Mind Wandering Behind the Wheel: Performance and Oculomotor Correlates

Jibo He, University of Illinois at Urbana-Champaign, **Ensar Becic,** University of Minnesota, Minneapolis, **Yi-Ching Lee,** Children's Hospital of Philadelphia, Philadelphia, Pennsylvania, and **Jason S. McCarley,** University of Illinois at Urbana-Champaign

Objective: An experiment studied the frequency and correlates of driver mind wandering.

Background: Driver mind wandering is associated with risk for crash involvement. The present experiment examined the performance and attentional changes by which this effect might occur.

Method: Participants performed a car-following task in a high-fidelity driving simulator and were asked to report any time they caught themselves mind wandering. Vehicle control and eye movement data were recorded.

Results: As compared with their attentive performance, participants showed few deficits in vehicle control while mind wandering but tended to focus visual attention narrowly on the road ahead.

Conclusion: Data suggest that mind wandering can engender a failure to monitor the environment while driving.

Application: Results identify behavioral correlates and potential risks of mind wandering that might enable efforts to detect and mitigate driver inattention.

Keywords: driver behavior, mind wandering, attention, distraction, eye movements

Address correspondence to Jason S. McCarley, Beckman Institute, 405 N. Mathews, Urbana, IL 61801; mccarley@illinois.edu.

HUMAN FACTORS
Vol. 53, No. 1, February 2011, pp. 13–21.
DOI: 10.1177/0018720810391530.

INTRODUCTION

Drivers contend with various sources of distraction, including telephone conversations, interactions with in-vehicle information systems, and interactions with passengers (Hanowski, Perez, & Dingus, 2005; Heck & Carlos, 2008). Unfortunately, the cognitive demands imposed by these distractions can impair driver performance. Even hands-free distracting tasks can significantly increase a driver's subjective workload (Alm & Nilsson, 1994, 1995; Matthews, Legg, & Charlton, 2003) and can cause the driver to focus his or her oculomotor scanning narrowly on the region directly in front of the vehicle (Brookhuis, De Vries, & De Waard, 1991; Y. C. Lee, Lee, & Boyle, 2009; Recarte & Nunes, 2000, 2003; Victor, Harbluk, & Engström, 2005). Moreover, even after an object is fixated, cognitive distraction can impede visual detection and recognition (Strayer & Drews, 2007; Strayer, Drews, & Johnston, 2003). Not surprisingly, distraction engenders slow reactions to critical events (e.g., J. D. Lee, Caven, Haake, & Brown, 2001; Y. C. Lee et al., 2009; Strayer & Johnston, 2001; for reviews, see Caird, Willness, Steel, & Scialfa, 2008; Horrey & Wickens, 2006; Ishigami & Klein, 2009) and is a significant risk factor for crash involvement (Neale, Dingus, Klauer, Sudweeks, & Goodman, 2005; Redelmeier & Tibshirani, 1997; Violanti, 1997).

However, not all lapses of attention arise from overt secondary tasks. As demonstrated by a variety of findings, rather, off-task thoughts, or *mind wandering* (Smallwood & Schooler, 2006), can compromise human performance independent of secondary task demands. Mind wandering appears to reflect a default brain state (Mason et al., 2007) that emerges during tasks that are boring or low in processing demand (Forster & Lavie, 2009; Giambra, 1995; Kane et al., 2007). Cognitively, it entails a shift of attention away from the immediate task and context and toward task-irrelevant thoughts (Antrobus, Singer, Goldstein, & Fortgang, 1970; Smallwood, McSpadden, & Schooler, 2008; Smallwood & Schooler, 2006). Mind wandering, at least when it occurs unintentionally or without explicit awareness (Schooler, 2002; Schooler & Schreiber, 2004; Smallwood, McSpadden, & Schooler, 2007), is accompanied by performance losses in a variety of laboratory tasks, including tests of signal detection (Robertson, Manly, Andrade, Baddeley, & Yiend, 1997; Smallwood et al., 2007), reading comprehension (Schooler, Reichle, & Halpern, 2005; Smallwood, McSpadden, et al., 2008), vigilance (Giambra, 1995), and memory (Carriere, Cheyne, & Smilek, 2008). During reading, mind wandering is accompanied by an increase in mean fixation durations and a decrease in sensitivity to lexical factors that normally modulate fixation duration (Reichle, Reineberg, & Schooler, 2010), effects that imply slower and more shallow information processing. Like secondary-task driver distraction (Strayer & Drews, 2007), furthermore, mind wandering entails a decrease in the strength of the P300 component of the event-related potential (ERP; Smallwood, Beach, Schooler, & Handy, 2008), a marker of attentional processing depth (Kutas, McCarthy, & Donchin, 1977).

