IET Intelligent Transport Systems

Research Article

Mindfulness, inattention and performance in a driving simulator

ISSN 1751-956X
Received on 18th July 2014
Revised on 25th February 2015
Accepted on 23rd March 2015
doi: 10.1049/iet-its.2014.0172
www.ietdl.org

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Abstract: The following study will explore the link between mindfulness, driver inattention and a number of driving performance variables that were tested using the SIMUVEG driving simulator. 67 subjects between the ages of 19 and 27 completed the mindful attention awareness scale, attention-related driving errors scale and attention-related cognitive errors scale questionnaires, and were evaluated in two driving performance measures: time to line-crossing and mean speed. The results did not show a correlation between driving performance and mindfulness measures; they did show low but significant correlations with driver inattention measures. A regression analysis suggested that the specific measure of driver inattention is a predictor of driving performance, but the more general measures are not. These results are relevant to the assessment of psychological variables associated with driving performance.

1 Introduction

Over the past decade, there has been exponential growth in research on mindfulness and its applications. It has been associated with enhanced well-being, health, creativity, performance and attention, among other variables [1–3]. Mindfulness refers to paying conscious attention to an experience without judging it. Although there is not one universally accepted definition of mindfulness, the various definitions that do exist all characterise it as 'being aware of and paying attention to the present' [1]. Mindfulness is exercised in some recreational activities, such as meditation, and in everyday activities, such as eating and, of course, driving.

The possibility that mindfulness is related to driving performance is very appealing. It represents a departure from the usual discussion of the influence of negative factors (distraction, cognitive workload and perceptual complexity) on driving; instead, mindfulness offers a positive message: a greater focus on present circumstances would mitigate negative factors and improve driving performance. This hypothesis is especially attractive considering that, in principle, individuals can be trained to be mindful, meaning that a driver's behaviour can be improved through techniques such as meditation. In fact, Abdul Hanan *et al.* [4] have already advanced this hypothesis with respect to driving performance. They have suggested that mindfulness may be useful for predicting speeding behaviour. As noted by these authors, drivers should be alert and attentive to what happens in the current moment in the environment to choose the right action or focus and be fully aware of what is happening here and now. In short, mindful drivers are less prone to crashes. Should mindfulness have demonstrable potential, it could become a very valuable tool to improve driving performance and, consequently, reduce accidents. A review of the literature on driver distraction focused on situational awareness carried out by Kass *et al.* [5] recommends training in Mindfulness for novice drivers, because they hypothesise that this might help them to focus on the stimuli most relevant for driving. In a further study, Kass *et al.* [6] found that drivers who received Mindfulness training had greater situational awareness and better performance in a simulated driving environment than did a control group. Consistent with these studies, Feldman *et al.* [7] found that individuals with lower mindfulness reported more frequent texting-while-driving. These studies suggest a link between Mindfulness and driving behaviour.

Driving is a complex process that involves several perceptual, attentional and motor subtasks. It is well-known that attention (i.e. selective attention) is a fundamental ability for driving. Drivers must be able to select relevant stimuli and ignore those stimuli that are irrelevant to the task (distractors), adapting their behaviour to a constantly changing environment and anticipating future hazards [8]. When attention fails, there can be serious consequences, especially in critical situations. In fact, recent studies suggest that driver inattention is a factor in 80% of collisions and 65% of near crashes [9, 10].

Although there is not a general consensus on the driver inattention definition, it can be characterised as insufficient or no attention, to activities that are critical to safe driving [11]. This can be voluntary or involuntary, and have external causes (such as some incident on the road or engaging in a secondary task while driving) or internal (such as fatigue, alcohol or a driver's own stable traits). As Ledesma *et al.* [12] note, individual traits have not been studied as much as other possible sources of inattention, and it would be interesting to explore whether people who are prone to attentional failures in everyday life also demonstrate that tendency behind the wheel. Authors provide a scale to measure this concept in the driving context (ARDES, attention-related driving errors scale) [12]. The ARDES is a self-reporting measure that assesses individual differences in a person's proneness to commit attention-related errors while driving. This scale has been tested in several studies, showing that it has correct psychometric properties and that it is useful for evaluating individual differences with regard to driver inattention [12–15]. It is worth noting that in the original study of Ledesma *et al* [12] found that ARDES correlated significantly with the mindful attention awareness scale (MAAS) [1] one of the most popular evaluation measures of mindfulness that is focused on assessing one's attention/awareness of the present, and with the attention-related cognitive errors scale (ARCES) [16], which measures cognitive errors in general (e.g. everyday performance failures) that are not tied to a specific situation.

