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The impacts of perceptual load and driving duration on mind wandering in driving

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ABSTRACT

A significant portion of the risk of driver distraction comes from the cognitive consequences of attention deviating from the current task. While distraction can be due to external stimulations such as flashing billboards or a ringing phone, simply engaging in internally-generated task-unrelated thoughts (i.e., mind wandering) could raise one's crash risk as well. Compared to the extensive efforts in recent years to understand the mechanisms of external distraction, relatively little is known about internal distraction such as mind wandering. This study investigated how perceptual load and driving duration can impact both the rate of mind wandering and its costs on drivers' performance in vehicular control. Generalized additive mixed effects models were used to estimate these effects in both a lower perceptual load scenario and a higher perceptual load scenario in simulated driving. Our study found that, under a higher perceptual load, participants' minds wandered less often. Significant nonlinear effects for driving duration were found on vehicular control during mind wandering for both perceptual load conditions, while the effect of driving duration was linear for on-task periods. These results suggest that, while mind wandering, individuals' driving performance fluctuates greatly, which has significant implications on driving safety for individual drivers and overall traffic flow.

1. Introduction

While driving, we often engage in thoughts that are unrelated to the task, especially when travelling on familiar roads for daily commute (Burdett, Charlton, & Starkey, 2016). Engaging in these task-unrelated thoughts may potentially increase crash risks according to some recent correlational studies (Galéra et al., 2012; Qu et al., 2015). As revealed by a nationwide census of fatal crashes in 2010 and 2011, 62% of distracted driving involved in fatal car crashes was associated with being "lost in thought", in other words, internal distraction due to mind wandering (Erie Insurance, 2012). During mind wandering, drivers reduce their scanning to the peripheral areas in the visual field (He, Becic, Lee, & McCarley, 2011) and respond more slowly to braking events (Yanko & Spalek, 2014). While these studies provide useful insights into how mind wandering could negatively influence driving performance, only a few studies examined the factors that impact how frequently we mind wander and the direct consequence of mind wandering on vehicular control. In a recent survey study, Burdett et al. (2016) identified several individual trait, state and road environmental factors that play a role in mind wandering during everyday driving. It was found that drivers were more likely to report mind wandering on familiar than unfamiliar roads,

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and when drivers were tired. The study also revealed general associations between increased mind wandering and younger age, poorer attention and cognitive abilities, and more driving violations and lapses. In another study (Yanko & Spalek, 2014), participants drove at a greater speed and followed more closely with a lead vehicle when mind wandering. These studies provide an initial insight into the impact of mind wandering on driving, however in contrast to the body of research on what leads to less or more driver engagement in external distraction (e.g., Chen & Donmez, 2016; Feng, Marulanda, & Donmez, 2014) and how this distraction impacts driving performance (Caird, Johnston, Willness, Asbridge, & Steel, 2014; Strayer & Johnston, 2001; Young, Regan, & Lee, 2009), more research is needed. Informed by fundamental research in the field of cognitive psychology on mind wandering (Forster & Lavie, 2009; Smallwood, Obonsawin, & Reid, 2002; Smallwood et al., 2004), this study assessed two potentially important factors, *perceptual load* and *driving duration*, that could influence the rate of mind wandering and maybe also its effect of task performance in driving.

