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Effects of Mindfulness Training on Simulated Driving: Preliminary Results

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Abstract Mindfulness training was examined in relation to drivers' (ages 21 to 38 years) situation awareness and performance. University students enrolled in a Buddhist psychology class were taught concentration techniques in which they were instructed to focus their attention on their breath and mindfulness techniques in which they learned to objectively notice whatever arises in consciousness. These students were to practice these techniques in their everyday activities in order to improve their mindfulness and concentration. Students enrolled in a human factors psychology course served as the control group in which they were not taught mindfulness training exercises. Students in the Buddhist psychology course scored significantly highly on a scale used to assess their ability to concentrate, though differences in mindfulness between the groups were not significant. Situation awareness was assessed using a query method in a driving simulator. Mindfulness and concentration levels were both significantly related to situation awareness for driving (rs=0.80 and 0.61, respectively). Mindfulness training may greatly impact actual driving performance over time by improving drivers' awareness of their environment and enabling them to block out distractions and to quickly identify hazards. Whereas recent technological advances for improving driving safety (e.g., tactile warnings) have been studied, mental exercises for improving SA in driving have only recently been studied and warrant further research.

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Introduction

In the USA, automobile accidents claim the lives of approximately 40,000 individuals annually (US Census Bureau 2011). In 2009, 16% of these fatalities were categorized as distracted driving incidents, which is a significant increase from the 10% of fatalities that were categorized as distracted driving incidents in 2005 (National Highway Traffic Safety Administration 2011). This alarming trend has led to distracted driving becoming recognized as a social epidemic (US Department of Transportation 2010).

While public focus appears to be on eliminating mobile phone usage as a solution to distracted driving, many researchers are also interested in any component that may contribute to driver distraction. Researchers have identified potential cognitive causes of distracted driving by investigating the role of attention (Baldock et al. 2007; Weaver et al. 2009), cognitive load (Forster and Lavie 2008; Horrey and Wickens 2006; Recarte and Nunes 2003), risk perception (Rhodes and Pivik 2011; Vanlaar and Yannis 2006), and situation awareness (Kass et al. 2007). This research often allows for applications that focus on improving driver attention and safety through technological devices such as haptic seat displays (Fitch et al. 2007), lane departure warnings (Jermakian 2011; Kozak et al. 2006), and adaptive cruise control (Vollrath et al. 2011).

Although cognitive processing has been a main interest of driving researchers, training programs to enhance cognitive processing have mostly been studied in specialized driving populations such as older adults (Ackerman

et al. 2008; Edwards et al. 2009; Vance et al. 2010). The cognitive training programs, which may alter the manner in which internal and external distractions are handled, have proven to be useful in improving driving performance. For example, Ball et al. (2010) found that older adults who completed a 5-week cognitive training program in speed of processing and reasoning had decreased incidents of real-world collisions in the 6 years following the training programs. Interestingly, there has been very little research that has examined the effect of cognitive training in combating driver distraction in younger adults. The current study examines this area by assessing the role of mindfulness training in simulated driving performance.

Mindfulness has been described as openness to novelty, alertness to distinction, sensitivity to different contexts, awareness of multiple perspectives, and orientation in the present (Demick 2000; Langer 1997). Kabat-Zinn (2003) defined mindfulness as "the awareness that emerges through paying attention on purpose, in the present moment, and nonjudgmentally to the unfolding of experience moment by moment" (p. 145). According to Mikulas (2007, 2011), mindfulness is moving and sharpening the focus of awareness within the field of consciousness. Mindfulness has been shown to alter both lower-level processing, such as simple reaction time (van den Hurk et al. 2010b), and upper-level cognitive processing, such as attention, executive functioning, and working memory capacity (for a review, see Chiesa et al. 2011). Training in mindfulness has been shown to improve performance (i.e., greater ability at ignoring distracters) on the Embedded Figures Test (Kubose 1976), improved sustained attention on an auditory counting task (Valentine and Sweet 1999), and greater levels of orienting and executive attention in the Attention Network Test (van den Hurk et al. 2010a).

In order to optimize mindfulness, some degree of concentration is required (Mikulas 1986, 2007). Concentration involves actively maintaining controlled focus of attention for designated periods of time. In developing concentration, an individual learns through direct experience how to quiet the mind's inner dialog and ruminations. As a result, it becomes easier to notice when the mind has wandered, where it has gone, and how to gently but firmly bring attention back to the object or task (Mikulas 1986). Baer (2007) suggested that airline pilots may benefit from mindfulness training by being able to redirect the mind away from problematic thoughts and feelings (reducing stress and anxiety), thus improving their ability to focus on the task at hand. Such an approach may prove beneficial to drivers as well.

