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Heather E.K. Rodd
Department of Psychology, University of Guelph, Guelph, Ontario, Canada

Lana M. Trick
Department of Psychology, University of Guelph, Guelph, Ontario, Canada

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PREDICTORS OF MIND-WANDERING WHILE DRIVING

Heather E.K. Rodd & Lana M. Trick
Department of Psychology, University of Guelph
Guelph, Ontario, Canada
Email: hrodd@uoguelph.ca

Summary: Mind-wandering occurs when individuals experience task-unrelated-thoughts, which can interfere with their performance. The goal of this study was to investigate mind-wandering while driving, as predicted both by time on task, and by individual differences in executive working memory, as measured by the *Sustained Attention to Response Task (SART)*. Participants completed a total of three drives during their hour in the driving simulator. During these drives, participants were periodically asked whether they were thinking of driving; the proportion of trials where they reported they were not thinking of driving was used as an index of mind-wandering. As a secondary index, at the end of each drive, participants also rated how difficult they felt it was to focus during the drive. Driving speed, steering variability, and self-report driving performance were also recorded. As predicted, self-reports indicated that drivers had increased difficulty focusing their attention with time on task, particularly in the last two drives; however, the increase in off-task thoughts per drive did not reach significance. Similarly, although driving speed increased as a function of time-on-task, and SART scores predicted driving speed, the interaction between SART scores and time-on-task did not have the predicted effect on steering variability. Overall, the best predictors of mind-wandering were fatigue and number of hours of sleep the previous night. Lastly, those who reported more mind-wandering also reported more instances of emotional rumination (e.g., worries, feeling guilty).

OBJECTIVES

Mind-wandering is a cognitive state in which individuals find their attention diverted from the task at hand, instead engaged in thoughts unrelated to the task—often without intention or awareness. In some cases, mind-wandering can be a harmless pursuit—such as when a person finds themselves daydreaming during idle moments—but it can be dangerous if it occurs during a task such as driving (Teasdale et al., 1995). In this study we will be investigating mind-wandering in a driving simulator, measuring the incidence of mind-wandering as a function of time on task, and looking at how driving performance changes as mind-wandering incidents become more frequent. We will also be investigating individual difference variables that may predict mind-wandering. In the following sections we will first discuss the literature on mind-wandering in general, and then how it relates to driving.

There are a number of ways in which to understand mind-wandering, but one influential theory suggests that mind-wandering is best understood as a lapse in executive working memory (the executive). The executive is thought to control attention, and under ideal circumstances it ensures that goal-related thoughts receive priority, facilitating task completion. Mind-wandering is believed to represent a case where the executive fails to inhibit task-unrelated-thoughts (TUTs) from intruding into consciousness and consequently interfering with completion of the task (McVay & Kane, 2010; Watkins, 2008).

The contention that mind-wandering occurs due to lapses in executive control is supported by research suggesting that factors that compromise executive control—things like physical fatigue—also increase mind-wandering (Mikulincer, Babkoff, Caspy, & Weiss, 1990; Poh, Chong, & Chee, 2016). Extended demands on executive working memory, such as that which occurs with increased time spent on attention-demanding activities, has also been associated with mind-wandering (Risko, Anderson, Sarawal, Engelhardt, & Kingstone, 2012). With continued attention to the task, executive resources are depleted, and TUTs begin to intrude. There is also reason to suspect that individual differences in the executive might predict a tendency towards mind-wandering. One common measure for assessing executive working memory is the *Sustained Attention to Response Task* (SART: Robertson, Manly, Andrade, Baddeley, & Yiend, 1997). If this task indeed provides an indication of executive functioning, then it reasonable to assume that those who score poorly on the SART may also report more incidents of mind-wandering or off-task thoughts (e.g., McVay, Kane, & Kwapil, 2009).

Mind-wandering poses a risk on the road as well. Many drivers engage in long daily commutes, performing the same drive day after day, until it becomes a monotonous routine. Engagement with too many task-unrelated-thoughts could compromise their ability to notice relevant safety-related changes in the driving environment (He, Becic, Lee, & McCarley, 2011; Regan, Hallett, & Gordon, 2011). Furthermore, those engaged in mind-wandering may also be more likely to speed and maintain inadequate headway distance to lead vehicles, practices that further increase the risk of a collision (Yanko & Spalek, 2013).