Perceptual load, that is the amount of external information an individual has to process during a task, can significantly impact how frequently we engage in mind wandering. Using a visual search task, Forster and Lavie (2009) found that when the perceptual load was high, individuals' reported fewer occurrences of mind wandering. Using electroencephalogram (EEG) to measure drivers' brain activities in simulated driving, Lin et al. (2016) found that drivers had an increased activation in the default mode network, a brain network associated with mind wandering, when they received both visual and kinematic (i.e., motion) feedback (higher perceptual load) rather than only visual feedback (lower perceptual load). This finding suggests a brain mechanism linking low perceptual load (manipulated via the deprivation of motor sensory information) and mind wandering, although there was no behavioral measure of mind wandering. Perceptual load can play an important role in driving. Individuals in increased perceptual load conditions drove more slowly, had more variable lateral lane positions (Engström, Johansson, & Östlund, 2005; Horberry, Anderson, Regan, Triggs, & Brown, 2006), and experienced exacerbated external distraction costs (Strayer, Drews, & Johnston, 2003). While the influence of perceptual load in the driving domain has been well charted for external distractions, the effect of perceptual load on mind wandering in driving remains unclear. Documenting this influence will help inform where it may be most dangerous and prolific, as often real driving is more complicated than the rural drives typically used in mind wandering research (see Table 1). Based on the results of Forster and Lavie (2009), we expect that the rate of mind wandering will decrease as the complexity of the driving environment increases. Mind wandering requires cognitive resources to maintain the current train of thought (Smallwood, 2010; Smallwood & Schooler, 2006), and an increased external load reduces the resources available for mind wandering to occur. Using this reasoning, driving scenarios are kept intentionally simple in order to maximize the rate of mind wandering (He et al., 2011). However, the cost of using simple scenarios, such as those without other vehicles, is that the majority of contexts in which accidents occur cannot be investigated. As only 33% of accidents occur with only a single vehicle involved, 46% of accidents with vehicles going straight, and 46% on two lane roads (National Highway Traffic Safety Administration, 2008), the scenarios typically being tested in mind wandering research make up the minority of accidents. Therefore, it is important to expand our explorations on mind wandering and driving performance to more complex driving environments. To achieve this goal using driving simulation, a first step is gaining a better understanding of the level of complexity that can be used in laboratory studies while maintaining sufficient statistical power.

While the impact of perceptual load on driving behavior during mind wandering has received little attention, some corollaries may be drawn between mind wandering and cognitive distractions as attention shifts inwards and away from the external environment. Kaber and his colleagues (2012) found that when drivers were under simultaneous cognitive and visual demands, they had an increased rate of steering errors and reported the task as being more demanding than either condition (visual or cognitive) alone. In another study investigating the impact of simultaneous visual and cognitive load, Engström et al. (2005) found that visual and cognitive load impacted driving performance in different ways, and that the magnitude of the cost of either did not increase in the presence of the other. Of course, mind wandering and cognitive load induced from an external task are not identical, as the content of mind wandering can be hugely variable and the individual may be unaware they are engaging in it. However, interestingly, Martens and Brouwer (2013) found that internally induced cognitive distraction had comparable effects on driving as externally induced cognitive extraction. Therefore, it is reasonable to speculate that while mind wandering in a higher perceptual load environment, drivers may experience greater detriments to their driving performance relative to a lower perceptual load environment.

Another potentially important factor in understanding the impact of mind wandering on driving is duration. Task duration can influence mind wandering in multiple ways, as individuals' minds wander more often when engaged in a practiced task (Teasdale et al., 1995), a task for a prolonged duration (Smallwood et al., 2002, 2004), or when they were tired (Burdett

Table 1
Complexity of simulated driving scenarios used in mind wandering studies.

	He et al. (2011)	Yanko and Spalek (2014)	Dündar (2015)
Incoming Traffic	No	No	No
Lanes	2	4	2
Intersections	No	No	No
Pedestrians	No	Yes	No
Rural	Yes	Yes	Yes
Peripheral Objects	Yes	No	No

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et al., 2016). Limited research has been conducted on the effect of task duration during mind wandering, however there is reason to believe that they may be important. Familiarity with the road is correlated with increased driver inattention (Yanko & Spalek, 2013) and decreased sensitivity to changes on the road (Martens & Fox, 2007); these changes may make sense in the light of the increased probability of mind wandering as driving requires less attention. Indeed, participants' self-reported rates of mind wandering were higher on familiar roads than unfamiliar ones (Burdett et al., 2016). Additionally, certain factors such as perceptual load may impact the relationship of reported mind wandering and task duration, by either increasing the rate mind wandering is reported or the maximum at which the rate of mind wandering plateaus. As the relationship of mind wandering and task duration is likely not linear due to the differential impact of practice and fatigue by time, it is important to account for these non-linear trends. If non-linear trends are present but unaccounted for, during analysis, standard error estimates for predictor variables (such as perceptual load) will be artificially low, leading to an increased chance of Type I error (McKeown & Sneddon, 2014). We expect that rate of reported mind wandering will increase initially as individuals acclimate to the simulator, and then plateau for a period of time until fatigue sets in, and the rate begins to increase again. Another possible influence of task duration on how mind wandering impacts driving control is increased variation in control over time relative to when on-task. As the impact of task duration on mind wandering influences on behavior have not yet been explored, this question was approached in an exploratory manner.

