



Mind-wandering while driving: The impact of fatigue, task length, and sustained attention abilities

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ABSTRACT

Mind-wandering involves a lapse in attention due to preoccupation with one's own thoughts, the experience of which may interfere with performance on a primary task. The goal of this study was to investigate how task length and fatigue influenced the tendency to mind-wander while driving. We were also interested in whether the propensity to mind-wander could be predicted by individual differences in sustained attention, as measured by the *Sustained Attention to Response Task (SART)*. Participants completed three 20–25 min drives, during which time pre-recorded thought-probes prompted participants to answer whether they were thinking of driving. Mind-wandering was measured both during the drive (in terms of the percentage of thought-probe trials where drivers reported that they were not thinking of driving), as well post-task (in terms of self-rated difficulty in focusing attention). Driving speed, steering variability and hazard response time were measured by the driving simulator, and drivers also rated their performance post-task. There were significant increases in self-rated difficulty focusing with time on task, and non-significant increases in reported mind-wandering. Driving speeds and steering variability also increased with time on task, but individual differences in sustained attention as measured by the SART did not predict these changes. Overall, the best advance predictor of mind-wandering was the number of hours of sleep the previous night. Mind-wandering and difficulty focusing were correlated with negative emotional rumination (e.g., worries, guilt, anger), though it is unclear whether negative emotionality causes mind-wandering or vice versa. This research has implications for both basic and applied research on individual differences and cognitive distraction, as well as practical safety implications in areas of driver training and autonomous vehicle development.

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1. Introduction

Each day, millions of individuals around the world get in their cars and engage in the relatively routine task of driving to and from the various places that they need to be. For instance, commuters in the Toronto region drive an average of 33 min to get to work; 25% drive for 45 min or more ([Statistics Canada, 2016](#)). Furthermore, commercial drivers and those on more occasional trips may face even longer drives. During these trips and over long periods of time, drivers must attend to signs and traffic lights, the speed of their own vehicle and the movement of other vehicles, cyclists, and pedestrians. At the same time, they must remain vigilant so that they can recognize and respond to hazards in a timely manner. However, it is often

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difficult to remain completely focused on a given task for extended periods of time, and consequently drivers may be tempted by distractions, diverting their attention away from the driving task. Driver distraction is a leading cause of collisions (e.g., Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). Many studies show that performance deteriorates when drivers are distracted by external secondary tasks such as cellular phone conversations and texting. However, drivers may also become distracted by their own thoughts, a phenomenon known as *mind-wandering* (e.g., Barron, Riby, Greer, & Smallwood, 2011; Christoff, Ream, & Gabrieli, 2004; Gouraud, Delorme, & Berberian, 2017; Randall, Oswald, & Beier, 2013; Smallwood, Obonsawin, & Reid, 2002; Teasdale et al., 1995).

This study had two goals: the first was to assess the incidence of mind-wandering and the accompanying changes in driving performance as a function of time on task and individual differences in sustained attention. To do this we used a high-fidelity driving simulator that measured moment-to-moment changes in steering, speeding, and hazard response. The second goal was to investigate factors that correlate with the incidence of mind-wandering while driving, including indices of sustained attention, fatigue, and negative rumination. In the sections that follow we first review literature on mind-wandering—with special emphasis on the research on mind-wandering while driving—before moving on to a description of our study.

1.1. What is mind-wandering?

Mind-wandering is defined as a shift in attention away from the perceptual demands of the main task towards the processing of more personal goals (Smallwood & Schooler, 2006). This off-task attentional shift may result in performance deficits (e.g., McVay, Kane, & Kwapil, 2009; see Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012, as it relates to mind-wandering during lectures), impairing perceptual encoding (Antrobus, 1968; Giambra, 1995; Schooler, Reichle, & Halpern, 2004; Seibert & Ellis, 1991; Smallwood, McSpadden, & Schooler, 2008), and deficits in time perception (Terhune, Croucher, Marcusson-Clavertz, & Macdonald, 2014).