With regard to driving performance, three subtasks are usually mentioned as important to maintaining control of a vehicle: maintaining longitudinal control (i.e. controlling speed); maintaining lateral control (i.e. staying in one lane); and avoiding obstacles. The hypothesis to be tested in this paper is whether the previously mentioned attentional and mindfulness scales are related to driver performance in two of these key aspects: longitudinal and lateral control. Speed, one of the variables related to longitudinal control, has already been associated with mindfulness by [4]. It would appear that the variable lateral control would be correlated as well, since attention to the present would help one maintain the continuous control required of it. The third important driving subtask, avoiding obstacles, was not covered in this study but should be the objective of subsequent research planned in the future.

The performance variables were evaluated in a driving simulator to approximate real life situations. In brief, subjects responded to the previously mentioned scales and drove in a driving simulator. We expect that the scores on the scales will correlate with the performance measures taken in the driving simulator.

2 Method

2.1 Description of the study

In this study, subjects completed a number of questionnaires that evaluate mindfulness and inattention (described further in the measurements section that follows) and drove in a SIMUVEG driving simulator [17] for approximately 20 min. Subjects were not given any special instructions beyond being told to drive as they normally would in the situations presented to them by the simulator. These situations are based on real traffic accidents that can be avoided by driving normally, hence they are standard situations, neither easy nor difficult. To control the effect of being evaluated on their behaviour behind the wheel, half of the subjects completed the questionnaires before taking a turn on the simulator and the other half did hence afterwards.

Driving simulation is used in numerous experimental tests concerning road safety all over the world. Moreover, it is proven that there is a correlation between the measures obtained in a simulator and the measures obtained in real road tests. Driving simulation also provides a lot of advantages, among other aspects, it enables subjects to drive in practically the same situations; therefore it strongly enhances data comparison.

2.2 Participants

72 subjects from the City of Valencia, Spain, participated in the study; five, however, were discarded because of incomplete data. All participants were required to have a valid driver's license. Subjects were recruited by students enrolled in a research course. Students in the course contacted other students not in the course and brought them to the driving simulator facilities. The age of participants ranged from 19 to 27; the mean age was 22 (DS = 1.69). Participants had their driver's licenses for an average of 3.22 years (DS = 1.69), with 8 years being the maximum. In terms of gender, 35 participants were female and 32 were male.

Subjects were healthy and were encouraged to wear corrective lenses if they had them. None experienced severe symptoms of simulator sickness, but some did describe low levels of discomfort; even in these cases, though, it was not an issue that prevented the subject from going through with the test.

2.3 Test materials and equipment

The high-fidelity SIMUVEG driving simulator (see Fig. 1) was used for this study. This is a fixed platform simulator with three 6 × 1, 5 m screens that completely cover a participant's field of vision under normal conditions. Three 2000 lumen XGA projectors display three-dimensional (3D) images in real time. The images were created with software developed in-house [18]. The projectors run on a standard computer that is connected to a Renault Twingo automobile with sensors on the steering wheel, brakes, throttle and so forth. The car features manual transmission, a rearview mirror and two side-view mirrors. The driving simulator's audio system reproduces 3D audio and Doppler effects.