Not surprisingly, driver mind wandering is a risk factor for crash involvement. In the classic Indiana Tri-Level Study of the Causes of Traffic Accidents (Treat et al., 1979), 56% of the in-depth crash cases analyzed involved failures of visual recognition, and among these, 15% involved drivers who were preoccupied by competing thoughts at the time of the accident. More recent analyses of crashes involving failures of driver attention have found that roughly 5% of the drivers were not engaged in a secondary task or attending to external distractors at the time of their crash but could be classified simply as "inattentive/lost in thought" (Stutts, Reinfurt, Staplin, & Rodgman, 2001) or "not paying attention/daydreaming" (Glaze & Ellis, 2003). Other work has found correlations between crash risk and a questionnaire measure of everyday inattentiveness (Larson, Alderton, Neideffer, & Underhill, 1997) and between accident risk and the tendency to participate in cognitive activities, such as daydreaming or thinking about personal problems, while driving (Violanti & Marshall, 1996).

Thus, like secondary-task distraction, mind wandering appears to compromise driver performance. Little is yet known, however, about the behaviors or performance changes by which mind wandering might engender driver risk, information that may be valuable for efforts to detect or mitigate inattentiveness (e.g., Donmez, Boyle, & Lee, 2006; D'Orazio, Leo, Guaragnella, & Distante, 2007; J. D. Lee, 2009). The goal of the present experiment was therefore to identify changes in driver behavior and performance that occur during mind wandering. Participants performed a car-following task in a high-fidelity driving simulator, and measures of vehicle control and oculomotor behavior were compared during and after episodes of self-reported mind wandering. Episodes of mind wandering were detected through a self-caught procedure in which participants were simply asked to report any time they found themselves mind wandering, a methodology that past work has validated for detecting unintentional episodes of off-task thought (Giambra, 1989; Schooler et al., 2005; Smallwood & Schooler, 2006). For converging evidence of self-report validity in the current task, the simulated driving environment varied between no-wind and heavy-wind conditions. Because vehicle control should demand more attention in heavy wind than in no wind, heavy wind should allow for fewer episodes of mind wandering.

Note that J. D. Lee, Young, and Regan (2009) distinguished *driver distraction*, the "diversion of attention away from activities critical for safe driving toward a competing activity" (p. 34) from *driver inattention*, "diminished attention to activities that are critical for safe driving in the absence of a competing activity" (p. 32). By these definitions, mind wandering might be considered a form of distraction in which off-task thinking is the competing task (cf. Wickens & Horrey, 2009). However, in keeping with the terminology of the studies described above and of the mind wandering literature, we use the term *inattention* to describe mind wandering and use the term *secondary-task distraction* to describe failures of attention that accompany an overt competing task.

METHOD

Participants

Eleven female and 7 male participants (mean age = 22 years, *SD* = 3.3) were recruited from the community of the University of Illinois. All participants were screened to ensure normal or corrected-to-normal vision, at least 4 years of experience as a licensed driver, and no history of simulator sickness. Participants' mean self-reported driving distance per year was 5,600 miles (range = 100 to 15,000 miles). Participants were paid $8 per hour for a 2.5-hr experimental session.

Apparatus

Data were collected in a fully immersive, fixed-base driving simulator consisting of a 1998 Saturn SL body within a wraparound environment with 135° forward and rear visual fields. Eight Epson Powerlite 703C projectors (1,024 × 768 pixels of resolution) projected the driving scenes onto eight separate screens. Road and traffic information was visible through the interior and exterior rear view mirrors.

Simulator control dynamics were modeled after a four-door Saturn sedan. The driving environments and traffic scenarios were created using HyperDrive Authoring Suite Version 1.6.1 and displayed by Drive Safety's Vection Simulation Software (Version 1.6.1; DriveSafety, 2004). Measures of driving performance were sampled at 60 Hz. Eye and head movements were sampled at 30 Hz with a Smart Eye Pro 3.0 system (SmartEye AB, 2004) with the use of three dashboard-mounted Sony XC HR50 monochrome cameras. The Smart Eye system estimates gaze position by tracking facial features and matching them to a driver profile established during a calibration procedure. Because gaze position estimates are based on an array of facial features tracked with multiple cameras, the system is robust against occasional feature occlusions. Time-stamped simulator and eye tracker data were synchronized and combined for analysis in postprocessing.

