ouimet as well as the McGill University Faculty of Medicine Institutional Review Board (IRB #A03-E20-16B).

Participants

Initial recruitment. Men and women aged 18-24 years ($N = 400$) participated two previous studies. Candidates were notified about these studies through kiosks and advertising at various colleges and universities in the greater Montreal area, as well as through other media such as Facebook and local newspapers (e.g., Metro, 24h). These recruitment efforts were conducted entirely in French.

Recruitment for the present study. Participants of these studies who agreed to be contacted about future opportunities to participate in research (93.7% agreed) were eligible to be contacted for the present study. Candidates were contacted by phone and, if deemed eligible for the present study, scheduled for a testing session. Testing, including measures related to the present study and a larger study conducted by Dr. Ouimet, took approximately four hours. Participants were given $75 as compensation for their participation.

Initial inclusion/exclusion criteria. The inclusion criteria for the original studies were as follows: being 18-24 years old, possessing a probationary or regular license allowing unsupervised driving, having driven regularly in the past three months, and having previously had at least two alcoholic drinks in one sitting. In Quebec, drivers must hold a probationary licence for 24 months prior to receiving a regular licence. While permitting independent driving, the probationary licence prohibits drivers from receiving more than four demerit points or driving after consuming any alcohol (i.e., compared to 15 demerit points and < 0.08 mg/100 ml blood alcohol content with a regular licence for drivers older than 21 years of age) (Ouimet, 2012). Because these studies involved the consumption of alcohol, exclusion criteria included: problematic alcohol consumption (detected with select questions from the Alcohol Use Disorders Identification Test), pregnancy, breastfeeding, physical and/or mental health problems, and the use of medications that could interact or interfere with alcohol consumption (e.g., liver disease, ongoing depression, or other psychiatric disorders). Additionally, participants were prohibited from using drugs or alcohol 48 hours prior to testing. On the day of testing, they were screened for recent drug use and alcohol consumption with the DrugWipe® 6 S and the Alco-Sensor® IV, respectively. If they tested positive for drugs or alcohol, study candidates had their testing session rescheduled to a different day. Participants who suffered from simulation sickness during a practice driving simulation session were also excluded.

Inclusion/exclusion criteria for the present study. The inclusion criteria for the present study were as follows: having previously agreed to be contacted about future studies, being a male between the ages of 18-21 years, possessing a probationary or regular license allowing unsupervised driving, and regular driving over the past three months (i.e., no less than once per week). Participants were excluded from the study if they showed overt signs of intoxication from drugs or alcohol at the time of testing, or signs of simulation sickness.

Measures

Predictor variables (PV)

Sustained Attention to Response Task. The Sustained Attention to Response Task (SART) was originally designed by Robertson et al. (1997) to measure action slips caused by lapses in sustained attention. The computerized behavioural task used in the present study was adapted from the original task by Millisecond Software for their Inquisit© platform (Draine, 2009). The task computer was a Dell Optiplex 990, with an Intel i7 processor (3.40 gigahertz), 4 gigabytes of RAM, and an integrated Intel HD Graphics 2000 chipset. The task was presented on a 24-inch monitor with a resolution of 1920 x 1080 pixels. Stimuli, which constituted numbers ranging from 1 to 9, were presented for 250 ms with an inter-stimulus mask displayed for 900 ms.

Quantity of commission errors (i.e., when participants press the keyboard spacebar erroneously in response to the number 3) was used in the present study to measure trait absentmindedness. The total number of commission errors for each participant could range from 0 to 25. Errors of commission have been correlated with self-reported mind wandering and are commonly used as a behavioural index of this subjective construct (Helton, Kern, & Walker, 2009; McVay & Kane, 2009; McVay, Meier, Touron, & Kane, 2013; Smallwood et al., 2004; Smallwood, McSpadden, et al., 2007). Performance on the SART is relatively stable with a test-retest reliability of $r = .76$ over an interval of one week (Robertson et al., 1997). In order to prevent external distraction from confounding task performance, participants completed the SART in a controlled environment (i.e., a quiet, windowless room).

Day Dreaming Frequency Scale. A French adaptation of the Day Dreaming Frequency Scale (DDFS; Giambra, 1993; Stawarczyk, Majerus, Van der Linden, & D'Argembeau, 2012) was used to measure the frequency with which individuals experience mind wandering on a daily basis. This scale originated as a component of the Imaginal Processes Inventory, developed by Singer and Antrobus (1963, 1970, 1972). In the present study, it served as a subjective counterpart to the behavioural index provided by the SART. The instrument contains 12 questions that ask participants to rate themselves on statements such as, "I daydream at work or in class" with responses on a 5-point Likert scale ranging from 1 "Not often" to 5 "Many times per day." It also includes statements such as, "Instead of paying attention to people and events around me, I pass __% of my time lost in thought" with the five possible responses ranging from "0%" to "At least 50%". We calculated a mean Likert score, with higher scores indicating a greater propensity for mind wandering.

The DDFS has been validated with other measures of mind wandering including subjective reports of self-generated thought indexed using experience sampling during the SART (Stawarczyk et al., 2012). The original English version of this questionnaire has been shown to have a single-factor structure with loadings of 0.50 or greater (Giambra, 1980a), an estimated internal consistency of .91 (Cronbach's alpha), and a test-retest reliability of $r = .76$ over an interval of up to a one year (Giambra, 1993). Stawarczyk et al. (2012) used principle component analysis to verify the single-factor structure of their French version that was used in the present study, which also achieved a Cronbach's alpha of .91, indicating very good internal consistency.

Dundee Stress State Questionnaire. The Thinking Content scale of the Dundee Stress State Questionnaire (DSSQ; Matthews, Desmond, Joyner, Carcary, & Gilliland, 1996) was adapted for the present study and used as a retrospective self-report measure of mind wandering experienced during the driving simulation. The scale asks participants to rate themselves on 16 statements such as, "I thought about personal worries" or, "I thought about something that happened earlier today." Participants rated themselves on a Likert scale that ranged from 1 “never” to 5 “very often.” A mean Likert score represented each participant’s responses with higher scores indicating more mind wandering.

The DSSQ Thinking Content scale has been used in many mind wandering studies where it was desirable to avoid disrupting the participant with thought probes while performing a task (Barron et al., 2011; Finnigan, Schulze, & Smallwood, 2007; Smallwood et al., 2004; Smallwood, O'Connor, & Heim, 2005). The original English version of the scale has two factors, task-related cognitive interference (CI-TR) and task-irrelevant cognitive interference (CI-TI). Both sub-scales have shown good internal consistency indicated by Cronbach’s alphas of .77 and .85, respectively. Across-task (i.e., pre-task vs. post-task) test-retest reliability was $r = .57$ for CI-TR and $r = .37$ for CI-TI, as well as $r = .37$ for CI-TR and $r = .49$ for CI-TI over an interval of three weeks (i.e., pre-task vs. pre-task) (Matthews et al., 1999). Stawarczyk et al. (2012) did not replicate these psychometric properties with their back-translated French version, however. The French DSSQ was included in the present study as a supplementary measure of state mind wandering, while the SART and DDFS operationalized trait absentmindedness.