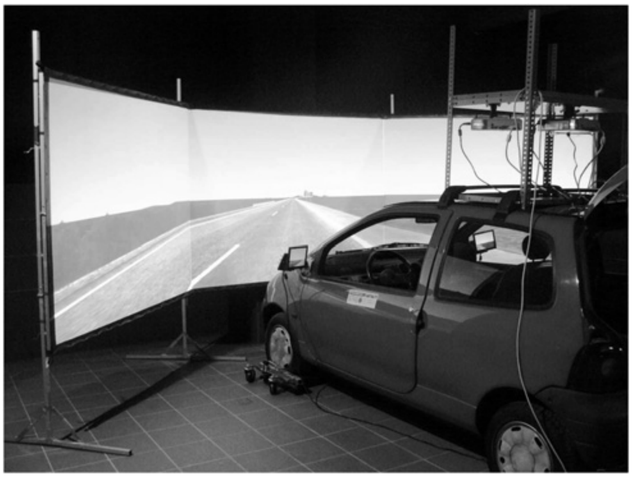

Fig. 1 *SIMUVEG driving simulator*

There are two SIMUVEG scenarios: first, a low traffic highway part designed to acquaint the subject with the basics of driving in the simulator; and second, a two-way rural road part that presents several traffic events, such as a truck stopped on the verge of a lane, a tailing car, curves and so on. The first 4.5 km of the total 18 km were used for training purposes; we did not evaluate driving performance while training. The training track takes place on the same rural road as the test track and gives subjects a feel for operating the simulator, including steering, braking, speeding and so forth.

2.4 Measures

Three kinds of measures were taken in this study: general questions about the subject; inattention and mindfulness self-rating scales; and driving simulator performance measures.

2.5 General questions

Subjects responded to questions about their driving experience and habits. This study, however, did not analyse these responses.

- How long have you been driving?
- Driving frequency (1 = almost every day; 2 = some days a week; 3 = some days a month).
- Kilometres driven per week.
- Have you ever got a traffic ticket? (1 = No; 2 = Yes, once; 3 = Yes, more than once).
- Have you ever experienced a significant distraction while driving?
- Do you use your mobile telephone while driving?

2.6 Inattention and mindfulness scales

The following scales were used to measure inattention and mindfulness.

MAAS: *The Mindful-Attention Awareness Scale* [1], Spanish-language version [19]. The MAAS has 15 items that evaluate general awareness and attention to current events and experiences. All items are negatively worded (e.g. 'I find it difficult to stay focused on what's happening in the present') and were reversed for the analysis. In this study, subjects responded to MAAS items using a 5-point scale, from 'almost never' –1– to 'almost always' –5–. It should be noted that we chose not to reverse the results in the scale as is customarily done in other studies, and therefore the scores in this study reflect absentmindedness rather than mindfulness. In our sample, the scale had a Cronbach's α of 0.82.

ARDES: The ARDES [12], was used to assess driving attention-related errors. This scale's 19 items refer to non-intentional driving errors resulting in whole or in part from attentional failures (e.g. 'At a street corner, I fail to realise that a pedestrian is crossing the street'). Participants were asked to read each item and indicate on a 5-point scale the frequency with which the described situations happened to them, ranging from 'never or almost never' –1– to 'always or almost always' –5–. In this study, this scale's Cronbach's α was 0.82.

ARCES: The 'Attention-related cognitive errors scale' [16] is a 12-item scale describing everyday performance failures arising directly or primarily from brief failures of sustained attention. For example, one item reads: 'I have absent-mindedly placed things in unintended locations (e.g. putting milk in the pantry or sugar in the fridge)'. As in the MAAS and ARDES, participant's used a 5-point scale to indicate the frequency with which the described situations happened to them, ranging from 'never or almost never' –1– to 'always or almost always' –5–. In the present study, this scale's Cronbach's α was 0.89.

2.7 Driving simulator performance

Driving simulators offer a number of potentially useful measures to evaluate performance [20]. In this case, 'Speed' was chosen as a measure of longitudinal control. The variant of 'time to line crossing' (TLC) [21] described below was used to evaluate lateral control. Note that in a driving simulator measures are evaluated continuously, providing several values per second. Since the data analysis we carried out was at the subject level, we needed to summarise the values in some way. The data reduction process we used is described below.

Mean speed (MS): The SIMUVEG simulator measures mean speed as the average of maximum speeds computed every ten meters of driving. This value is very close but not equal to the simple average speed computed by dividing the total distance travelled by the total time. It is assumed that low values in this measure are related to increased mental workload, and that drivers often try to compensate for increased workload by reducing speed [20].

Average of minimum TLCs (MTLC): This measure is based on the TLC used for measuring lateral control. Thus, the minimum TLC value is calculated every ten meters as an indicator of the maximum risk of driving off the road. An average for all the maximum values is calculated per subject. High values in this variable can be interpreted as associated with good lateral control, whereas low values would imply repeated episodes of bad lateral control.