In concentration meditation, the mind and body often become relaxed. Barnes et al. (2001) demonstrated that transcendental meditation was effective in decreasing systolic blood pressure, heart rate, and cardiac output during simulated driving sessions. Results also showed that meditation participants drove at higher maximum speeds than the control group. Barnes et al. (2001) suggested that instead of arousal level affecting perceptual-motor coordination, the meditation first improved perceptual-motor coordination, which in turn led to the ability to lower the level of sympathetic arousal. This is consistent with previous studies of meditation and reaction time (Holt et al. 1978).

Concentration via meditation practices differs from simple relaxation techniques in that it has the potential to improve selective attention and attention span (Langer and Moldoveanu 2000). For instance, Rutschman (2004) found that, using a divided-attention task, meditation and relaxation showed improvements in success on simultaneous tasks; however, meditation increased sustainability in attentional processes beyond those of relaxation. The ability to maintain sustained attention and avoid distractions can be vital to safe driving.

An increase in attention while driving may allow drivers to increase situation awareness (SA), which is the ability to attend to a dynamic environment and involves the extraction, integration, and assessment of task-relevant information (Kass et al. 1991). Endsley (1988) described SA as comprising three levels: perception (e.g., current speed, presence of other vehicles or pedestrians, traffic signs and signals), comprehension (e.g., understanding what a yield sign denotes in the context of current traffic patterns), and projection (e.g., a driver, attempting to merge into traffic, accurately predicts that it is safe to do so based on the relative speed and direction of oncoming vehicles). Driving performance, although seemingly automatic to experienced drivers, is actually a complex task that requires continual analysis (Ma and Kaber 2007). High levels of SA should allow drivers to take appropriate actions to avoid collisions and other hazards. Likewise, Baer et al. (2009) noted that mindfulness implies an awareness of one's actions and not operating on *automatic pilot*. This may suggest that increasing SA through mindfulness training may serve as an effective strategy for improving driver safety and preventing driving violations.

To test this hypothesis, this study examined whether drivers who received mindfulness training had greater SA and better performance in a simulated driving environment than did a control group.

Method

Participants

Sixteen participants were recruited from psychology courses at the University of West Florida (eight men, eight

women). Half of the participants were students in a Buddhist psychology course (five men, three women) which emphasized the Eastern practices of mindfulness and concentration. Control participants (three men, five women) were recruited from a human factors psychology course, which emphasized human–machine interaction. The mean age of participants was 24.9 years (SD=4.7) and did not differ significantly between groups. All participants possessed a valid driver's license and, as a whole, drove an average of 242.85 km (150.90 miles) per week (SD= 194.73 km, 121.00 miles). The average driving distance per week did not differ significantly by group.

Materials

The Mindfulness Questionnaire is composed of 45 statements pertaining to awareness which are rated on a 5-point Likert scale indicating how often the statement is true (e.g., I lose track of time; I notice how my beliefs often influence what I see and how I feel). This scale was found to be highly reliable in the current study, possessing an internal consistency of α=0.92. The Concentration Scale is composed of 46 items pertaining to one's focus and control of attention that are also rated on a 5-point Likert scale indicating how often the statement is true (e.g., I am unable to focus on what I want to focus on; I find my mind racing uncontrollably). This scale was also found to be highly reliable, α=0.96. Some construct validity evidence is provided through the relationship of these scales to other measures of attention. Krawietz et al. (2007) found that scores on the Mindfulness Questionnaire and Concentration Scale were related to scores on Farmer and Sundberg's (1986) Boredom Proneness Scale (r=−0.37 and r=−0.56, respectively) and the Adult Behavior Checklist (Barkley et al. 1996) for assessing attention deficit/hyperactivity disorder (r=−0.30 and r=−0.60, respectively).

Driving performance was assessed in a simulator using STISIM Drive software (2003) (developed by Systems Technology, Inc.). The driving scene was projected on the wall in front of participants using an NEC NP60 projector with the image measuring approximately 4 by 7 ft. Participants controlled the vehicle using Logitech G-25 pedals and steering wheel. To become familiar with the vehicle dynamics, participants first drove a 5- to 6-min practice scenario containing suburban roads with only a few programmed hazardous events (e.g., cars backing out of driveways). The 5.18-km (3.22-mile) testing session lasted approximately 10 to 12 min and was similar to the practice scenario, but with additional urban roads and more hazardous events. The scenario was purposely designed to be challenging so that any impaired attention would be likely to have negative consequences. The scenario required that the participants travel on a continuous roadway with minimal lane changes and without any turns greater than 90°. Driving performance was measured by the number of traffic miscues (i.e., traffic light/stop sign violations, collisions with other vehicles or pedestrians, and speeding).