Driving Environment and Task

The simulated driving environment comprised a straight, two-lane rural road with small hills on one side and pasture, cattle, and houses on the other. There was no traffic in the opposing lane. The driving environment was purposely dull to encourage mind wandering (Kane et al., 2007). The road was divided into two segments, one with no wind and the other with heavy lateral wind. Direction of the wind, leftward or rightward, varied randomly within segments. The sequence of the no-wind and heavy-wind segments was counterbalanced across drives. The participants did not know the sequence of the wind conditions before beginning each drive, and did not know the location at which the wind conditions would change.

A car-following task tested the participants' vehicle control. Participants were asked to maintain lateral control and a safe headway distance while following a lead car (a blue Grand Prix) and keeping ahead of a trailing car (a red Grand Prix). The trailing vehicle was used to motivate participants to check their mirrors. The lead car drove at an average speed of 45 mph, accelerating or decelerating within the range from 40 mph to 50 mph at random intervals. The participants' car began each drive positioned midway between the lead and the following vehicle, which maintained a constant distance of 200 m from each other. Participants were told to keep their attention on the driving task as much as possible and were instructed that they should press a button on the steering wheel to report any time they found themselves mind wandering. To clarify the task for them, participants were given a definition and examples of mind wandering. Mind wandering was defined as "thinking about any task-unrelated images and thoughts," and behind-the-wheel mind wandering was illustrated with the examples of planning a schedule, having recollections of childhood, or simply having a blank mind.

Procedure

After arriving at the lab, participants completed an informed consent form, a screening questionnaire inquiring about their driving experience and propensity for simulator sickness, and a demographic questionnaire. After the calibration procedure for the eye tracker, participants were provided with a description of the experimental task and then completed a practice drive including both no-wind and heavy-wind conditions to familiarize themselves with the simulator and the driving environment. The experiment began after participants reported they understood the task and were comfortable in the simulator. Each participant completed four experimental drives of approximately 15 min each, with rest between drives.

RESULTS

Frequency of Mind Wandering

Participants reported more episodes of mind wandering per drive in no-wind conditions ($M = 5.69$) than in heavy-wind conditions ($M = 3.72$), $t(17) = 3.67, p < .01$. Thus, as expected, driving conditions that placed heavier demands on attention appeared to produce fewer episodes of mind wandering.

Correlates of Mind Wandering

Further analyses were carried out to determine how performance changed during mind wandering. For this purpose, the time window from –13 s to –4 s prior to each button press was designated as a mind wandering interval and the window from 20 s to 29 s after the button press as an attentive interval. Intervals were limited to 10-s duration to minimize the risk that analysis would extend beyond the onset of each mind wandering episode (cf. Smallwood, Beach, et al., 2008), as past work has indicated that the mean interval between shifts of thought topic is roughly 14 s (Klinger, 1978). The time window from –3 s to 0 s was excluded from analysis to avoid possible contamination from the demand to execute a button press when reporting a mind wandering episode, and the window from 20 s to 29 s postreport was chosen as the interval of attentive driving to eliminate the influence of potential corrective overadjustments to their driving behavior that participants might make immediately when emerging from mind wandering. This therefore represented a conservative test of the potential changes that occurred during mind wandering. Analyses using the time window from 4 s to 13 s postreport as the interval of attentive driving produced effects of mind wandering similar to those reported here.

Dependent measures were analyzed using 2 × 2 within-subject ANOVAs with mental state (mind wandering vs. attentive) and wind turbulence (no wind vs. heavy wind) as factors. Measures chosen for preliminary analysis were the mean and standard deviation of lane position, velocity, headway distance to lead car, time to contact the lead car, and the horizontal and vertical standard deviation of gaze position. Measures of lane position, velocity, headway distance, and time to contact assessed the participants' ability to monitor and control the vehicle, whereas the horizontal and vertical standard deviation of gaze position measured how broadly participants distributed their visual attention. Where appropriate, post hoc analyses of additional measures explored effects revealed by the analyses of preliminary measures.

No collisions between the participants' vehicle and either the lead or the following vehicle occurred during data collection. Because 2 participants reported no episodes of mind wandering in either the no-wind or heavy-wind condition, analyses reported as follows included data from only 16 participants.