Criterion variables (CV)

Driving Simulation. The custom-built driving simulator that was used for this study (see Figure 2) was developed and is located at the *Université de Sherbrooke* in Longueuil, Quebec. It is designed to deliver an immersive and naturalistic driving experience. It consists of a full Smart® car, a 150° front visual field produced by three digital projectors, and 5.1 surround sound with a speaker located under the front hood and a subwoofer located under the driver's seat to simulate the sounds and vibrations from an engine. The instrument panel also houses a working speedometer that displays driving speeds in the virtual environment. The simulation computer has an Intel i7 processor (2.80 gigahertz), 12 gigabytes of RAM, and an ATI Radeon 5800 graphics card with one gigabyte of dedicated DDR5 memory. It receives signals from the steering wheel in addition to the gas and brake pedals at a rate of 60 Hz. The simulation chamber is soundproofed and lighting is kept dim so as not to interfere with the projected image or the integrated eye-tracking system.

Studies comparing driving performance in a simulator to self-report data and on-road testing have demonstrated the validity of driving simulator performance estimates (Reimer, D'Ambrosio, Coughlin, Kafrissen, & Biederman, 2006; Wang et al., 2010). While not necessarily reflective of absolute performance values (i.e., absolute validity), driving simulation has been found to validly predict on-the-road differences among individuals for several behavioural metrics (i.e., relative validity), including driving speed (Mullen, Charlton, Devlin, & Bedard, 2011)

The driving task took approximately one hour and 10 minutes to complete. It consisted of two, fixed-distance simulations (i.e., approximately 30 minutes each) with a 10-minute break in between. Participants drove both rural and urban scenarios (see Figure 3) including both highways and city streets with opportunities to pass other vehicles as well as intersections with and without controls (i.e., traffic lights, stop signs, or yield signs). Neither of the two simulations contained traffic events that required sudden maneuvers or hard braking. They were identical except for five empirically selected route modifications, including lane width (four versus five lanes), intersection type (Y versus T), sight-line around a curve (obstruction versus no obstruction), urban density (immediately apparent versus delayed), and urban demarcation (entrance sign versus no entrance sign). During the ten-minute break, participants were permitted to use the washroom and walk in the hallway while accompanied by an experimenter.

Speed (km/h) in the driving simulator served as a measure of risky driving behaviour. It was calculated in real-time at a rate of 60 Hz, using scaled virtual models of the vehicle and simulated environment. Mean driving speed across the full one-hour drive was calculated for each participant. Mean driving speed on the road has been shown to reliably predict crash risk, with a mean speed increase of 1 km/h corresponding to a 3% increase in the likelihood of a road traffic crash (Aarts & van Schagen, 2006). Speeding is also consistently associated with other risky driving behaviours, particularly for young male drivers (Jonah, 1997; Lastovicka, Murry, Joachimsthaler, Bhalla, & Scheurich, 1987; Simons-Morton et al., 2011; Williams, 2003).

Mediator variable

Eye-Tracking. Visual attention was quantified during the driving simulation using FaceLab 5® eye-tracking technology (see Figure 4). The eye-tracker uses two cameras to record head and eye movements at a rate of 60 Hz, which allows for unconstrained head movement while driving. The eye-tracking system relies on a feature-based dark pupil tracking method with a reported accuracy error of 0.50° to 1.00°.

Horizontal gaze variability (i.e., the standard deviation of horizontal eye movements in degrees of visual angle) was used to quantify driver visual attention. Gaze variability (commonly horizontal) has been used in a number of driving studies to assess drivers' visual attention to road conditions and events (Ouimet et al., 2013; Recarte & Nunes, 2000, 2003; Reimer, 2009).

Previous research on mind wandering while driving has demonstrated a relationship between reduced horizontal scanning (i.e., gaze variability) and the mind wandering state (He et al., 2011). Additionally, in exploratory analysis, we examined mean vertical gaze position (i.e., the mean gaze location along the y-axis in degrees), which is an eye-tracking variable associated with driving performance monitoring. Specifically, it could indirectly signify how often drivers look down at the speedometer, which was found to decrease while performing a cognitive distractor task (Recarte & Nunes, 2000).

Moderator variable

Color-Word Interference Test. The Color-Word Interference test (CWIT; Stroop, 1935) in which participants are presented with colour words printed in a variety of ink colours, was developed to study the effects of interference between competing cognitive processes. Shorter response times in the word-reading condition compared to the colour-naming condition are thought to reflect executive inhibition of an automatic tendency to read the text (Banich et al., 2000; Cohen et al., 1990; Milham et al., 2003). The present study includes data that were collected using a relatively recent adaptation of this task (Delis, Kaplan, & Kramer, 2001a) that comprises four sections: color naming, in which participants name the colour of a printed square; word reading, in which participants read colour words printed in black ink; inhibition, in which participants name the ink colour of incongruent colour words; and inhibition/switch, in which participants either name the ink colour or read the incongruent colour word depending on whether or not a black box is present.

Total errors (i.e., self-corrected and uncorrected), which could range from 0 to 100, made during the inhibition and inhibition/switch conditions, were combined to indicate executive control capacity. Performance on the CWIT has been linked to stable individual differences in selective attention (MacLeod, 1991), goal maintenance, and working memory capacity (Kane & Engle, 2003), which are important aspects of executive control. Internal consistency for this version of the task is moderate to high as indicated by Cronbach's alphas ranging from .62 to .86. Similarly, test-retest reliability, ranging from $r = .49$ to $r = .90$ over a mean interval of 25 days, is also moderate to high (Delis, Kaplan, & Kramer, 2001b). The task was performed with an experimenter using hard-copy materials. Verbal responses were tape-recorded and performance was manually coded by two coders. A third coder resolved any disagreements.