To assess SA, a procedure based on Endsley's (1995) Situation Awareness Global Assessment Technique was used (see also Kass et al. 2007). During the scenario, the simulator was paused three times, and participants were asked three questions (nine total) pertaining to the scenario (e.g., What is the current posted speed limit? Were there pedestrians at the last intersection?). These questions assessed participants' awareness of the environment.

Procedure

Participants from the Buddhist psychology course were required to actively engage in mindfulness and concentration exercises during the 15-week semester. The course was taught by a professor with extensive knowledge of mindfulness training exercises. This instructor has over 40 years of research and practical experience in the area of mindfulness and has conducted many mindfulness and meditation workshops all over the world. Each class period consisted of 2 h of lecture and/or discussion and 1 h of laboratory time. Mindfulness and concentration techniques were described during lectures, but further instruction and practice, as well as other activities (e.g., using mantras, creating mandalas, other meditation techniques), were conducted during the laboratory portion of the course. Laboratory exercises typically built upon the previous weeks' exercises, material, and assignments. Exercises during the first half of the semester focused primarily on concentration skills (e.g., quieting of the mind). Students were taught to pay attention to their own breath, to notice when their minds wandered, and to gently, but firmly, bring their attention back onto their breath. They were asked to practice this technique in real-world settings (e.g., control mind wandering when talking with others or when listening to music). During the second half of the semester, training exercises focused primarily on mindfulness. This training followed the formal sequence of Vipassana (i.e., Theravada mindfulness meditation). Students were taught to cultivate an awareness of where their mind goes (e.g., thoughts, sounds) and to notice the thoughts and the feelings that are triggered. To verify that students were practicing mindfulness and concentration outside of the classroom, they were required to either keep a log or write a paper describing their experiences with the techniques. Students were given a specific list of topics they were required to include in their paper or log (e.g., mantras, attitudes, rising and falling of thoughts). Of the 22 students who were enrolled in the course, eight volunteered to participate in the study. Control participants, drawn from the human factors course, did not

engage in these exercises. Of the 32 undergraduate students enrolled in this class, eight volunteered to participate. At the end of the semester, all participants completed the Mindfulness Questionnaire (Mikulas 1990) and the Concentration Scale (Krawietz et al. 2007).

While survey data were collected from all 16 participants, only 14 students kept their scheduled appointments to complete the driving portion of the study (seven in each group), and only 13 of those individuals fully completed the questionnaires (though all 16 students did complete their respective courses). Both groups completed practice and test driving scenarios in a simulator. Students in the experimental group were asked to use what they learned from their mindfulness training exercises in class when driving in the simulator, but did not receive specific directions on how to do so.

Results

To assess the differences between participants in the mindfulness training condition and the control group, scores on the Mindfulness Questionnaire and Concentration Scale were compared across classes toward the end of the 15-week semester. Although the mindfulness training participants scored significantly higher on the Concentration Scale (M=185.57, SD=15.62) than did the control group (M=161.74, SD=25.78), $t(13)=2.12$, $p=0.05$, the difference in scores on the Mindfulness Questionnaire, though in the predicted direction, was not significant (M_{exp}=164.32, SD_{exp}=18.90, vs. M_{ctl}=149.13, SD_{ctl}=19.74), $t(13)=1.52$, $p=0.15$. Participants who completed the mindfulness training answered significantly more SA questions correctly during the simulator pauses (M=6.00, SD=1.00) than did the control group (M=4.43, SD=0.98), $t(12)=2.98$, $p<0.01$. Drivers in the two groups did not differ significantly in their simulated driving performance in terms of the number of speeding violations or collisions with other vehicles or pedestrians. Though drivers in the control group combined to commit more than three times as many traffic light/stop sign violations (M=1.00, SD=0.82) than did those in the mindfulness training group (M=0.29, SD=0.49), $t(12)=1.99$, $p=0.07$, this difference did not reach the criterion (0.05) level of significance.