Lateral control. Lateral vehicle control was assessed through analysis of mean and standard deviation of lane position. Mean of lane position was analyzed as the offset in meters of the vehicle's center from the center of the lane. Positive values indicate offset to the right of the lane, and negative values indicate offset to the left. Average offset values were positive, indicating that participants generally drove to the right of the lane. Analysis revealed a reliable main effect indicating that participants drove farther to the right in heavy-wind conditions than in no-wind conditions ($M = .013$ m vs. 0.09 m), $F(1, 15) = 5.91, p = .03, \eta^2_{partial} = .28$, but showed a nonreliable main effect of mental state, $F(1, 15) = 3.14, p = .10, \eta^2_{partial} = .17$, and a nonreliable interaction, $F < 1$. Analysis of the standard deviation of lane position likewise produced a highly reliable main effect indicating greater variability in heavy-wind conditions ($M = .02$ m vs. 0.19 m), $F(1, 15) = 111.29, p < .01, \eta^2_{partial} = .88$, but no reliable main effect of mental state and no reliable interaction, both Fs < 1.

Longitudinal control. Preliminary analyses of longitudinal vehicle control examined means and standard deviations of velocity, headway distance to the lead car, and time to contact the lead car. Mean velocity showed no reliable effects, all Fs < 1, a finding that is unsurprising given that the participant's mean velocity was determined by the velocity of the lead and trailing vehicles. The remaining five measures of longitudinal control all showed reliable main effects indicating higher means and higher variability in heavy wind, all ps < .01. However, only one measure, the standard deviation of velocity, produced a reliable main effect of mental state, indicating slightly lower variability during mind wandering than during attentive driving (M = .03 m/s vs. .04 m/s), $F(1, 15) = 6.73$, $p = .02$, $\eta^2_{\text{partial}} = .31$. The interaction of Wind Turbulence × Mental State was nonsignificant in all measures, all Fs ≤ 1.03.

Vertical and horizontal deviation of gaze position. Approximately 14% of gaze data samples were dropped during eye tracking. However, the pattern of effects reported next was unchanged when data were reanalyzed to include only those participants for whom less than 10% of samples was dropped (n = 9, M = 5.2% of samples dropped).

Analysis of mean values of the standard deviation of horizontal eye position (Figure 1) produced neither a reliable main effect of wind turbulence, $F < 1$, nor a reliable interaction, $F(1, 15) = 2.94$, $p = .11$, $\eta^2_{\text{partial}} = .16$, but did reveal a reliable main effect of mental state, $F(1, 15) = 14.19$, $p < .01$, $\eta^2_{\text{partial}} = .49$, indicating that the horizontal dispersion of the participants' gaze was smaller during mind wandering than during attentive driving. To examine this effect more closely, a further analysis assessed the proportion of gaze dwell time spent in the side mirrors (Figure 2). Left- and right-side checks were combined for analysis. Analysis produced no reliable main effect of wind condition and no reliable interaction, both Fs < 1, but did evince a reliable main effect indicating less time spent gazing at the side mirrors during mind wandering than during attentive driving (M = 6% vs. 8%), $F(1, 15) = 8.42$, $p = 0.01$, $\eta^2_{\text{partial}} = .36$. Eye tracking data did not allow for analysis of rearview mirror checks.

Analysis of the standard deviation of vertical gaze position produced a reliable main effect

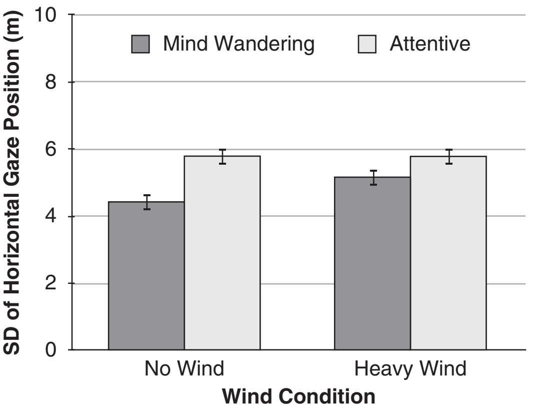

Figure 1. Mean of the standard deviation of horizontal gaze position as a function of mental state and wind turbulence. Error bars indicate within-subject standard errors (Loftus & Masson, 1994) based on the main effect of mental state.

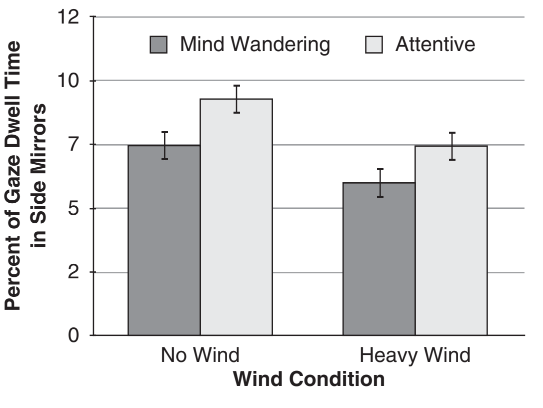

Figure 2. Percentage gaze dwell time spent in the side mirrors as a function of mental state and wind turbulence. Error bars indicate within-subject standard errors (Loftus & Masson, 1994) based on the main effect of mental state.

indicating broader vertical scanning in heavy wind than in no wind (M = .10 m vs. .08 m), $F(1, 15) = 7.16$, $p = .02$, $\eta^2_{\text{partial}} = .32$, but showed no reliable main effect of mental state, $F < 1$, and no reliable interaction, $F(1, 15) = 1.42$, $p = .25$, $\eta^2_{\text{partial}} = .09$.