2.8 Data analysis

Correlation coefficients were calculated between the simulator performance measures (MS and MTLC) and the MAAS, ARDES and ARCES scales. In addition, a linear regression analysis was undertaken to determine whether a combination of the scales can serve as predictors of performance in the driving simulator (predictor variables: ARDES, MAAS, ARCES; Dependent variables: MTLC, MS; Method: Enter).

3 Results

Descriptive results are shown in Table 1. The values are for 67 valid subjects. Note the high value of asymmetry in the MTLC variable (2.391) and the moderate positive asymmetry values of the other variables.

Pearson and Spearman correlations were calculated among the variables. Small differences probably because of slightly curvilinear relations between the variables were found between the two types of correlations; consequently, we decided to report only ordinal correlations. These are shown in Table 2 with significant correlations flagged with asterisks (*<0.05;**<0.01). The pattern of the correlations is rather simple, with self-rating scales on mindfulness and inattention displaying strong correlations between them, and performance measures (MS and MTLC) showing moderate correlations between them. The ARDES scores, on the other hand, correlated significantly with MS and MTLC, although these correlations were rather moderate. Finally, the ARCES score correlated significantly with MS – again, only moderately – but not with MTLC.

Table 1 Descriptive statistics for the variables in the study

	Min.	Max.	Mean	SD	Asymmetry
MAAS	21.00	56.00	35.04	8.36	0.47
ARCES	16.00	50.00	28.14	7.83	0.50
ARDES	19.00	50.00	30.95	6.79	0.37
MS	61.17	105.69	82.05	9.68	0.70
MTLC	3.69	51.20	12.55	8.95	2.39

Table 2 Spearman correlations among the variables in the study

	ARDES	ARCES	MAAS	MS	MTLC
ARDES	1.00				
ARCES	0.597**	1.00			
MAAS	0.523**	0.617**	1.00		
MS	0.253*	0.241*	0.165	1.00	
MTLC	−0.320**	−0.166	−0.078	−0.419**	1.00

The regression analysis of the total sample suggested that ARDES is a significant predictor of MTLC (standardised $\beta = -0.42$; $t = -2{,}51$, $p<0.05$), but MAAS ($\beta = 0.17$; $t = -1.08$, $p > 0.05$) and ARCES (standardised $\beta = 0.02$; $t = 0.09$, $p > 0.05$) are not. With respect to the MS variable, no significant effect was observed in any of the scales: ARDES ($\beta = 0.02$; $t = 0.14$, $p > 0.05$), MAAS ($\beta = 0.01$; $t = 0.04$, $p > 0.05$), ARCES ($\beta = 0.14$; $t = 0.79$, $p > 0.05$).

4 Conclusions

As we have discussed in the introduction, the idea of a connection between mindfulness and driving is very attractive because it opens up the possibility of training the individuals in being more focused in the present moment and consequently being more attentive in risk situations.

Unfortunately, our study does not lend this hypothesis much support. The results indicate that there were no significant correlations between the MAAS scores (the typical method for measuring mindfulness) and the two driving performance measures. Rather, the results indicate there were significant correlations between the driving performance measures and the ARDES, a questionnaire that is specifically designed to measure inattention while driving. On the other hand, a more general inattention measure (one designed to measure inattention while performing everyday activities) was correlated with only one of the driving performance measures (MS-mean speed) but not the other (MTLC-average of minimum TLCs). This suggests that specific measures of inattention while driving have a greater potential to predict some general aspects of driving performance than more general inattention measures, such as the ARCES. Finally, the mindfulness measure was not associated with these two performance indicators.

However, despite these conclusions, we do not believe the matter has yet been settled. The current study has several limitations and therefore its conclusions should be regarded as preliminary and subject to modification based on future research. In particular, we see that this study has limitations in terms of the driving performance measures taken, the effects of training, the sampling and the different effects on groups. These limitations are discussed below.