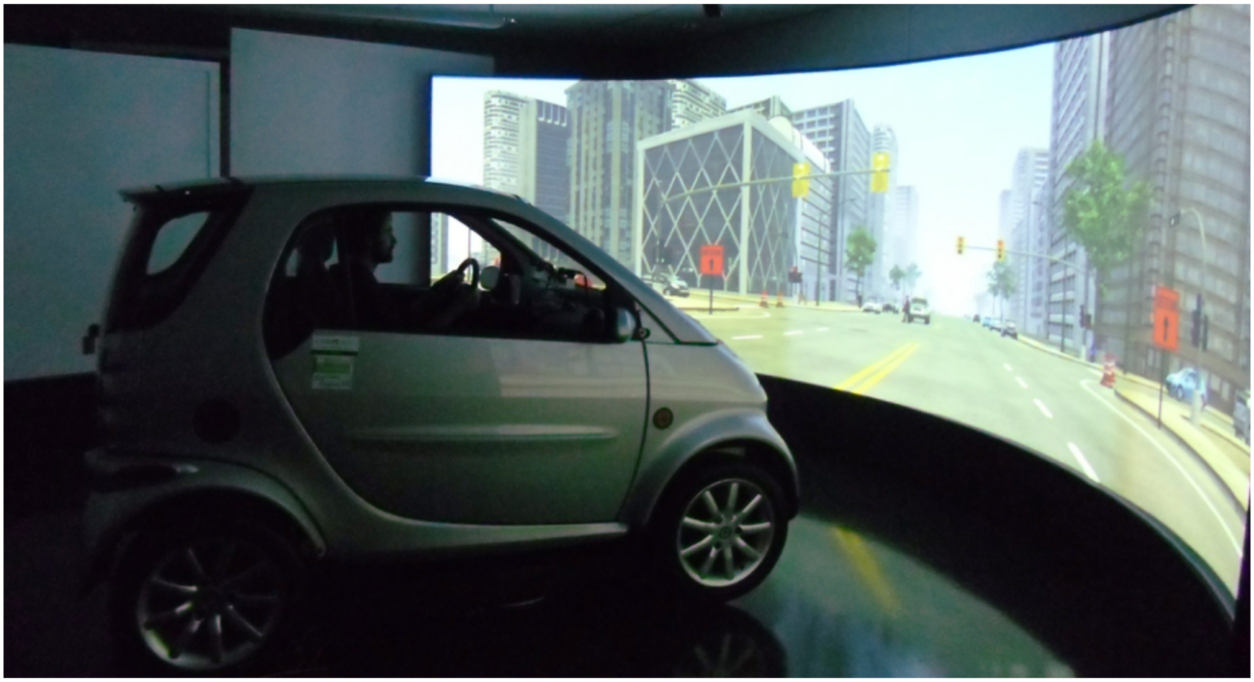

Figure 2. The high-fidelity driving simulator located at the *Université de Sherbrooke*. The system encompasses a SMART car, a 150° projected front visual field, and 5.1 surround sound.

Figure 3. Three snapshots from the driving simulation depicting both rural and urban scenarios. The black and white circles indicate where the participant was looking at the moment these images, extracted from our existing database, were recorded.

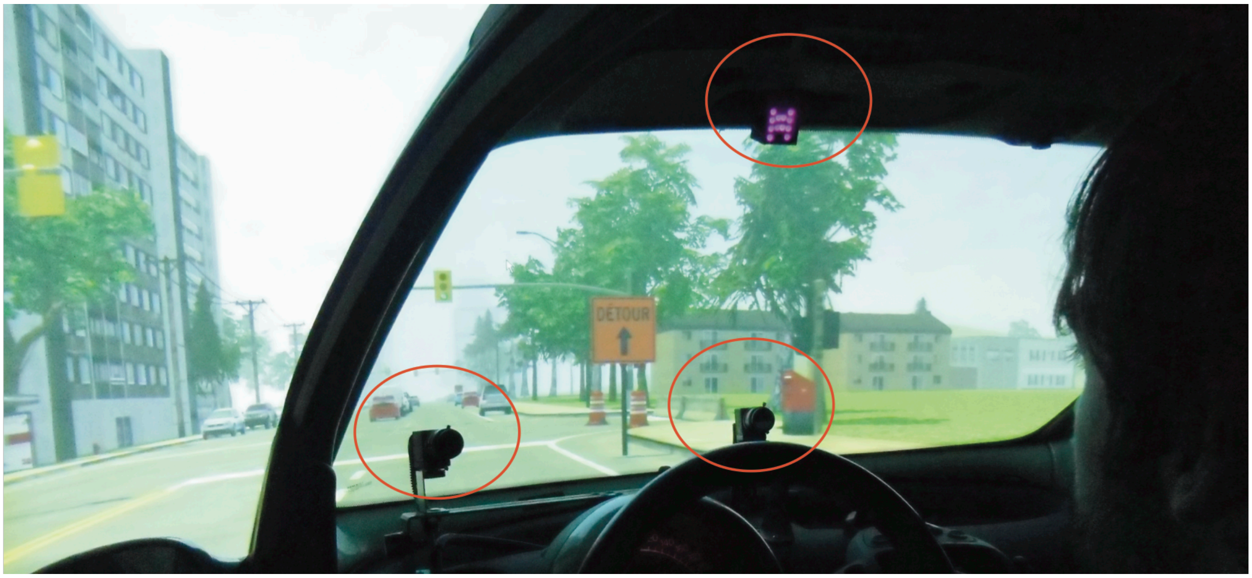

Figure 4. The FaceLab5® eye-tracking system built-in to the driving simulator. It measures head and eye movements. There is an infrared emitter (indicated by the top red circle), and two cameras (bottom left and right red circles).

Procedures

Participants' appointments were scheduled for 9:00 am or 1:00 pm at the *Université de Sherbrooke* campus in Longueil. Upon arrival, participants presented the experimenter with their license to confirm their age and license type. After having read and signed the *Centre hospitalier universitaire de Sherbrooke*-approved Informed Consent Form, they performed a 10-minute practice-run in the simulator. This was preceded by an eye-tracking calibration procedure in the simulation room, which involves looking at the center of targets displayed on the simulator's projection screen. Then participants completed the SART, which took approximately 4 minutes. Afterwards, participants proceeded to drive the first simulation. Following a 10-minute break, participants drove the second simulation. Immediately after, participants filled out the DSSQ as well as the DDFS. Participants were then presented with a series of videos depicting corresponding sections of the two simulation sessions. They were asked questions for each video regarding how hazardous they perceived these aspects of the simulation to be, how much they were mind wandering during each segment, and to what extent they were distracted by their thoughts (not presented here). Finally, participants completed the demographics questionnaire. CWIT data was collected as part of the original two studies in which participants had taken part.

Analysis

All analyses were conducted using IBM SPSS Statistics software (SPSS; version 22). Separate regression models were constructed to test H1 and H2. This method was chosen to separately evaluate the behavioural (i.e., SART commission errors) and subjective (i.e., DDFS scores) aspects of trait absentmindedness for predicting risky driving and driver visual attention, while also assessing the predictive value of each model as a whole. The PROCESS macro (version 2.15) for SPSS was used to conduct a mediation analysis to test H3 and a moderation analysis to test H4 (Hayes, 2013).

H1. A standard multiple regression, using the "to enter" method, was performed between risky driving behaviour (CV; i.e., mean speed) and all three of the mind wandering predictor variables (PV; i.e., SART commission errors, DDFS scores, and DSSQ scores).

H2. A standard multiple regression, using the "to enter" method, was performed between driver visual attention (CV; i.e., horizontal gaze variability) and all three of the mind wandering predictor variables (PV; i.e., SART commission errors, DDFS scores, and DSSQ scores). In exploratory analysis, a standard multiple regression was also performed between mean vertical gaze position (CV) and all three of the mind wandering predictor variables.

H3. A simple mediation analysis was conducted using ordinary least squares (OLS) path analysis to estimate driver visual attention (Mediator) from trait absentmindedness (PV; i.e., SART commission errors) as well as risky driving behaviour (CV; i.e., mean speed) from both driver visual attention (Mediator; i.e., mean vertical gaze position) and trait absentmindedness.

H4. A simple moderation analysis was conducted using hierarchical multiple regression to estimate risky driving behaviour (CV; i.e., mean speed) from trait absentmindedness (PV; i.e., SART commission errors) as well as from executive control capacity (Moderator; i.e., CWIT errors) and its interaction with trait absentmindedness.

Treatment of missing data and outliers. Due to technical error, eye-tracking data was lost for three participants, reducing the sample size of our analyses involving measures of driver visual attention to n = 27. Given the highly complex and fragile nature of head and eye-tracking technology, it is not uncommon to encounter some accidental data loss. Additionally, one outlying (i.e., > +/- 3.29 standard deviations) mean speed score and an outlying CWIT score were adjusted to the next most extreme (i.e., < +/- 3.29 standard deviations) values plus one unit (i.e., 1.00) (Tabachnick & Fidell, 2013).