Empirical studies typically measure mind-wandering in one of two different ways. Some employ periodic thought probes during the task, where a tone, voice, or other similar signal prompts participants to report whether their thoughts were on- or off-task (reports can be given verbally, or by using a button). This technique has the advantage of immediacy, but it cannot provide detailed information about the mind-wandering episode without unduly disrupting the ongoing task. Alternatively, participants may be given post-task questionnaires such as the *Dundee Stress State Questionnaire* (DSSQ: Matthews, Dorn, & Glendon, 1991), the *Mindful Attention Awareness Scale* (MAAS: Brown & Ryan, 2003), or the *Imaginal Processes Inventory* (IPI) *Daydreaming Subscale* (IPI: Singer & Antrobus, 1970). These types of questionnaires are a good way of measuring the types of thoughts that individuals may have experienced during different types of tasks, as they contain questions relating to the contents and emotional aspects of mind-wandering episodes. However, the disadvantage of post-task measures is that they may not capture cases where participants are unaware that their minds were wandering, and thus they may be unable to report on the nature of these off-task thoughts.

Research suggests that thoughts experienced during mind-wandering episodes generally fall into two main categories: task-related interference (TRIs), and task-unrelated-thoughts (TUTs). The first type, task-related interference (TRI), falls into the grey area between task-unrelated and on-task thinking. These types of thoughts may be cued by the content or context of the task, and so reflect an individual's overall experience of the task. For instance, a driver coming to a stop might notice that their brakes are becoming noisier than usual. However, because such thoughts don't focus on the execution of specific steps or responses, they don't directly contribute to the overall outcome (Barron et al., 2011; McVay & Kane, 2009; Smallwood, Riby, Heim, & Davies, 2006). In contrast, TUTs are thoughts completely unrelated to the driving task (e.g. planning an upcoming vacation on the way to work).

Though sometimes spontaneous and seemingly random, TUTs can be cued by current situational or environmental factors, and typically revolve around things such as daily life events, creative musings and problem solving, or concerns and worries (Brown & Ryan, 2003; Carciofo, Du, Song, & Zhang, 2014; Marcusson-Clavertz, Cardena, & Terhune, 2016; McMillan, Kaufman, & Singer, 2013; McVay & Kane, 2012; McVay et al., 2009; Smallwood & Andrews-Hanna, 2013). For example, an individual might think about a troublesome issue at work during their morning commute. Thoughts relating to family, friends, and personal well-being also commonly feature in mind-wandering episodes (Buckner, Andrews-Hanna, & Schacter, 2008). Other kinds of off-task thoughts include daydreams and ruminations (He, Bécic, Lee, & McCarley, 2011; McVay & Kane, 2009; Ricard, Lutz, & Davidson, 2014; Robison & Unsworth, 2015). Although these terms have often been considered synonymous with mind-wandering, some consider them to be a somewhat different mental experiences involving slightly more conscious direction than the relatively unintentional and unguided drifting seen with mind-wandering and TUTs in general (Marcusson-Clavertz et al., 2016; Matthews, Warm, Reinerman, & Langheim, 2010; Ottaviani et al., 2015). Daydreams are described as positive and often fantasy-like in nature—more similar to sleeping dreams than other off-task thoughts (Pritzl, 2003; Regan, Hallett, & Gordon, 2011; Singer, 1975). Conversely, ruminations reflect a tendency to overanalyze and dwell on negative past events or experiences (Brown & Ryan, 2003; Smallwood & O'Connor, 2011).

Lapses into TUTs may be deliberate, as occurs when an individual daydreams to relieve the boredom of a routine task (e.g., Robison & Unsworth, 2017; Seli, Risko, & Smilek, 2016; Seli, Risko, Smilek, & Schacter, 2016). However, there may also be times when TUTs emerge unintentionally, and individuals may be surprised when they “come to” and realize that their minds have wandered off-task (e.g., Cheyne, Solman, Carriere, & Smilek, 2009; Kane & McVay, 2012; Schooler et al., 2011;

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