DISCUSSION

On average, participants reported multiple instances of mind wandering during each 15-min drive, and as expected, mind wandering was less frequent when wind conditions made the driving task more demanding of attention. Lateral vehicle control appeared robust to mind wandering, showing no reliable differences between intervals of inattentive and attentive driving. Longitudinal control showed only modest changes during inattention, with drivers showing a decrease in the variability of velocity but no changes in headway distance or time to contact the lead vehicle. Mind wandering was accompanied, however, by a narrowing of visual attention, with drivers gazing less at their side mirrors and reducing the horizontal dispersion of gaze position, much as they do during secondary-task distraction (Brookhuis et al., 1991; Y. C. Lee et al., 2009; Recarte & Nunes, 2000, 2003; Victor et al., 2005).

The current data thus suggest that driver mind wandering entails a failure to scan or monitor the environment, an effect that might easily contribute to the increased crash risk associated with behind-the-wheel inattentiveness (Larson et al., 1997; Violanti & Marshall, 1996). These results add to a large and growing body of evidence that cognitive load can compromise driver performance and document that this compromise can occur even in the absence of overt secondary distraction. This of course does not imply that the performance consequences of mind wandering are the same as those of secondary-task distraction (Smallwood, Baracaia, Lowe, & Obonsawin, 2003). For example, although susceptibility to mind wandering varies with primary-task demands (e.g., Forster & Lavie, 2009; Giambra, 1995; Kane et al., 2007; Smallwood, Baracaia, et al., 2003; Smallwood, Obonsawin, & Heim, 2003), the frequency, content, and cognitive demands of mind wandering are only indirectly controlled by the external world. In contrast, secondary-task load can be imposed and modulated very directly by the agent's environment (cf. Drews, Pasupathi, & Strayer, 2008). Secondary-task distraction may thus be more difficult to disengage from than mind wandering. Secondary-task load may also have inherently stronger or deeper consequences than mind wandering. As noted earlier, both mind wandering and secondary-task distraction decrease the strength of the P300 component of the ERP (Smallwood, Beach, et al., 2008; Strayer & Drews, 2007). Secondary-task distraction, however, has also been shown to delay P300 onset (Strayer & Drews, 2007), whereas mind wandering has not (Smallwood, Beach, et al., 2008). Nonetheless, the present results suggest that mind wandering can affect driver performance in at least some ways similar to secondary-task distraction.

Mind wandering–related performance losses beyond those observed here, of course, are also possible. Most notably, the current experimental procedure, using the self-caught method of detecting mind wandering episodes, did not allow for comparing drivers' responses to road hazards or sudden critical events (e.g., the onset of brake lights in a lead car) during periods of mind wandering and attentiveness. Alternative methods of detecting mind wandering (Smallwood & Schooler, 2006) can potentially do so, however, and past findings (Robertson et al., 1997; Smallwood et al., 2007; Smallwood, Beach et al., 2008) along with the data reported above suggest that mind wandering is likely to hinder the ability to notice and respond to external events demanding quick action. The design of current driving task might also have hidden or mitigated additional possible changes in car following during mind wandering. Here, a trailing car followed the participant's vehicle, maintaining a constant separation from the lead car. As noted, the purpose of the trailing vehicle was to provide incentive for participants to check their rearview and side mirrors. The presence of a trailing vehicle, however, might also have encouraged participants to maintain a higher speed or lower headway distance during mind wandering than they otherwise would. Indeed, drivers with secondary-task distraction often decrease their speed (e.g., Alm & Nilsson, 1994; Haigney, Taylor, & Westerman, 2000) or increase headway distance (e.g., Kubose et al., 2006; Strayer, Drews, & Crouch, 2006). Further work will be necessary to determine whether such changes might occur during mind wandering when there is no trailing vehicle to discourage them.