Results

Sample

Out of the sample of 400 participants in the two initial studies, 110 were eligible candidates. Of these, 47 were successfully contacted for the present study. Of those, 35 agreed to participate, but five of whom could not find a suitable time in their schedule. The study includes data from 30 males aged 18-21 (N = 30, mean age = 19.93, SD = 0.91). Information about the study sample (e.g., ethnicity, education, annual income, traffic violations) can be found in Table 1. Descriptive statistics for our predictor, criterion, mediating, and moderating variables are summarized in Table 2.

Table 1

Demographic and Driving Behaviour Characteristics of the Young Male Driver Sample

Variable	*n*	*M or (%)*	*SD*
Age		19.9	0.91
Ethnicity			
White	24	(80.0)	
Arabic	3	(3.30)	
Other	3	(16.60)	
Language Preference[a]			
French	23	(76.7)	
English	3	(10.0)	
Other	4	(13.3)	
Civil Status			
Single-Never Married	26	(88.7)	
Common-law	4	(13.3)	
Completed Education			
Partial College	15	(50.0)	
Technical College	3	(10.0)	
General College	3	(10.0)	
Partial University	8	(26.7)	
Bachelor, Master, Ph.D.	1	(3.30)	
Employment			
Full-Time Studies + Part-Time Work	16	(53.3)	
Full-Time Studies + Seasonal Work	8	(26.7)	
Full-Time Studies	4	(13.3)	
Full-Time Work (min 35 hours/week)	2	(6.70)	

Table 1

Demographic and Driving Behaviour Characteristics of the Young Male Driver Sample

(Continued)

Personal Annual Income			
$0 - $999	1	(3.30)	
$1,000 - $5,999	5	(16.7)	
$6,000 - $11,999	15	(50.0)	
$12,000 – $19,999	6	(20.0)	
$20,000 - $29,999	3	(10.0)	
Licence Type			
Regular	24	(80.0)	
Probationary	6	(20.0)	
Number of Years Since Provisional Licence		2.53	1.23
Kilometers Driven / Week (Past 12 Months)		199.2	188.1
Traffic Violations[b]		1.03 (53.3)	1.43
Excess Speed	12	1.67 (40.0)	0.98
Failing to Stop (Stop Sign)	4	1.75 (13.3)	0.96
Failing to Stop (Red Light)	1	1.00 (3.33)	
Cell Phone Use	1	1.00 (3.33)	
Other	2	1.00 (6.67)	0.00
None	14	(46.7)	

Notes. $N = 30$. [a]All participants were fluent in French. [b]The total number of traffic violations per participant ranged from 0 to 5. The traffic violation means indicate the average number per participant in that category. The percentages indicate the proportion of participants out of the total sample who had at least one violation in that category. One participant had their license temporarily suspended for driving while impaired by alcohol.

Table 2

Sample Data Means and Standard Deviations for Each Predictor and Criterion Variable

Variable	*n*	*M*	*SD*
SART Commission Errors	30	11.7	6.23
Daydreaming Frequency Scale	30	3.46	0.69
Dundee Stress State Questionnaire	30	2.11	0.44
Color-Word Interference Test Errors	30	5.00	3.21
Mean Driving Speed (km/h)	30	59.6	5.65
Horizontal Gaze Variability (°)	27	0.17	0.03
Mean Vertical Gaze Position (°)	27	-0.11	0.05

Notes. $N = 30$. SART = Sustained Attention to Response Task. SART Commission Errors can range in number from 0 to 25. Mean scores on the Daydreaming Frequency Scale and the Dundee Stress State Questionnaire can range from 0.00 to 5.00. Errors on the Color-Word Interference Test can range in number from 0 to 100. Due to some missing eye-tracking data, the sample size was smaller ($n = 27$) for analyses involving driver visual attention variables.

H1: Trait Absentmindedness Predicts Risky Driving Behaviour

Results of the multiple regression analysis predicting mean driving speed are summarized in Table 3. The model was significant, predicting 46% of the variance in mean speed from SART commission errors, DDFS scores, and DSSQ scores, $F(3, 26) = 7.29$, $p < .01$, $R^2 = .46$. The regression coefficients for SART errors and DDFS scores differed significantly from zero. The contribution of DDFS scores went in the opposite direction to that hypothesized, however. Furthermore, the regression coefficient for DSSQ scores was not significant. Figure 4 illustrates the linear relationship between SART errors and mean driving speed.

Table 3

Summary of Multiple Regression Analysis for Trait Absentmindedness Predicting Mean Driving Speed

Variable	*B*	*95% CI*	*β*	*t*	*p*
(intercept)	62.5	[50.9, 74.1]			
SART Commission Errors	0.44	[0.17, 0.72]	0.49	3.29	.00
DDFS Mean Scores	-3.34	[-6.01, -0.67]	-0.41	-2.57	.02
DSSQ Mean Scores	1.65	[-2.46, 5.77]	0.13	0.83	.42

Notes. $N = 30$. *CI* = confidence interval, DDFS = Daydreaming Frequency Scale, DSSQ = Dundee Stress State Questionnaire, SART = Sustained Attention to Response Task. Mean driving speed was measured in kilometers per hour.