In this study, we examined how perceptual load and driving duration impact mind wandering rates and costs in simulated driving. Perceptual load was manipulated via controlling the amount of visual information in the driving environment (different from Lin et al., 2016). Participants completed a simulated driving task and reported their minds' state (on-task or mind wandering) intermittently (similar to the probing method used in Yanko & Spalek, 2014). We measured the rate of mind wandering through the use of sporadic probes that required responses from participants, and vehicular control through lateral velocity, lateral acceleration, longitudinal velocity, and longitudinal acceleration. We hypothesized that when under a higher perceptual load, individuals' minds would wander less often, and the influence of mind wandering on driving control measures will increase. Additionally, we expected that driving duration will display a nonlinear relationship for mind wandering rate, increasing at the beginning of the experiment (practice effect) and end (fatigue effect). Lastly, we explored possible nonlinear effects for driving duration on mind wandering costs.

2. Methods

2.1. Participants

A total of 43 undergraduates (17 women, 26 men) participated in this study. All participants were required to have normal or corrected-to-normal vision and a valid driver's license. Three participants (two women, one man) were removed from analysis due to language barriers, falling asleep, and excessive speeding during the simulated driving task (mean speed > 100 mph). As a result, the final sample included in analysis consisted of 15 women (mean age: 19.40 years, age range: 18–21 years) and 25 men (mean age: 18.96 years, age range: 18–21 years). Participants were recruited from an introductory psychology course from North Carolina State University, and were compensated with course research credits.

2.2. Driving simulator

Driving simulations were run using a low-fidelity STISIM Drive 3 console simulator (Fig. 1). The use of STISIM was deemed appropriate for the study given the established relative validity for lateral position (Törnros, 1998) and speed (Bella, 2008; Godley, Triggs, & Fildes, 2002). Participants were seated in a full-size fixed base driver seat equipped with a steering wheel, gas/brake pedals, and a button panel for reporting their minds' state (i.e., on task, or mind wandering). The driving scenarios

Fig. 1. The STISIM Drive 3 Console simulator used in this experiment.

were displayed on three 42″ monitors covering a field of 135° of visual angle horizontally and 24° vertically. Vehicular control data, including lateral lane position, lateral velocity and acceleration, longitudinal velocity and acceleration, was sampled every 0.1 s. During analyses, these vehicular control data was truncated to only one data point per second. This was deemed sufficient for analyses based on the small amount of variance in driving measures on the millisecond scale. All measures were recorded using feet.

2.3. Driving scenarios

All simulated driving occurred on a two-lane rural highway through a series of hills and curves. Participants were instructed to follow a lead vehicle which maintained a constant distance from the driver. The lower perceptual load condition had no other traffic on the road, minimal objects in the visual field (Fig. 2). In contrast, in the higher perceptual load condition participants encountered incoming traffic (on average two per minute), houses, trees, and intersections. None of these objects required any action by the participant and other components of the drives were identical in the lower and higher perceptual load conditions, in order to keep interactability of the environment constant across the conditions. In both conditions, the speed limit was 45 mph and was posted every 1.2 miles. Full length drives were 40.4 miles, and training drives were 3.7 miles.

2.4. Mind wandering probes

Throughout the drives participants were probed by a pure tone (400 Hz, 1 s duration), and they had to report whether their thoughts had been task-related or task-unrelated by pressing the corresponding marked buttons to the right of the steering wheel. Take-related thoughts were described as any thoughts related to the current task, while task-unrelated thoughts were described as thoughts unrelated to the current task (such as thinking about eating during an exam). Mind wandering probes occurred at a random interval between 30 and 90 s, with a total of 15 per full-length drive. This probing method is similar to the one used in Yanko and Spalek (2014) and is one of the typical methods in the cognitive psychology literature on mind wandering (e.g., Smallwood, McSpadden, & Schooler, 2008). Compare to other methods (e.g., self-caught method, He et al., 2011), this probing method is able to capture mind wandering with and without awareness. Vehicular control data from the 0–15 s interval prior to the mind wandering probe was used in the subsequent analyses, an interval used previously in Smallwood, Beach, Schooler, and Handy (2008).