In this study, we worked with only two general driving performance parameters, one related to longitudinal control (MS) and the other with lateral control (MTLC). Although these two parameters are essential to driving, it is debatable how important they are to good driving. For instance, with respect to speed, the optimal speed value is unclear, and driving too fast as well as too slow can be considered bad driving. This reasoning leads us to consider the need to study possible non-linear relationships between speed and the mindfulness and inattention measures in greater detail. There is a hint of this type of relationship in the fact that ordinal correlations showed stronger effects than linear correlations, suggesting a more complicated association between the variables than the one hypothesised here. With respect to MTLC, given the correlation found with MS, there exists the possibility that its correlation is partially dependent on MS; consequently, a model that includes it would be of interest.

Further, both of these measures are general driving measures. It can be argued, therefore that the concepts discussed herein are only relevant in specific situations where attention or focus on the present may make more of a difference. In short, although avoidance of obstacles is another key component of driving, we simply did not consider it here. Therefore measures such as reaction to hazards or to conditions that require monitoring, such as changes in the speed limit, would be more sensitive than the ones used here. Including subtasks as part of the test situation, such as responding to a phone call or paying attention to an in-vehicle information system [22, 23], might be of interest here.

In addition, in this study we have only measured the level of driver mindfulness and inattention, and we have correlated it with the indicators. It would be interesting to also see if the manipulation of these levels, via mindfulness training for drivers or perhaps in techniques for avoiding distractions, impacts performance. Our results suggest that it might be useful to focus on things that cause inattention while driving, but this would have to be tested in a future study.

Yet another limitation of this study is that we used a convenience sample comprised of young people to represent the general population of drivers. It is possible that the effects we explored are not strong enough to reveal themselves in this sample, but they could possibly manifest themselves in samples of special groups of drivers, such as those with a history of accidents or with cognitive or health problems [24]; if this were the case, such results could lead to measures that would benefit such drivers by helping them compensate for their debilities. On the other hand, mindfulness could be an interesting concept for explaining why young people are more involved in traffic accidents, despite being a group age with similar or even higher mental resources than the older group ages.

Finally, as is the norm with driving simulator studies, it should be stressed that the findings ought to be confirmed in real-life settings. In the particular case of this study, naturalistic driving [25] might provide the ideal framework, in combination with the methodology used here, for further research.

5 References

1 Brown, K.W., Ryan, R.M.: 'The benefits of being present: Mindfulness and its role in psychological well-being', *J. Pers. Soc. Psychol.*, 2003, **84**, (4), pp. 822–848

2 Keng, S., Smoski, M.J., Robins, C.J.: 'Effects of mindfulness on psychological health: A review of empirical studies', *Clin. Psychol. Rev.*, 2011, **31**, (6), pp. 1041–1056

3 Segal, Z.V., Williams, J.M.G., Teasdale, J.D.: 'Mindfulness-based cognitive therapy for depression' (Guilford, Nueva York, 2002)

4 Abdul Hanan, S., King, M.J., Lewis, I.M.: 'Are you a mindful driver? A review of the potential explanatory value of mindfulness in predicting speeding behaviour'. Proc. of 2010 Australasian Road Safety Research, Policing and Education Conf., National Convention Centre, Canberra, 31 August–3 September 2010

5 Kass, S.J., Cole, K.S., Legan, S.: 'The role of situation awareness in accident prevention', in Smet, A.D. (Ed.): 'Transportation accident analysis and prevention' (Nova Science Publishers, Inc, New York, 2008), pp. 107–122

6 Kass, S., Van Wormer, L., Mikulas, W., Legan, S., Bumgarner, D.: 'Effects of mindfulness training on simulated driving: Preliminary results', *Mindfulness*, 2011, **20**, (4), pp. 236–241

7 Feldman, G., Greeson, J., Renna, M., Robbins-Monteith, K.: 'Mindfulness predicts less texting while driving among young adults: Examining attention-and emotion-regulation motives as potential mediators', *Pers. Individual Differ.*, 2011, **51**, (7), pp. 856–861

8 Fort, A., Martin, R., Jacquet-Andrieu, A., Combe-Pangaud, C., *et al.*: 'Attentional demand and processing of relevant visual information during simulated driving: A MEG study', *Brain Res.*, 2010, **1363**, pp. 117–127