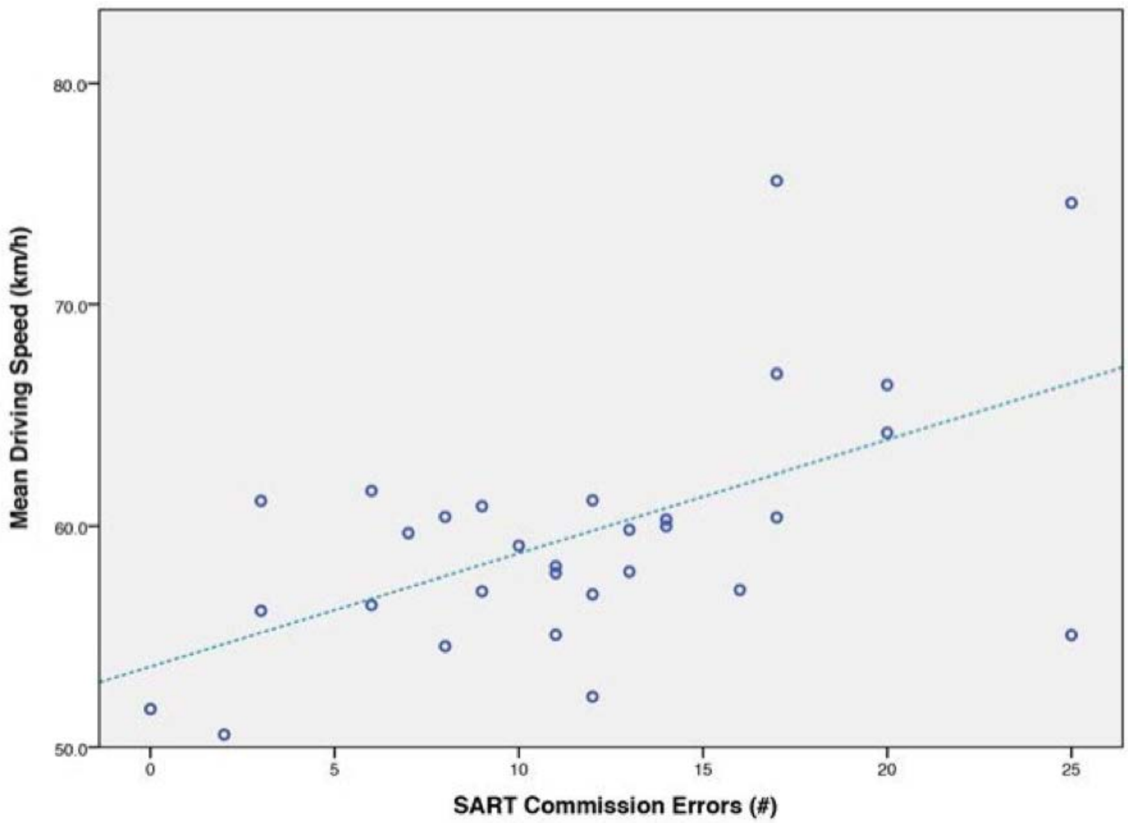

Figure 5. SART = Sustained Attention to Response Task. Linear relationship between SART errors and mean driving speed. SART commission errors predicted 32% (r = .57) of the variance in mean driving speed.

H2: Trait Absentmindedness Predicts Driver Visual Attention

Results of the multiple regression analysis predicting horizontal gaze variability are summarized in Table 4. The variance explained by the model did not differ significantly from zero, $F(3, 23) = 1.97$, $p = .15$, $R^2 = .20$. The three regression coefficients, representing the contributions of SART errors, DDFS scores, and DSSQ scores, were not significant.

Results of the exploratory multiple regression analysis predicting mean vertical gaze position are summarized in Table 5. The model was significant, explaining 45% of the variance in mean vertical gaze position from SART errors, DDFS scores, and DSSQ scores, $F(3, 23) = 6.35$, $p < .01$, $R^2 = .45$. Out of the three predictor variables, only the regression coefficient for SART errors differed significantly from zero.

Table 4

Summary of Multiple Regression Analysis for Trait Absentmindedness Predicting Horizontal Gaze Variability

Variable	*B*	*95% CI*	*β*	*t*	*p*
(intercept)	0.10	[0.03, 0.16]			
SART Commission Errors	0.00	[0.00, 0.00]	0.38	1.95	.06
DDFS Mean Scores	0.00	[-0.01, 0.02]	0.05	0.25	.81
DSSQ Mean Scores	0.02	[-0.01, 0.05]	0.36	1.71	.10

Notes. $N = 27$. *CI* = confidence interval, DDFS = Daydreaming Frequency Scale, DSSQ = Dundee Stress State Questionnaire, SART = Sustained Attention to Response Task. Horizontal gaze variability was measured in degrees of visual angle.

Table 5

Summary of Multiple Regression Analysis for Trait Absentmindedness Predicting Mean Vertical Gaze Position

Variable	*B*	*95% CI*	*β*	*t*	*p*
(intercept)	-0.22	[-0.34, -0.10]			
SART Commission Errors	0.01	[0.00, 0.01]	0.70	4.34	< .01
DDFS Mean Scores	0.00	[-0.03, 0.03]	0.02	0.12	.90
DSSQ Mean Scores	0.02	[-0.03, 0.06]	0.13	1.72	.48

Notes. *N* = 27. *CI* = confidence interval, DDFS = Daydreaming Frequency Scale, DSSQ = Dundee Stress State Questionnaire, SART = Sustained Attention to Response Task. Mean vertical gaze position was measured in degrees of visual angle.

H3: Driver Visual Attention Mediating Trait Absentmindedness and Risky Driving

Evidence for the hypothesized link between trait absentmindedness and horizontal gaze variability was not found. Thus, mean vertical gaze position was used for an exploratory analysis instead. SART performance was chosen as the predictor variable for this analysis because it was the only trait absentmindedness variable that significantly contributed to both of the previous models tested in H1 and H2.

The OLS analysis produced a model that significantly predicted mean vertical gaze position from SART errors, $F(1, 25) = 19.38$, $p < .01$, $R^2 = .44$. A second model predicting mean driving speed from mean vertical gaze position and SART errors was significant, $F(2, 24) = 4.09$, $p < .05$, $R^2 = .25$. The regression coefficients representing the contributions of mean vertical gaze position, $t(26) = 0.17$, $p = .87$, $B = 3.85$, and SART errors, $t(26) = 2.03$, $p = .05$, $B = 0.42$, in predicting mean driving speed did not significantly differ from zero. Finally, the indirect effect mediated by mean vertical gaze position was not significant, *95% CI* [-0.36, 0.23], $B = 0.02$. Thus, the null hypothesis was retained.

H4: Executive Control Moderating Trait Absentmindedness and Risky Driving

Moderation analysis produced a significant model predicting mean speed from SART errors, CWIT errors, and their interaction, $F(3, 26) = 12.30$, $p < .01$, $R^2 = .77$. The regression coefficient representing the contribution of SART errors in predicting mean speed was significant, $t(29) = 5.62$, $p < .01$, $B = 1.01$. While the regression coefficient for CWIT errors did not differ significantly from zero, $t(29) = 0.71$, $p = .48$, $B = 0.25$, there was a significant SART x CWIT interaction term, $t(29) = -3.18$, $p < .01$, $B = -0.08$. Furthermore, the interaction term significantly increased the variance explained by the model, $F(1, 26) = 10.09$, $p < .01$, $\Delta R^2 = .16$.

The results show the negative moderating role of executive control in the relationship between trait absentmindedness and risky driving. Thus, participants with high SART errors (i.e., high trait absentmindedness) and low CWIT errors (i.e., high executive control capacity) drove faster on average than those with high SART errors and high CWIT errors (i.e., low executive control capacity). Figure 5 illustrates the moderation effect by showing the relationship between SART errors and mean driving speed at three points along the distribution of CWIT scores (e.g., -1 *SD*, *M*, +1 *SD*).