2.5. Procedure

Participants first consented to their participation in the experiment and filled out a brief questionnaire comprised of demographic questions about their age, sight, driving history, and gender. Afterwards participants were informed about the general task procedure, simulated driving and the mind wandering probes (asking whether the thoughts immediately before the probe was task-related or task-unrelated). Examples of task-related thoughts (e.g. thinking about incoming traffic) and task-unrelated thoughts (e.g. thinking about eating during a test) were provided. Additional examples were given when participants needed elaboration. After a brief practice drive, each participant drove both the lower perceptual load and higher perceptual load scenarios in a randomly chosen order (low - high, or high - low) with this task order counterbalanced between participants. In between the two drives, participants were given a brief two-minute break before starting the next drive.

3. Results

We used generalized additive mixed models (GAMMs) to examine the impacts of perceptual load and driving duration on the rate of mind wandering and its costs on vehicular control performance, including lane position, lateral and longitudinal velocity and acceleration. GAMMs were run using the mgcv package (Wood, 2004) in the R environment. Generalized additive models allow for modeling of nonlinear relationships using smoothing functions, while mixed modeling allows

Fig. 2. Typical scenes of the lower perceptual load condition (left) and the higher perceptual load condition (right).

for random effect specification on the individual level. All models included a random intercept for participant, and a random slope for driving duration. Driving duration (i.e., time since the start of a drive) was measured using the simulator, with the two-minute break included between the two drives. We consider a smooth effect for driving duration during both mind wandering and on-task thoughts; the other covariates are assumed to have a linear effect. Both smooth effects of driving duration are modeled using thin plate regression splines; the smoothing parameters are estimated using restricted maximum likelihood estimates (REML), as generalized cross-validation (GCV) tends to overfit (Wood, 2011) and can experience problems with correlated covariates (such as reported mind wandering and driving condition in this study) in repeated measures designs (Wood, 2006). Some caution should be used in interpreting psuedo-R^2 for nonlinear models, as it is an approximate estimate (Spiess & Neumeyer, 2010). Concurvity was assessed for each GAMM with no obvious problems present. An interaction of a smooth effect for driving duration and perceptual load was initially included, however the smooth effects either appeared linear or contained 0 within the entirety of their confidence interval, and so were removed from the final models. Mind wandering rate was modelled using a single smooth effect for driving duration (Fig. 3), and driving performance measures were modeled with a smooth effect for driving duration during mind wandering (Fig. 4, left panel) and a separate smooth effect for on-task (Fig. 4, right panel).

Gender was included in all models based on the results of Qu et al. (2015), in which a significant interaction was found between gender and dangerous driving behaviors for high mind wandering individuals. In addition to gender, age and order of presentation for perceptual load conditions (high - low, low - high) were added as covariates.

3.1. Rate of mind wandering

Participants reported mind wandering to 50% of the probes in the lower perceptual load condition and to 41% of the probes in the higher perceptual load condition. A binomial family logistic additive mixed model was used to analyze the rate of reported mind wandering. No significant autocorrelation was present in the residuals. Variables included in the model were age, gender, order of presentation of the scenarios, perceptual load condition, and driving duration. The addition of a smooth effect for driving duration was statistically significant (χ^2 (3.18, 1158) = 12.15, $p = 0.017$), with a rise in the rate of mind wandering for approximately the first 12 min (Fig. 3). A main effect was found for lower rates of mind wandering in the higher perceptual load condition ($b = -0.41$, $z = -2.69$, $p = 0.007$). Overall, the model displayed a weak to moderate fit ($R^2 = 0.19$).