More interestingly, the study of mind wandering may explain *why* such performance changes occur during secondary-task distraction. Decreases in speed and increases in headway distance can increase a distracted driver's margin of safety and are often interpreted as compensatory strategies for mitigating the costs of high cognitive load (Alm & Nilsson, 1994; Haigney et al., 2000). However, other data question the idea that distracted drivers modulate their behavior to minimize risks. Drivers generally underestimate the performance costs of secondary-task distraction, for example (Horrey, Lesch, & Garabet, 2008; Lesch & Hancock, 2004; White, Eiser, & Harris, 2004), implying that they may feel little need to modulate their behavior in response to a distracting task. Moreover, even drivers who increase their car-following headway during secondary-task distraction may fail to show any compensatory changes when performing the more complex maneuver of passing a car (Horrey & Simons, 2007). These results suggest that performance changes that appear to compensate for the risks of secondary-task distraction may not actually be purposeful adaptations to high load but might rather be among the unintended consequences of high load. Performance changes that look like strategic *responses* to distraction, that is, might in fact be the inherent *products* of that distraction. Methods for distinguishing strategic from nonstrategic performance changes may therefore be necessary to gauge the full mental toll of driver distraction and inattention.

The study of mind wandering may provide one such method. Strategic compensatory behaviors are difficult to distinguish from unintended consequences of secondary-task distraction because drivers will often, if not always, be aware that they are performing a secondary task. In contrast, mind wandering that occurs without a driver's conscious awareness disallows intentional compensatory behaviors. Performance changes that occur before a report of self-caught mind wandering, and presumably before the driver has become conscious of mind wandering, cannot be attributed to strategic behavioral changes. Such effects will thus be more likely to reflect inherent and unintended consequences of inattention or, at best, automatic and nonconscious adaptations to inattention. By differentiating between strategic and nonstrategic consequences of inattention, the study of mind wandering might thus inform the understanding of distracted driving more generally.

KEY POINTS

- Driver mind wandering is a risk factor for crash involvement.
- Participants in the current study were asked to report self-caught episodes of mind wandering while they performed a car-following task in a high-fidelity simulator.
- During mind wandering, participants tended to scan the environment more narrowly.

REFERENCES

Alm, H., & Nilsson, L. (1994). Changes in driver behaviour as a function of handsfree mobile phones: A simulator study. *Accident Analysis & Prevention*, *26*, 441–451.

Alm, H., & Nilsson, L. (1995). The effect of mobile telephone task on driver behavior in a car following situation. *Accident Analysis & Prevention*, *27*, 707–715.

Antrobus, J. S., Singer, J. L., Goldstein, S., & Fortgang, M. (1970). Mindwandering and cognitive structure. *Transactions of the New York Academy of Science (Series 2)*, *32*, 242–252.

Brookhuis, K. A., De Vries, G., & De Waard, D. (1991). The effects of mobile telephoning on driving performance. *Accident Analysis & Prevention*, *23*, 309–316.

Caird, J. K., Willness, C. R., Steel, P., & Scialfa, C. (2008). A meta-analysis of the effects of cell phones on driver performance. *Accident Analysis & Prevention*, *40*, 1282–1293.

Carriere, J. S. A., Cheyne, J. A., & Smilek, D. (2008). Everyday attention lapses and memory failures: The affective consequences of mindlessness. *Consciousness and Cognition*, *17*, 835–847.

Donmez, B., Boyle, L. N., & Lee, J. D. (2006). The impact of distraction mitigation strategies on driving performance. *Human Factors*, *48*, 785–804.

D'Orazio, T., Leo, M., Guaragnella, C., & Distante, A. (2007). A visual approach for driver inattention detection. *Pattern Recognition*, *40*, 2341–2355.

Drews, F. A., Pasupathi, M., & Strayer, D. L. (2008). Passenger and cell phone conversations in simulated driving. *Journal of Experimental Psychology: Applied*, *14*, 392–400.

DriveSafety. (2004). Vection simulation software (Version 1.6.1) [Computer software]. Available from http://www.drivesafety.com

Forster, S., & Lavie, N. (2009). Harnessing the wandering mind: The role of perceptual load. *Cognition*, *111*, 345–355.

Giambra, L. M. (1989). Task-unrelated thought frequency as a function of age: A laboratory study. *Psychology and Aging*, *4*, 136–143.

Giambra, L. M. (1995). A laboratory method for investigating influences on switching attention to task-unrelated imagery and thought. *Consciousness and Cognition*, *4*, 1–21.

Glaze, A. L., & Ellis, J. M. (2003). *Pilot study of distracted drivers*. Richmond, VA: Survey and Evaluation Research Laboratory, Center for Public Policy, Virginia Commonwealth University.