9 Dingus, T.A., Klauer, S.G., Neale, V.L., *et al.*: 'The 100-car naturalistic driving study, phase II – Results of the 100-car field experiment' (National Highway Traffic Safety Administration, Washington, DC, 2006)

10 Klauer, S.G., Dingus, T.A., Neale, V.L., *et al.*: 'The impact of driver inattention on near-crash/crash risk: An analysis using the 100-car naturalistic driving study data' (National Highway Traffic Safety Administration, Washington, DC, 2006)

11 Regan, M., Hallett, C., Gordon, C.: 'Driver distraction and driver inattention: Definition, relationship and taxonomy', *Accid. Anal. Prev.*, 2011, **43**, (5), pp. 1771–1781

12 Ledesma, R.D., Montes, S.A., Poó, F.M., López-Ramón, M.F.: 'Individual differences in driver inattention: The attention-related driving errors scale', *Traffic Inj. Prev.*, 2010, **11**, (2), pp. 142–150

13 Ledesma, R.D., Montes, S.A., Poó, F.M., López-Ramón, M.F.: 'Measuring individual differences in driver inattention. Further validation of the attention-related driving errors scale', *Human Factors J. Human Factors Ergon. Soc.* published online 18 August 2014, doi: 10.1177/0018720814546530

14 López-Ramón, M.F., Castro, C., Roca, J., Ledesma, R.D., Lupiañez, J.: 'Attentional networks functioning, age, and attentional lapses while driving', *Traffic Inj. Prev.*, 2011, **12**, pp. 518–528

15 Roca, J., Padilla, J.L., López-Ramón, F.M., Castro, C.: 'Assessing individual differences in driving inattention: Adaptation and validation of the attention-related driving errors scale to spain', *Transp. Res. F Traffic Psychol. Behav.*, 2013, **21**, pp. 43–51

16 Cheyne, J.A., Carriere, J.S., Smilek, D.: 'Absent-mindedness: Lapses of conscious awareness and everyday cognitive failures', *Conscious Cogn.*, 2006, **15**, (3), pp. 578–592

17 Sánchez, M., Valero-Mora, P., Pareja, I.: 'Interfaz de usuario en el desarrollo de un simulador de conducción'. Interacción 2002. I Jornadas de Interacción Persona-Ordenador, Granada, 2000

18 Sánchez, M., Valero-Mora, P., Coma, I., *et al.*: 'Construcción de escenarios de conducción para el sistema informática de evaluación interactiva de conductores por medio de simulación (EVICA): La realidad no es siempre un buen modelo para la construcción de simuladores' (León, 1999)

19 Montes, S.A., Ledesma, R.D., García, N., Poó, F.M.: 'The mindful attention awareness scale (MAAS) in an argentine population', *Meas. Eval. Couns. Dev.*, 2014, **47**, (1), pp. 43–51

20 ISO: 'Road vehicles- ergonomics aspects of transport information and control systems- procedure for assessing suitability for use while driving' (ISO, Geneve, 2003)

21 Van Winsum, W., Brookhuis, K.A., De Waard, D.: 'A comparison of different ways to approximate time-to-line crossing (TLC) during car driving', *Accid. Anal. Prev.*, 2000, **32**, (1), pp. 47–56

22 Valero-Mora, P.M., Stevens, A.: 'Human-centred design and assessment of information technologies in traffic', *IET Intell. Transp. Syst*, 2013, **7**, (2), pp. 171–173

23 Valero-Mora, P.V., Tarín, M.B., Tontsch, A., Montoro, I.P., García, M.S.: 'Effects of manually entering navigator destinations while driving in a simulator', *IET Intell. Transp. Syst*, 2012, **6**, (4), pp. 397–403

24 Felipo, V., Urios, A., Valero-Mora, P., *et al.*: 'Serum nitrotyrosine and psychometric tests as indicators of impaired fitness to drive in cirrhotic patients with minimal hepatic encephalopathy', *Liver Int.*, 2013, **33**, (10), pp. 1478–1489

25 Valero-Mora, P.M., Tontsch, A., Welsh, R., *et al.*: 'Is naturalistic driving research possible with highly instrumented cars? Lessons learnt in three research centres', *Accid. Anal. Prev.*, 2013, **58**, pp. 187–194