3.2. Driving control measures

GAMMs on driving control measures all displayed significant autocorrelation of residuals, even with the random effect structure taken into account. This is likely due to the fact that while the random effect structure accounted for dependence within individuals and across probes, it did not account for the dependence within probes. We would expect that driving speed at time T seconds would be correlated to driving speed at T + 1 s. A nested autoregressive lag 1 (AR[1]) autocorrelation structure was specified within each mind wandering probe, starting at the point 15 s before the probe to the time 1 s before the probe. Rho was initially set based on the lag 1 autocorrelation value, and then visually inspected and adjusted, with a final value of 0.94. An AR(1) appeared to be sufficient to account for the residual autocorrelation. Variables included in

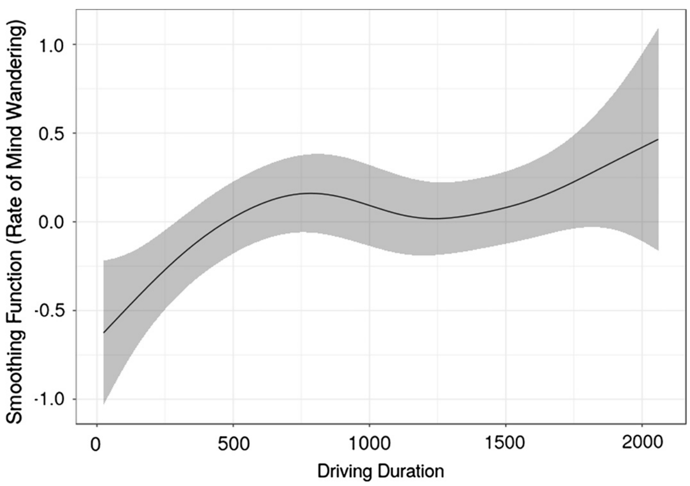

Fig. 3. Rate of mind wandering over time (seconds), with the y-axis as the smoothing function for reported mind wandering and the grey region represents the 95% confidence interval. This plot can be interpreted as the rate of mind wandering increasing from the beginning of the study, and then plateauing until the end of the study.

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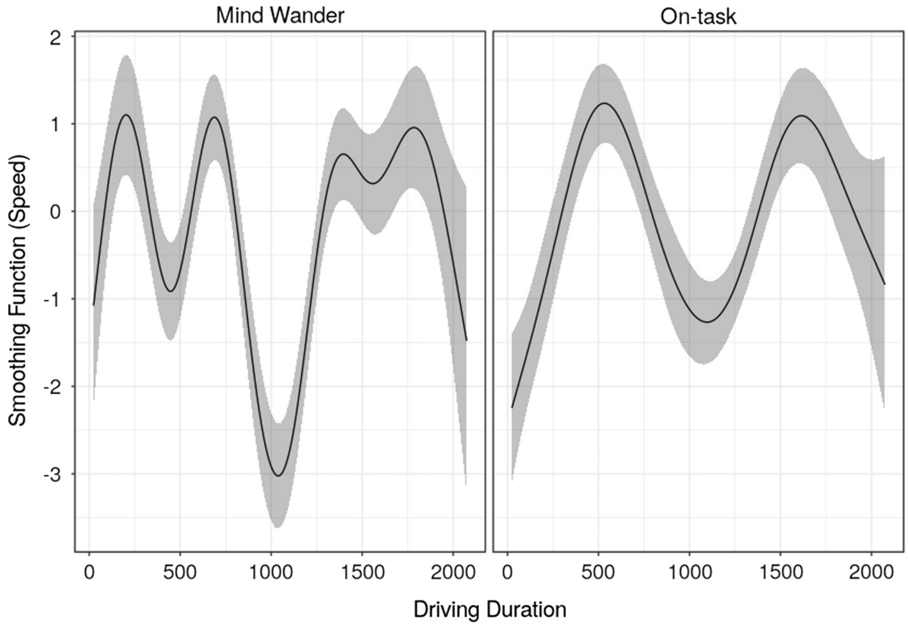

Fig. 4. Smoothing function for longitudinal velocity over time (seconds) for mind wandering (on the right) and on-task thoughts (on the left), with the grey regions representing 95% confidence interval. Differences in the variability over time can be seen between the two thought types, with more oscillations in speed over time during mind wandering compared to on-task.

Table 2
Generalized additive mixed model (GAMM) with autoregressive lag 1 (AR[1]) for driver speed.