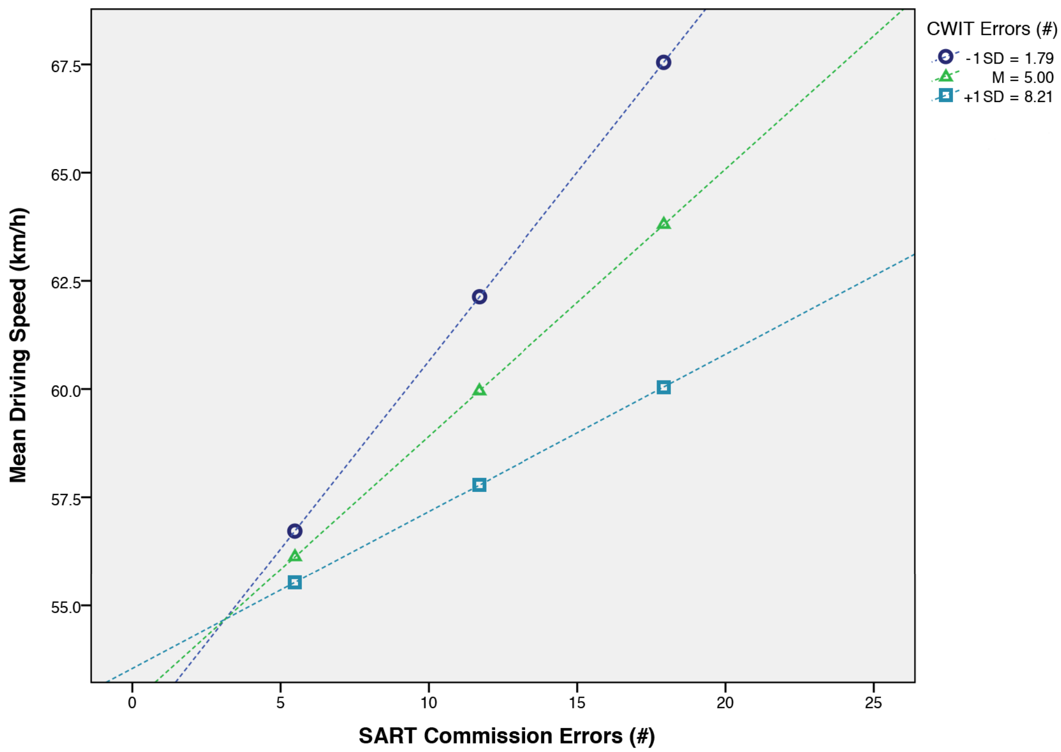

Figure 6. CWIT = Color-Word Interference Test, SART = Sustained Attention to Response Task. The interaction of trait absentmindedness and executive control in predicting mean driving speed. A scatterplot representing the relationship between SART errors and mean speed at three CWIT error values: -1 *SD* = 1.79 (purple circles), *M* = 5.00 (green triangles), and +1 *SD* = 8.21 (blue squares). CWIT errors represent inappropriate responses (i.e., incorrectly saying the colour word or the ink colour) in the inhibition and inhibition/switch conditions of the CWIT. The distinct slopes illustrate the moderating role of executive control.

Discussion

The present study examined whether trait absentmindedness predicts risky driving behaviour among young male drivers in a simulator. We also explored the perceptual and cognitive mechanisms that could contribute to this relationship. Our results confirm the main hypothesis that trait absentmindedness positively predicts risky driving behaviour. SART errors explained 32% of the variance in mean driving speed. Moreover, executive control capacity, as indicated by CWIT performance, significantly moderated this association by improving model accuracy by 16%. Contrary to our hypotheses, greater self-reported mind wandering tendencies predicted slower mean driving speeds. In addition, the extent of trait absentmindedness did not predict horizontal gaze variability as hypothesized. Driver visual attention was also not found to mediate the relationship between trait absentmindedness and risky driving as hypothesized. Overall, despite mixed support for the four tested hypotheses, these findings nevertheless suggest that individual differences in trait absentmindedness and executive control are important for understanding the variability in risky driving among young drivers.

Trait Absentmindedness and Risky Driving

The significant relationship between trait absentmindedness and faster mean driving speeds suggests that the propensity for mind wandering contributes to risky driving in the young male driver population. This is a novel finding, as past studies have focussed on the effects of mind wandering states on driving performance. For example, a recent study using experience sampling and driving simulation detected increases in driving speed during mind wandering episodes (Yanko & Spalek, 2013). The results of this previous study and the present study converge to indicate that mind wandering, both as a state and a trait characteristic, are associated with increased risky driving. These findings also align with earlier research demonstrating that stable differences in the self-reported frequency of cognitive failures linked to lapses of attention predict an individual's likelihood of causing a road traffic crash (Larson & Merritt, 1991). The present study builds on this previous work by demonstrating the predictive validity of a behavioural measure of attention (i.e., the SART). It also leverages driving simulation for a more detailed assessment of the driving behaviours, associated with the stable propensity for absentmindedness, that can increase the likelihood of a crash.

Mind wandering appears to be distinct from external forms of secondary task distraction, such as cell phone use, in how it affects driving behaviour. External distraction is associated with speed reduction (Caird et al., 2008). In contrast, the results of the present study (i.e., H1) and previous work indicate that mind wandering is associated with speed increases. Both forms of distraction, however, are associated with longer response times to sudden traffic events (Caird et al., 2014; Caird et al., 2008; Yanko & Spalek, 2013). The speed differences between internal and external distraction may be explained by decreased awareness of distraction-related impairment associated with mind wandering compared to external distraction (Horrey et al., 2008; Sanbonmatsu et al., 2015). The distinct combination of increased speed and delayed response times associated with mind wandering may also explain why some estimates of crash rates due to internal distraction are higher than those for external distraction (Young & Salmon, 2012). Future research is needed to determine how these behavioural manifestations of internal distraction may interact with specific driving situations to increase the likelihood of a crash.

The present study also explores the subjective dimension of internal distraction (i.e., self-generated thought), which underlies the previously established link between cognitive failures and road traffic crashes. An unexpected finding was that, in contrast to the above direct relationships, scores on the DDFS were inversely correlated with risky driving behaviour. Self-report scores frequently diverge from behavioural and physiological measures of a given construct (Cyders & Coskunpinar, 2011; Nisbett & Wilson, 1977). It has been suggested that this may be due to the intermittent and inaccurate deployment of meta-awareness, which refers to one's explicit awareness of the contents of conscious experience (Schooler, 2002). This theory explains why individuals are often unaware of their mind wandering until some time has passed (e.g., you reach the end of a paragraph only to realize that you did not retain any information), or they are prompted to reflect on their mental state by a thought probe, for example (Schooler, Reichle, Halpern, & Levin, 2004; Smallwood, McSpadden, & Schooler, 2008).

It may be that the DDFS is more sensitive to mind wandering of which individuals have meta-awareness (Mason et al., 2007), while errors on the SART catch mind wandering that goes unnoticed. This possibility received support in previous research by Smallwood, McSpadden, et al. (2007). These investigators found that only mind wandering of which individuals reported having no awareness until being asked, was correlated with errors on the SART. If this is the case, meta-awareness may mitigate the negative influence of mind wandering on driving behaviour. This would be in line with research demonstrating that meta-awareness of mind wandering states is associated with less acute task performance deficits compared to those related to mind wandering that goes unnoticed (Schooler et al., 2011). Additional research examining trait-level differences in meta-awareness could test whether scores on the DDFS and the SART predict the proportion of mind wandering episodes that individuals notice compared to their overall frequency of internal distraction states while driving.

Trait Absentmindedness and Driver Visual Attention

The hypothesized relationship between trait absentmindedness and horizontal gaze variability was not found. In contrast, exploratory analyses revealed that SART errors significantly predicted mean vertical gaze position, which is consistent with previous research on cognitive distraction while driving (Recarte & Nunes, 2000). A mediation effect of driver visual attention in the relationship between trait absentmindedness and risky driving was also not found. Our hypotheses were informed by the evidence for perceptual decoupling (Smallwood, 2013) in conjunction with indications of 'visual tunnelling' during states of mind wandering while driving (He et al., 2011). He et al. (2011) used a self-caught experience sampling technique with driving simulation in order to compare participants' eye movements over 10 seconds shortly before and after a button press indicating mind wandering. This method is contingent on the participant having meta-awareness of their mind wandering. One study (Reichle, Reineberg, & Schooler, 2010) used eye-tracking to measure oculomotor changes during mind wandering while reading. Erratic eye movements during reading were only associated with self-caught mind wandering but not probe-caught episodes, which showed regular eye movements. Thus, it is possible that oculomotor signs of mind wandering depend on having meta-awareness of one's mental state. Future research could test this possibility by comparing drivers' eye movements during mind wandering, indicated by probe-caught versus self-caught experience sampling methods.