There have been several studies linking lapses in attention during everyday tasks to individual differences in executive function as measured by tests like the SART (e.g, McVay, Kane, & Kwapil, 2009). In the present study, we investigated mind-wandering in a driving simulator in drivers with high and low executive function (as determined by their SART scores). In particular, we were interested in seeing whether the percentage of mind-wandering incidents would increase over the course of three simulated drives. Mind-wandering was assessed in two ways: we queried drivers as to whether they were thinking about driving or about something else on four occasions during each drive, and at the end of each drive we had them rate how difficult it was to focus during the drive. We also tried to address the nature of these task-unrelated thought using scales on the *Dundee Driver Stress State Questionnaire* (DSSQ: Matthews, Dorn, & Glendon, 1991), particularly those measuring emotional rumination (i.e., worry, guilt, anger). Finally, driving performance was assessed both by the driving simulator itself, and through subjective self-reports. Overall, we predicted that tendency to mind-wander would increase across drives, both as measured by the percentage of trials where drivers reported TUTs and through self-reported difficulty with focusing, and that this would be accompanied by an increase in driving speed and standard deviation of lateral position (SDLP: the standard deviation of the distance between the centre of the vehicle and the centre of the lane when steering). Compared to drivers with high SART scores, we expected that those with low scores would report more mind-wandering (more difficulty focusing and a higher percentage of off-task trials), as well as higher driving speeds and SDLP. Lastly, we predicted that mind-wandering would correlate positively with fatigue and emotional rumination, and negatively with the number of hours of sleep the night before.

METHODS

Participants

Forty licensed drivers were recruited from the University of Guelph's psychology participant pool (31 female, *M* age = 18.7, *SD* = 1.21). All had at least a G2 license, which in Ontario's graduated licensing program permits unsupervised driving on all roadway types. Of all individuals, 27% had a full (G) license. Participants reported an average of 7.4 hours of sleep for the previous night (*SD* = 1.3), and on a scale of 1-9—where 1 indicated no fatigue at all and 9 indicated extreme fatigue—reported a mean fatigue level of 3.1 (*SD* = 1.8).

Apparatus and Stimuli

A fixed base Oktal Driving Simulator was used for this experiment, which consisted of a Pontiac G6 car body surrounded by 300º of viewing screens (Figure 1). The vehicle is equipped with standard vehicle controls, all of which function as they would in an actual vehicle. Additionally, speakers and vibration transducers simulate the sounds and sensations experienced during acceleration, and force-feedback in the steering wheel simulates the feeling of steering a real car. Mounted on the dashboard (above the center console) were two response buttons, labelled "Yes" and "No" (Figure 1). When queried, participants were required to press one button if they were thinking of driving, and the other if they were not.

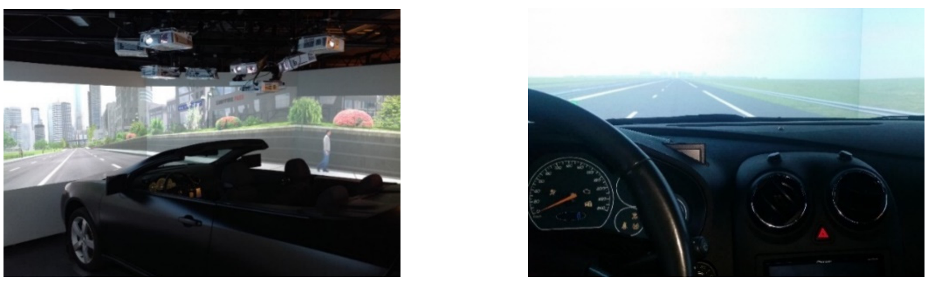

Figure 1. (Left) fixed base OKTAL driving simulator, (Right) dash-mounted buttons used when drivers had to indicate they were thinking of driving (left button) or off-task (right button)

This study was part of a larger project where a variety of driving behaviours were measured (including some in urban areas). However, for this study, measurements were taken during a relatively uneventful highway portion, where mind-wandering was more likely to occur. These segments consisted of a straight road with little scenery, and a posted speed limit of 100 km/h.

Executive working memory was assessed using the *Sustained Attention Response Task* (SART), which is a go/no-go task where individuals must maintain continuous attentional control while responding to a rapid sequence of digits. This task involved tapping an iPod screen every time a digit was presented, *except* when that digit was a "5". Of interest were response latencies and number of errors (both missed responses and failures of inhibition, where individuals made a response to "5" when they were required to withhold response). The *SART* was administered twice to ensure reliability, and from this a total score was calculated for each individual. An intake questionnaire was also used to assess demographic variables, driving history, fatigue, and the hours of sleep obtained the night previous. At the end of each drive, a 9-point Likert scale was used to assess perceived difficulty in focusing on the drive, and following the conclusion of all three drives, participants filled in the *Dundee Driver Stress Questionnaire* (DDSQ).