Parametric coefficients	Estimates	Standard error	*t*-value	*p*-value
(Intercept)	53.88	16.26	3.31	<0.001*
Age	0.81	0.82	0.98	0.325
Gender (male)	−3.08	1.75	−1.76	0.079
Order (PL-high first)	3.88	1.73	8.95	<0.001*
Mind wandering	−0.51	0.18	−2.76	0.006*
PL (high)	−0.97	0.26	−3.71	<0.001*
MW × PL (high)	0.79	0.26	3.06	0.002*
Smooth terms		Estimated *df*	*F*-value	*p*-value
s(duration) × MW		8.63	13.76	<0.001*
s(duration) × OT		7.12	17.96	<0.001*
Random effects				
re(ID)		35.40	2977.97	<0.001*
re(duration, ID)		34.93	2733.24	<0.001*

Note: Reference variables for the estimate were on-task thought, females, low perceptual load, and low perceptual load first for the order of presentation. For the smooth terms, s() represented a thin plate spline, and re() represented a random effect for ID and random slope for duration/ID.
* notes significance level in the mixed model $p < .05$.

the models were age, gender, response to mind wandering probes, perceptual load, order of presentation of the driving scenarios (i.e., lower or higher perceptual load condition), a smooth effect for driving duration while mind wandering, and a smooth effect for driving duration while on-task (Table 2). No main effects were found for model predictors for driver acceleration, lane deviation, and lateral acceleration. A number of significant effects were found for driver speed (Table 2). The smooth effect of driving duration was significant for both mind wandering and on-task, with a significant interaction of mind wandering and perceptual load, as well as a significant main effect for presentation order (Table 2). The smooth effect for driving duration while mind wandering displayed a significantly higher frequency of variation (distance between peaks) than when on-task (Fig. 4). Overall the model fit was strong ($R^2 = 0.64$).

4. Discussion

The primary objective of this study was to explore the influence of driving duration and perceptual load on the rate of mind wandering and its influence on vehicular control measures. In the study, participants completed simulated driving while being intermittently probed about their minds' states. Responses to these probes were recorded together with vehicular control performance measures. Participants reported lower rates of mind wandering while driving in a more visually complex environment which included oncoming traffic, peripheral objects, and intersections. This finding is consistent with Forster and Lavie (2009) in which participants reported lower rates of mind wandering during lower perceptual load conditions during a visual search task. Even with the decreased rate of mind wandering in the higher perceptual load driving condition, the rate of mind wandering was high enough (41%) to preserve sufficient statistical power. Given this result, future research can investigate the impact of mind wandering in other driving situations; an important finding considering single vehicle crashes make up just 33% of accidents, and only 50% of accidents occurred when the driver was going straight (National Highway Traffic Safety Administration, 2008). Additionally, considering the ubiquitous nature of mind wandering and the fact that it does not always impact performance (Smallwood, Obonsawin, & Heim, 2003), it would be more beneficial to research its impact during high-risk situations, rather than only a limited set of generic driving scenarios.

There was a significant interaction between the influence of mind wandering and perceptual load on driver speed. For both mind wandering and on-task, driving speed was lower during the lower perceptual load scenario. Engström et al. (2005) found similar results, as visual distraction led to decreased driving speed. The same slowing down effect is found during distracted driving in general (Alm & Nilsson, 1995; Burns, Parkes, Burton, Smith, & Burch, 2002; Haigney, Taylor, & Westerman, 2000; Rakauskas, Gugerty, & Ward, 2004), though the speed change is likely not a conscious choice (Charlton, 2004; Lewis-Evans, De Waard, & Brookhuis, 2011). The lower speed during distractions has been thought to be a form of compensatory behavior (Young, Regan, & Hammer, 2007) as individuals self-regulate to compensate for the decreased attentional resources available for driving. During the lower perceptual load condition, people drove faster while engaged in on-task thoughts compared to mind wandering, however the opposite was found in the higher perceptual load condition, as people drove faster while mind wandering than when engaged in on-task thoughts. These results may be explained when considering that mind wandering likely requires executive resources to maintain a train of thought (Smallwood, 2010; Smallwood & Schooler, 2006), and is associated with increased activation in some brain regions of executive systems in addition to the recruitment of the default mode network (Christoff, Gordon, Smallwood, Smith, & Schooler, 2009). The use of executive resources while mind wandering would likely leave less resources available to engage in self-regulation and monitoring, potentially limiting the occurrence of compensatory behaviors such as speed changes in more distracting environments such as the higher perceptual load condition. Some support for this has been found in Yanko and Spalek (2014), where they observed that mind wandering was associated with decreased headway distance compared to an external distraction.