Furthermore, in contrast to these previous studies, the present study separately measured trait mind wandering to predict oculomotor behaviour while driving in a simulator. Thus, it is possible that the effect was not detectable at the trait level. Alternatively, the task of self-reporting mind wandering when it occurs while driving may be cognitively distracting to drivers, which influences their eye movements (Recarte & Nunes, 2000). Comparing eye movements recorded during a driving session with experience sampling, to those recorded without experience sampling, could test this second possibility.

The Moderating Role of Executive Control

In the present study, the hypothesized role of executive control in moderating the link between trait absentmindedness and mean driving speed was supported (i.e., negative moderation by CWIT errors). This finding suggests that greater executive control capacity in conjunction with high trait absentmindedness may increase risky driving. According to the Task-Capability Interface model, the optimal threshold at which driving is experienced as challenging is higher for those with greater executive control, specifically working memory capacity (Fuller, McHugh, & Pender, 2008). Individuals with greater working memory experience more mind wandering when task demands are low compared to those with lower working memory (Levinson et al., 2012; Rummel & Boywitt, 2014). Therefore, those with greater executive control may drive faster because they are less challenged by the task of driving, and thus, experience more mind wandering. Furthermore, since executive control helps to maintain and buffer internal trains of thought, it is possible that greater executive control, in conjunction with low meta-awareness, facilitates more absorptive mind wandering (Smallwood, Brown, Baird,

& Schooler, 2012; Smallwood, Fishman, & Schooler, 2007). Intense mind wandering can relieve boredom (i.e., an unpleasant state of disengagement from ongoing tasks) when task demands are low, and thus, could lead to greater distraction-related risky driving (Eastwood, Frischen, Fenske, & Smilek, 2012).

Alternatively, mind wandering with meta-awareness can be aversive. It is often linked to negative affect (Killingsworth & Gilbert, 2010), which can signal boredom (Eastwood et al., 2012). Thus, drivers who are predisposed to frequent mind wandering and have high executive control may drive faster to relieve boredom and negative affect by increasing task demands to optimize arousal and draw their attention to the task of driving (Fuller et al., 2008; Kane & McVay, 2012). Future research examining potential interactions between mind wandering tendency, boredom, negative affect, and executive control in predicting risky driving is needed to test these hypotheses.

External factors that disrupt executive control may also compromise meta-awareness of mind wandering and accompanying performance decrements. For example, under the influence of alcohol, which is known to impact executive processes (Weissenborn & Duka, 2003), there is an increased occurrence of mind wandering with a concurrent reduction in meta-awareness (Sayette, Reichle, & Schooler, 2009). Additionally, research indicates that young drivers tend to over-estimate their driving capabilities and 'calibrate' their speed liberally as a consequence (Fuller, 2005; Fuller et al., 2008). Given that higher trait absentmindedness and executive control predict faster driving, and that young drivers tend to be inaccurate about their capabilities, a disruption in executive control and meta-awareness could lead to heightened crash risk. As a result, under the influence of alcohol, those high in trait absentmindedness and executive control may drive faster despite their impairment. Future research should investigate whether executive impairment interacts with risky driving behaviour associated with high trait absentmindedness and executive control to increase crash risk. Additionally, it is worth exploring whether higher trait meta-awareness facilitates compensation for potential driving deficits resulting from the interaction of executive impairment and trait absentmindedness.

Limitations

A limitation of the present study is that it only included males aged 18-21 in its sample. Young male drivers are substantially more likely to be involved in a crash compared to age-matched females (Ivers et al., 2009; Turner & McClure, 2003). Nevertheless, little is presently known about potential gender differences in mind wandering. Therefore, while our sampling of young male drivers increased internal validity, it may have restricted the generalizability of our results to half of the young driver population. Additionally, the relatively small sample size of the present study reduced its power, thus increasing the likelihood of type II error and preventing the detection of small effects.

Furthermore, the findings of the present study are correlational and thus limited in terms of their causal significance. While it seems unlikely that risky driving behaviour influences mind wandering tendency, it may be possible that other variables, not measured here, are responsible for this relationship. Additionally, executive control capacity may be responsible for trait absentmindedness, which leads to risky driving behaviour. While this possibility has been widely discussed in the mind wandering literature, current methodological challenges limit causal claims regarding mind wandering and executive control (Smallwood, 2013). Furthermore, in the present study, we did not find a direct relationship between executive control and risky driving, which is usually assumed for mediation (Baron & Kenny, 1986; Hayes, 2009). Moreover, one study found that mind wandering still predicted 8% of the variance in task performance after accounting for executive control capacity (McVay & Kane, 2009). Thus, despite lacking an experimental manipulation, the present study demonstrates the predictive power of mind wandering tendency for risky driving in a simulator.

Another limitation of the present study concerns psychometrics and construct validity. To measure trait absentmindedness, we used the original stimulus presentation duration and inter-stimulus interval for the SART (Robertson et al., 1997). Most mind wandering studies use longer latencies, however, which are more conducive for capturing performance variation related to subjective mind wandering states preceding an error (Giambra, 1995). Shorter latencies appear to capture more consistent differences in the amount of self-generated thought independent of time (Smallwood et al., 2004), reflecting the trait-level analysis of the present study. Nevertheless, this choice reduces the study's compatibility with the rest of the mind wandering literature. There is still some evidence for a temporal relationship between responses on the fast SART and mind wandering states however (McVay et al., 2013), which supports the congruence of state and trait mind wandering constructs.

Additionally, participants received instructions to respond quickly and accurately to the on-screen stimuli. It has been demonstrated that an emphasis on rapid responding can introduce error related to factors that go beyond those related to lapses of attention (i.e., speed-accuracy trade-off). It remains unclear, however, whether individual differences in average response times (i.e., a personal bias toward either speed or accuracy), which are generally associated with impulsivity, are correlated with or orthogonal to trait absentmindedness. Future research should explore the links and potential overlap between trait absentmindedness and other stable characteristics that are known contributors to risky driving behaviour (e.g., impulsivity).

Finally, while participants were instructed not to consume alcohol or drugs 48 hours prior to the start of the experiment, recent drug and alcohol consumption was not objectively screened. Hence, recent substance use could have impacted participants' cognitive abilities, which in turn may have influenced their task performance and driving behaviours. Future research should better control for recent substance use as well as the participant's overall frequency of consumption. Indeed, the high rate of substance use in this population warrants exploration of the relationship between trait absentmindedness and acute (i.e., experimentally induced) and chronic substance use as it relates to risky driving.