Design and Procedure

The study involved a mixed factorial design, with drive (1st, 2nd, 3rd) as the within-subjects factor, and SART group (low, high) as the between-subjects factor. After filling out intake questionnaires and completing the SART for the first time, participants went on a 5-minute practice drive to become familiar with the simulator, after which they went on three different 20-minute drives. At four points during each drive a pre-recorded voice was played through the vehicle's speaker, asking *"Are you thinking about driving?"* If participants were thinking of driving, they were to press the button labelled "Yes"; if they were not, they were to press the button labelled "No". Driving performance was measured by the simulator during each drive, as well as after each drive when participants were asked to rate their own driving performance and difficulty focusing during the drive using 9-point Likert scales. At the conclusion of the three drives the drivers filled out the *DSSQ* and then completed the *SART* for the second time.

RESULTS AND DISCUSSION

Data analyses involved analyses of variance. To guard against violations of sphericity in repeated measures analyses, the *Greenhouse-Geisser* correction to the degrees of freedom was applied as needed (a conservative procedure). Effect sizes were measured using partial eta squared (η_p^2), and the *Least Significant Difference test* (LSD) was used for post-hoc tests of means. To facilitate clearer understanding, we will first discuss the effects of the experimental manipulation (time on task), followed by discussion on the impact of individual differences (*SART* scores).

Time-on-task: Repeated-measures analyses of variance were used to assess changes in performance across the three drives (Figures 2 and 3). There were two indices of mind-wandering: proportion of off-task reports (out of four reports per drive), and rated difficulty in focusing at the end of each drive. There were significant correlations between these two indices (r = .48, p < .01), and a significant increase across drives in terms of self-reported difficulty of focusing (mean ratings increased from 4.15 to 5.41 on a 9-point scale, where 9 indicated extreme difficulty focusing: $F(1.96, 76.5) = 6.70$, p = .002, $\eta_p^2 = .15$). However, the proportion of reported off-task (non-driving related) thoughts only increased from 26% to 33% across drives—a non-significant increase ($F(2, 77.1) = 1.86$, p = 1.62). Overall, these results suggest that the drives may not have been long or uneventful enough to produce consistent mind-wandering.

Driving speeds increased as a function of time-on-task, as predicted ($F(1.9, 71.4) = 3.19$, p = .047, $\eta_p^2 = .08$), with post-hoc tests indicating a significant increase in speed on the third drive. On the other hand, there was only a marginal (non-significant) increase in SDLP ($F(1.9, 68.6)$ = 2.95, p = .059, $\eta_p^2 = .074$). Interestingly, although objective measures suggested a trend towards poorer driving performance with increased time-on-task, there was no corresponding decrease in self-reported driving performance; in fact, there was a slight increase as time went on (*M* ratings increased from 5.92 to 6.26 on a 9-point scale, where 9 indicated maximal performance).

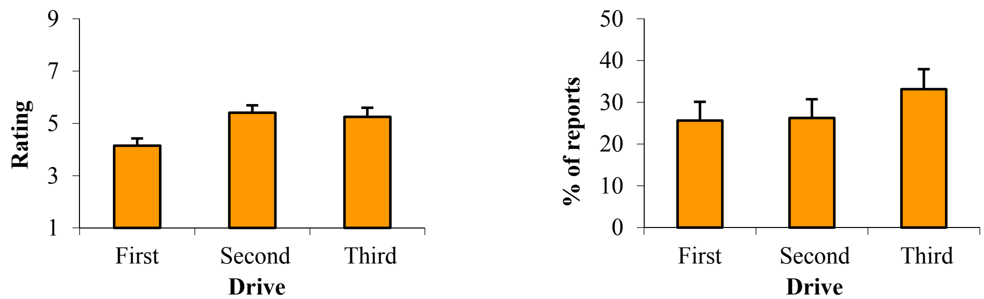

Figure 2. (Left) perceived difficulty of focusing on driving task, (Right) percentage of reported off-task thought trials during driving task, standard error bars included