Using generalized additive mixed models, we found nonlinear effects of driving duration on the rate of mind wandering, and on driving speed, meaning that both the rate of mind wandering and the cost on driving speed fluctuated over driving duration. An important consideration when interpreting our results on the effect of driving duration is that unlike typical longitudinal data where data at time point N and $N+1$ are the same, each time point was composed of different groups of individuals as they reported either mind wandering or on-task for that time. Note that this effect of driving duration was determined with the effect of perceptual load controlled for in the mixed models, with no differences found in the smoothing function for driving duration between the lower perceptual load and higher perceptual load conditions. The rate of mind wandering gradually rose for approximately the first 12 min, and then plateaued until near the end of the experiment (~27 min), where a nonsignificant positive trend started. The initial rise in the rate of mind wandering is akin to the effect of gaining experience or practice on a task, which lowers the cognitive resources required to perform it allowing for increased rates of mind wandering to occur (Teasdale et al., 1995). Once cognitive resource allocation to the external task (i.e., driving) and internal thought processes (i.e., mind wandering) stabilizes, rate of mind wandering is expected to remain consistent until fatigue effects start to play a significant role. The nonsignificant upward trend seen at the end of the experiment indicates that if the experiment were longer, fatigue effects may have started to develop, however it is likely that the change in driving conditions caused a rise in arousal, as perceptual variation can alleviate vigilance effects (Thomson, Smilek, & Besner, 2015).

Different nonlinear effects for the relationship of driving duration and driver speed were found during mind wandering versus on-task states, as mind wandering showed a greater amount of fluctuation over driving duration compared to the on-task state. Speed variations can negatively impact both driver safety and overall traffic flow (Stavrinos et al., 2013). Given how commonly mind wandering occurs on the road (~11% of accidents according to NHTSA, 2008) and in general (~50% of total wake time according to Killingsworth & Gilbert, 2010), and mitigation strategies such as removing the source of external distraction would not apply to this internal distraction, the potential impact on overall traffic flows on the road due to mind wandering could be profound. In addition, with the increasing levels of automation in vehicles, drivers may no longer need to execute sub-driving-tasks such as speed control and lane maintenance (e.g., Merat, Jamson, Lai, Daly, & Carsten, 2014), and subsequently experience more mind wandering due to the boredom rising from a "task-deprived" state. Understanding how mind wandering could change over driving duration and potentially impact performance is critical to road safety with high levels of vehicle automation, particularly when take-over events occur. Given the nonlinear relationship of driving duration and mind wandering, it is important to consider the use of nonlinear models for future mind wandering studies, as using linear models for nonlinear effects can inflate Type I error.

A number of limitations were present within this study. The generalizability of these results should be considered with some caution, as participants were all undergraduates with a constrained background and age range. Additionally, no distinction was provided for task-related interference in response to thought probes. According to Smallwood et al. (2004), task-related interference corresponds to a "strategic attempt to deploy attentional resources in response to ... demands which exceed one's ability to perform the task." Given the simplicity of following a leading vehicle, task-related interference was likely negligible. To the degree that task-related interference would be present, it would cause mind wandering effect sizes to be underestimated as "on-task" thoughts became a heterogenous category. Finally, only vehicular control measures such as lateral velocity, lateral acceleration, longitudinal velocity, and longitudinal acceleration were analyzed. While these are direct measures of how mind wandering affects drivers' performance on vehicular control, other measures such as visual scanning patterns and reaction time to unexpected braking events which have been found to be sensitive to mind wandering (He et al., 2011; Yanko & Spalek, 2014), were not measured. Further research should aim to understand how these measures may be change over time as a function of mind wandering, and the nature of that relationship.

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