Haigney, D., Taylor, R., & Westerman, S. (2000). Concurrent mobile (cellular) phone use and driving performance: Task demand characteristics and compensatory processes. *Transportation Research Part F: Traffic Psychology and Behaviour*, *3*, 113–121.

Hanowski, R. J., Perez, M. A., & Dingus, T. A. (2005). Driver distraction in long-haul truck drivers. *Transportation Research Part F: Traffic Psychology and Behavior*, *8*, 441–458.

Heck, K., & Carlos, R. (2008). Passenger distractions among adolescent drivers. *Journal of Safety Research*, *39*, 437–443.

Horrey, W. J., Lesch, M. F., & Garabet, A. (2008). Assessing the awareness of performance decrements in distracted drivers. *Accident Analysis & Prevention*, *40*, 675–682.

Horrey, W. J., & Simons, D. J. (2007). Examining cognitive interference and adaptive safety behaviours in tactical vehicle control. *Ergonomics*, *50*(8), 1340–1350.

Horrey, W. J., & Wickens, C. D. (2006). Examining the impact of cell phone conversations on driving using meta-analytic techniques. *Human Factors*, *48*, 196–205.

Ishigami, Y., & Klein, R. (2009). Is a hands-free phone safer than a handheld phone? *Journal of Safety Research*, *40*, 157–164.

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

Klinger, E. (1978). Modes of normal conscious thought. In K. S. Pope & J. L. Singer (Eds.), *The stream of consciousness: Scientific investigations into the flow of human experience* (pp. 225–258). New York, NY: Plenum.

Kubose, T., Bock, K., Dell, G., Garnsey, S., Kramer, A., & Mayhugh, J. (2006). The effects of speech production and speech comprehension on simulated driving performance. *Applied Cognitive Psychology*, *20*, 43–63.

Kutas, M., McCarthy, G., & Donchin, E. (1977). Augmenting mental chronometry: The P300 as a measure of stimulus evaluation time. *Science*, *197*, 792–795.

Larson, G. E., Alderton, D. L., Neideffer, M., & Underhill, E. (1997). Further evidence on dimensionality and correlates of the Cognitive Failures Questionnaire. *British Journal of Psychology*, *88*, 29–38.

Lee, J. D. (2009). Can technology get your eyes back on the road? *Science*, *324*, 344–346.

Lee, J. D., Caven, B., Haake, S., & Brown, T. L. (2001). Speech-based interaction with in-vehicle computers: The effect of speech-based e-mail on drivers' attention to the roadway. *Human Factors*, *43*, 631–640.

Lee, J. D., Young, K. L., & Regan, M. A. (2009). Defining driver distraction. In M. A. Regan, J. D. Lee, & K. L. Young (Eds.), *Driver distraction: Theory, effects, mitigation* (pp. 31–40). Boca Raton, FL: CRC Press.

Lee, Y. C., Lee, J. D., & Boyle, L. N. (2009). The interaction of cognitive load and attention-directing cues in driving. *Human Factors*, *51*, 271–280.

Lesch, M. F., & Hancock, P. A. (2004). Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? *Accident Analysis & Prevention*, *36*, 471–480.

Loftus, G. R., & Masson, M. E. J. (1994). Using confidence intervals in within-subjects designs. *Psychonomic Bulletin & Review, 1*, 476–490.

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T., & Macrae, C. N. (2007). Wandering minds: The default network and stimulus-independent thought. *Science*, *315*, 393–395.

Matthews, R., Legg, S., & Charlton, S. (2003). The effect of cell phone type on drivers' subjective workload during concurrent driving and conversing. *Accident Analysis & Prevention*, *35*, 451–457.

Neale, V., Dingus, T., Klauer, G., Sudweeks, J., & Goodman, M. (2005). *An overview of the 100-car naturalistic study and findings* (DOT HS Publication 05-0400). Washington, DC: National Highway Traffic Safety Administration.

Recarte, M. A., & Nunes, L. M. (2000). Effects of verbal and spatial-imagery tasks on eye fixations while driving. *Journal of Experimental Psychology: Applied*, *6*, 31–43.

Recarte, M. A., & Nunes, L. M. (2003). Mental workload while driving: Effects on visual search, discrimination, and decision making. *Journal of Experimental Psychology: Applied*, *9*, 119–137.

Redelmeier, D. A., & Tibshirani, R. J. (1997). Association between cellular-telephone calls and motor vehicle collisions. *New England Journal of Medicine*, *336*, 453–458.

Reichle, E. D., Reineberg, A. E., & Schooler, J. W. (2010). Eye movements during mindless reading. *Psychological Science*, *21*, 1300–1310.

Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). "Oops!" Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, *35*, 747–758.

Schooler, J. W. (2002). Re-representing consciousness: Dissociations between experience and meta-consciousness. *Trends in Cognitive Sciences*, *6*, 339–344.

Schooler, J. W., Reichle, E. D., & Halpern, D. V. (2005). Zoning-out during reading: Evidence for dissociations between experience and meta-consciousness. In D. T. Levin (Ed.), *Thinking and seeing: Visual metacognition in adults and children* (pp. 203–226). Cambridge, MA: MIT Press.

Schooler, J. W., & Schreiber, C. A. (2004). Experience, meta-consciousness, and the paradox of introspection. *Journal of Consciousness Studies*, *11*, 17–39.

Smallwood, J., Baracaia, S. F., Lowe, M., & Obonsawin, M. (2003). Task unrelated thought whilst encoding information. *Consciousness and Cognition*, *12*, 452–484.

Smallwood, J., Beach, E., Schooler, J. W., & Handy, T. C. (2008). Going AWOL in the brain: Mind wandering reduces cortical analysis of external events. *Journal of Cognitive Neuroscience*, *20*, 458–469.

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

Smallwood, J., McSpadden, M., & Schooler, J. W. (2008). When attention matters: The curious incident of the wandering mind. *Memory & Cognition*, *36*, 1144–1150.

Smallwood, J., Obonsawin, M., & Heim, D. (2003) Task unrelated thought: The role of distributed processing. *Consciousness and Cognition*, *12*, 169–189.

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin*, *132*, 946–958.

SmartEye AB. (2004). Smart Eye Pro 3.0 [Computer software]. Available from http://www.smarteye.se

Strayer, D. L., & Drews, F. A. (2007). Cell-phone-induced driver distraction. *Current Directions in Psychological Science*, *16*, 128–131.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. *Human Factors*, *48*, 381–391.

Strayer, D. L., Drews, F. A., & Johnston, W. A. (2003). Cell phone-induced failures of visual attention during simulated driving. *Journal of Experimental Psychology: Applied*, *9*, 23–32.

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science*, *12*, 462–466.

Stutts, J. C., Reinfurt, D. W., Staplin, L., & Rodgman, E. A. (2001). *The role of driver distraction in traffic*. AAA Foundation for Traffic Safety Crashes. Retrieved from http://www.aaafoundation.org/pdf/distraction.pdf

Treat, J. R., Tumbas, N. S., McDonald, S. T., Shinar, D., Hume, R. D., Mayer, R. E., Stansifer, R. L., & Catellan, N. J. (1979). *Tri-Level Study of the Causes of Traffic Accidents: Final report Volume 1. Causal factor tabulations and assessments* (DOT HS-805 085). Bloomington: Indiana University, Institute for Research in Public Safety.

Victor, T. W., Harbluk, J. L., & Engström, J. A. (2005). Sensitivity of eye-movement measures to in-vehicle task difficulty. *Transportation Research Part F: Traffic Psychology and Behaviour*, *8*, 167–190.

Violanti, J. M. (1997). Cellular phones and traffic accidents. *Public Health*, *111*, 423–428.

Violanti, J. M., & Marshall, J. R. (1996). Cellular phones and traffic accidents: An epidemiological approach. *Accident Analysis & Prevention*, *28*, 265–270.

White, M., Eiser, J., & Harris, P. (2004). Risk perceptions of mobile phone use while driving. *Risk Analysis*, *24*, 323–334.

Wickens, C. D., & Horrey, W. J. (2009). Models of attention, distraction and highway hazard avoidance. In M. A. Regan, J. D. Lee, & K. L. Young (Eds.), *Driver distraction: Theory, effects and mitigation* (pp. 57–69). Orlando, FL: CRC Press.

Jibo He received a BS in psychology and a BA in economics from Peking University in 2007 and is currently a PhD student in the Department of Psychology at the University of Illinois at Urbana-Champaign.

Ensar Becic received a PhD in psychology from the University of Illinois at Urbana-Champaign in 2009 and is currently a research associate in the Center for Transportation Studies at the University of Minnesota, Minneapolis.

Yi-Ching Lee received her PhD in industrial engineering from the University of Iowa, Iowa City, in 2006 and is currently a human factors researcher in the Center for Injury Research and Prevention at the Children's Hospital of Philadelphia.

Jason S. McCarley received his PhD in experimental psychology from the University of Louisville, Kentucky, in 1997 and is currently an assistant professor in the Department of Psychology at the University of Illinois at Urbana-Champaign.

Date received: April 18, 2010
Date accepted: October 27, 2010