The results of the t tests indicated that the greater SA demonstrated by the experimental group may be due to members' improved concentration skills, rather than mindfulness. That is, the group that received mindfulness training had both higher scores on concentration and better driving SA, but did not differ on mindfulness. However, these findings do not deny the possibility that mindfulness may affect SA. Instead, it may be possible that mindfulness is a higher-level concept that cannot be effectively trained in a relatively brief period of time and so does not differ between experimental and control groups. To determine if mindfulness does have an effect on SA, both groups were combined. Correlational data indicated that the amount of information about the driving environment recalled correctly (i.e., SA) was significantly related to one's mindfulness (r=0.80, $p<0.01$), as well as to concentration (r=0.61, $p<0.05$). In addition, mindfulness scores were significantly correlated with striking fewer pedestrians (although a rare event overall) in the simulation ($r=-0.61$, $p<0.05$). Despite the moderate ($r=-0.49$, $p=0.09$) correlation between mindfulness scores and the number of traffic light/stop sign violations, this relationship did not reach the criterion (0.05) level of significance, likely due to the small sample size. SA in relation to driving was validated by its strong correlation with traffic light/stop sign violations ($r=-0.65$, $p<0.01$). Other correlations with driving performance measures did not reach significance (see Table 1). This suggests that mindfulness and concentration both contribute significantly to SA, and higher levels of SA are associated with fewer incidents of traffic violations.

Discussion

Any conclusions drawn from the current pilot study must be made with caution. Given the short duration of the driving simulation, it is conceivable that mindfulness training may have a greater impact on driving performance than indicated. That is, despite facing more hazards in the 12-min simulation than one might anticipate in 12 min of

Table 1 Correlations among the constructs of mindfulness, concentration, situation awareness, and driving miscues

	1.	2.	3.	4.	5.	6.	7.
1. Situation awareness	–	0.80**	0.61*	−0.65*	−0.14	−0.11	−0.01
2. Mindfulness		–	0.69**	−0.49	−0.07	0.10	−0.61*
3. Concentration			–	−0.40	−0.08	0.12	−0.20
4. Stopping violations				–	0.13	0.03	−0.20
5. Speeding violations					–	0.01	−0.07
6. Vehicle collisions						–	−0.04
7. Pedestrian collisions							–

*$p<0.05$, **$p<0.01$

actual driving, the number of driving miscues was still very low. Even with so few incidents occurring, the current study showed that those with less concentration, and thus lower SA, were more likely to commit traffic light/stop sign violations. Outside the safety of the simulator, these types of driving errors could be serious and are much more likely to occur over longer durations with greater opportunity for incidents. However, the current findings are based on a limited sample of college students; thus, a larger-scale investigation is needed.

One unique contribution of the current research is that it is one of the few studies that clearly separate the measures of concentration and mindfulness. These two constructs are often confused and confounded in the literature (Mikulas 2011). Future research may aim to distinguish the specific driving-related tasks that are improved by training in each of these constructs. That is, by identifying which aspects of driving are impacted by greater mindfulness and which are impacted by greater concentration, perhaps training programs may be designed to target those skills that will be most beneficial to driver safety and performance.

One potential criticism may be the view that self-selection into treatment groups was a potential threat to the study's validity. This would suggest that participants from the Buddhist psychology course may have had greater concentration skills prior to enrolling in the course and therefore better driving SA and performance with or without the training. Although the lack of a pre-test does not allow this unlikely possibility to be refuted, it is more important to note that increased concentration has often been an outcome of mindfulness training (Mikulas 2007), and this particular training, even if it were the exception, would not nullify previous findings. That is, mindfulness training has reliably been shown to increase concentration, and this study has shown that increased concentration is related to increased SA and better driving performance. Moreover, mindfulness training may have many other indirect benefits for drivers. Increased mindfulness may be useful for reducing driver stress and anxiety in complex or frustrating driving conditions (e.g., Baer 2007; Kabat-Zinn 2003) which may aid in drivers' quick recovery from directed attention fatigue (Kaplan 1995) arising from the demands of a highly distracting environment.

To the authors' knowledge, this is the first study to demonstrate the relationship between the constructs of mindfulness and concentration and measures of situation awareness and driving performance. While drivers now commonly face many potential technological distractions in their vehicles (e.g., cell phones, navigation aids), a strategy of adding attention-demanding displays and warnings may merely serve to further overwhelm the cognitive resources of drivers. It must be noted again that the results of the current study are preliminary findings based on a relatively small sample. Future research is necessary to assess the effectiveness of mindfulness training for counteracting potential driving distractions and for creating a safer driving environment. Such a study may test mindfulness training exercises designed specifically to be conducted in conjunction with traditional drivers' education programs for developing motor skills, as well as attentional skills, in novice drivers. Any such study should control for prior meditation experiences and include pre- and post-testing.

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