Individual-differences analyses. We averaged SART performance across the two administrations of the test (*M* = 96.8%, range: 88 – 99.5%), and although scores were not as diverse as we had hoped, we divided participants into two groups using a median split. Mixed factorial analyses of variance were performed with SART group (low, high) as the between-subjects factor and drive (1^{st}, 2^{nd}, 3^{rd}) as the within-subjects factor. Although there were trends towards drivers with lower SART scores reporting a higher percentage of off-task thoughts per drive than the high score group (*M* = 33.33% as compared to 25.3%, respectively), and more difficulty in focusing during the drive (*M* = 4.6 and 4.2, respectively, where 9 indicated maximal difficulty), these differences were not significant and there were no SART X Drive interactions. However, SART scores did predict individual differences in driving speed: those with lower SART scores drove significantly faster than those with higher scores ($F(1,35) = 4.28$, p = .046, $p < .05$, $\eta_p^2 = .11$). From Figure 3, it is apparent that there was also a trend towards those with lower SART scores driving increasingly faster across drives, while those with higher SART scores maintained more consistent speeds, though this interaction was not significant ($p > .1$). We also found a marginal SART X Drive interaction in terms of SDLP, $F(1.9, 66.1) = 2.79$, $p = .07$) , $\eta_p^2 = .07$), though it was not as predicted: while those with higher SART scores displayed lower steering variability (SDLP) in the first drive, the pattern reversed in later drives. Finally, low and high SART groups were nearly identical in self-rated driving performance (*M* ratings = 5.94 and 5.97, respectively).

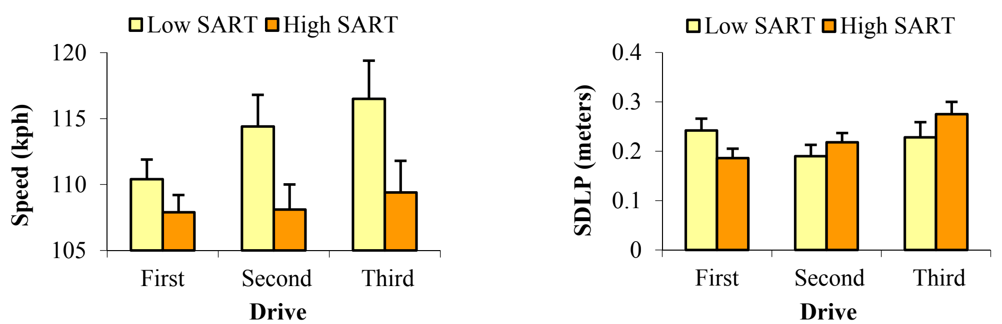

Figure 3. (Left) individual differences in driving speed, (Right) individual differences in steering, as measured by standard deviation of lateral position (SDLP), standard error bars included

Overall percentage of off-task trials during a drive proved to be the measure most related to other factors in the correlational analyses. There was a significant correlation between average proportion of off-task trials and number of hours of sleep night previous, though not with self-rated fatigue ($r = -.34$, $p < .05$, $r = .19$, $p > .1$, respectively). The correlation between off-task trials and SART scores was also not significant (r = -.22, p > .1), though off-task trials correlated well with certain DDSQ scales, with increased off-task trials being associated both with lower alertness and more emotional ruminations (r = - .35 and + .31, $p < .05$, respectively).

CONCLUSION

Although results were not as strong as anticipated, there was nevertheless some support for the contention that mind-wandering increases with time-on-task. Self-reported difficulty in focusing during the drive increased significantly from the first to third drive, and there was a non-significant increase in the proportion of trials where drivers reported that they were off-task (i.e., not thinking of driving). Although average speeds were always above the posted limit of 100 km/h, across all drives, driving speeds increased (p < .05). At the same time, there was also a marginal increase in steering variability, as measured by SDLP. Taken together, evidence from speed performance indicates that as driving time increases, executive controls may become fatigued, making it more difficult to focus solely on safe driving behaviours (such as speed maintenance). Furthermore, individual differences in executive working memory, as measured by the SART, predicted higher driving speeds (in excess of the posted limit). SART scores were also related to differences in SDLP across trials, though effects were not as expected. Differences between the low and high SART groups were most noticeable in the first drive, but as the drives progressed the two groups became more similar. By the last drive, SDLP for the high SART group was (non-significantly) higher than it was for the low SART group. However, although the high SART group displayed superior sustained attention abilities on the SART, they did not differ significantly from the low SART group in either mind-wandering tendencies or perceived difficulty of focusing. Furthermore, mind-wandering has previously been shown to cause a narrowing of peripheral attention (He, Becic, Lee, & McCarley, 2011), and as steering is believed to be under the control of peripheral attention (Wickens, 2002), it is perhaps not so surprising then that both groups ultimately experienced similar patterns in overall steering performance. Finally, percentage of off-task trials was correlated with reports of emotional rumination (e.g., worries, guilt, anger), but overall, correlational analyses revealed that the individual difference variable most predictive of mind-wandering in advance of the drives was the number of hours of sleep the night before. This suggests that the amount of sleep one receives is related to the ability to resist the intrusion of task-unrelated thoughts.

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