Future Directions

While the present study's results support the contribution of a trait-level propensity for internal distraction to risky driving in young drivers, additional questions remain unanswered. The role of meta-awareness in determining the extent to which mind wandering impacts driving performance remains unclear. Exploratory findings from the present study hint that meta-awareness is associated with slower mean driving speeds and that certain oculomotor manifestations of mind wandering (e.g., reduced horizontal gaze variability) may not be present at the trait level or when mind wandering goes unnoticed. In line with the present study's focus on trait as distinct from state mind wandering, future work should investigate methods for measuring trait meta-awareness and validate them against current metrics. For example, comparing the ratio of self-caught to probe-caught mind wandering during a task with scores on the DDFS and SART may reveal associations that validate the DDFS as a measure of trait meta-awareness. Alternatively, select items from a trait mindfulness scale that specifically concern meta-awareness could be used for this purpose (K. W. Brown & Ryan, 2003). It may also be possible to adapt signal-detection theory-based methods for measuring metacognitive accuracy for memory and perception to assess meta-awareness of mental states (Baird, Mrazek, Phillips, & Schooler, 2014; Seli, Jonker, Cheyne, Cortes, & Smilek, 2015). Examining the differences in driving behaviour while mind wandering with and without meta-awareness could shed light on its potential mitigating effects. One study showed that individuals can be motivated by rewards to monitor their thoughts more closely, offering hope for lessening the impact of mind wandering on driving through training meta-awareness (Zedelius, Broadway, & Schooler, 2015).

The few existing studies examining potential sex and gender differences in mind wandering tendency or severity are inconclusive (Giambra, 1980b; Mrazek, Smallwood, & Schooler, 2012; Ottaviani, Shapiro, & Couyoumdjian, 2013; Stawarczyk et al., 2012). No studies to our knowledge have investigated whether mind wandering tendency and gender interact to influence driving performance. There is some evidence that stereotype threat, in which an individual feels as though they are at risk of fulfilling a negative stereotype about their social group (e.g., gender, sexual orientation, ethnic background, etc.), can induce mind wandering (Mrazek et al., 2011). Indeed, stereotype threat elicited by reminding female participants of cultural biases concerning poor female driving capabilities has a negative impact on their performance (Yeung & von Hippel, 2008). Thus, it is possible that mind wandering mediates this association. Future research should examine baseline sex and gender differences in mind wandering tendency, how these rates interact with participants' experience of stereotype threat given the driving context, and how this differentially predicts driving behaviour. Comparing driving behaviour and mind wandering frequency among females who are exposed to either a cultural bias induction, a neutral induction, or a counter-stereotype induction (e.g., "a new study shows that women are as good if not better drivers than men") may also yield interesting results.

While research suggests that task demands, meta-awareness, and executive control influence whether mind wandering is detrimental to performance (Kane & McVay, 2012; Schooler et al., 2011), the content of self-generated thought may also be relevant in the context of driving. The Current Concerns model states that the occurrence and content of mind wandering is linked to the activation of personal goals or other "unfinished business" in working memory (Klinger, 2009; McVay & Kane, 2010). Certain types of mind wandering, such as negative rumination about the past and anxious worrying about the future, have been shown to influence mood (Poerio, Totterdell, & Miles, 2013) and are linked to present and future depression and anxiety symptoms (Carriere, Cheyne, & Smilek, 2008; Smallwood et al., 2005; Watkins, 2008).

In young, novice drivers, depression and anxiety symptoms are significant predictors of risky driving behaviour, with young males being especially susceptible to depression and females to anxiety (Scott-Parker, Watson, King, & Hyde, 2013; Scott-Parker, Watson, King, & Hyde, 2012). Moreover, dysphoric individuals exhibit greater decoupling from tasks as well as heightened physiological arousal while mind wandering, indicating greater intensity, compared to healthy individuals (Smallwood, O'Connor, Sudbery, & Obonsawin, 2007). Taken together, these findings suggest that the content of mind wandering, influenced by an individual's current concerns, may also be relevant for predicting risky driving among young drivers. Future research should examine whether depression or anxiety symptoms interact with mind wandering tendency to predict risky driving behaviour. Moreover, looking at different styles of mind wandering that are linked to personality traits (Singer & Antrobus, 1963; Watkins, 2008; Zhiyan & Singer, 1997) may reveal patterns of thought that promote recklessness on the road.

Implications

Given the growing evidence for elevated crash risk among individuals predisposed to mind wandering, a consideration of methods for intervention is imperative. Whereas many external distractors can be eliminated from the driving context, mind wandering is an endogenous activity that some individuals experience more often and are less capable of controlling than others (Kane & McVay, 2012). Moreover, given the covert nature of its occurrence and the associated inhibition of external information processing (Smallwood, 2013), online detection and prevention of mind wandering in the driving context may prove challenging compared to external distraction. Technologies capable of detecting mind wandering when it occurs (e.g., eye tracking, EEG) are presently hampered by impracticality, low reliability, and high cost (Bixler & D'Mello, 2015a, 2015b; Rodrigue, Son, Giesbrecht, Turk, & Höllerer, 2015). Furthermore, alert tones or flashing signals designed to warn drivers about their drifting attention could disrupt driving or go unnoticed while drivers are distracted by self-generated thought. These issues make addressing mind wandering within the driving context problematic. Enforcement of legislation banning cell phone use while driving has been moderately effective in reducing the associated crashes, injuries, and fatalities among young drivers (Lim & Chi, 2013). Internal distraction, however, may require a different approach that involves screening and tailored interventions based on driver predisposition.

By focussing on the trait propensity for mind wandering, as distinct from mind wandering as a state, it may be possible to curb its impact through detection and prevention that occurs outside of the driving context. Education and training programs based on proven techniques to help drivers compensate for this tendency are promising possibilities. In parallel to the growing mind wandering literature, a substantial body of work has explored the psychological and physiological benefits of mindfulness training (Baer, 2015; Grossman, Niemann, Schmidt, & Walach, 2004). Mindfulness is most commonly defined as, "paying attention on purpose, in the present moment, and nonjudgmentally, to the unfolding of experience moment to moment" (Kabat-Zinn, 2003, p. 145). Many forms of mindfulness training involve attending to one aspect of experience (e.g., the breath), passively noticing thoughts and feelings as they arise, letting them go, and returning attention to the chosen aspect.

Research has shown that mindfulness training can help manage the frequent occurrence of mind wandering through the cultivation of meta-awareness and cognitive control (Jankowski & Holas, 2014; Mrazek, Smallwood, & Schooler, 2012; Tang, Hölzel, & Posner, 2015). Mindfulness has been shown to promote external information processing and reduce cognitive failures, such as those linked to mind wandering and crashes (Herndon, 2008), which may also have implications for driver visual attention in reducing the "looked but failed to see" phenomenon (I. D. Brown & Great Britain, 2005; Koustanaï et al., 2008). Future research should employ rigorous testing methods such as randomized controlled trials, to assess the causal influence of mindfulness on mind wandering-related risky driving and performance deficits. Furthermore, investigating differences in treatment response based on changes in meta-awareness and executive control capacity would clarify the mechanism of action of mindfulness in reducing risky driving. At the same time, with mindfulness training usually taking weeks of practice to affect long-term changes (Treadway & Lazar, 2010), it would be prudent to explore methods, such as compliance-based incentives, to motivate young drivers to adhere to treatment. This research could pave the way toward mindfulness-based interventions designed to reduce risky driving associated with individual differences in mind wandering tendency and save the lives of young people.

Conclusion

The present study demonstrated that a trait tendency to mind wander predicts risky driving behaviour among young male drivers and that executive control capacity moderates this association. It also hinted that meta-awareness mitigates the negative impact of mind wandering on driving behaviour. Future work geared towards further uncovering the mechanisms that link trait absentmindedness and risky driving is warranted. This line of research could lead to the development of methods for detection and prevention that could mean the difference between life and death for some young drivers.

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