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**ORIGINAL PAPER**

# Serial mediation effect of the prefrontal cortex functions and mindful driving attitudes on the association between mindfulness and driver behavior

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**Abstract**
When examining the causes of motor vehicle crashes, the fact that driver-related factors are at the forefront makes it reasonable to investigate the driver behavior in improving traffic safety. The purpose of this research is to examine the relationships between mindful driving attitudes, prefrontal cortex functions, trait mindfulness and driver behaviors. A total of 528 drivers (62.9% male and 36.9 female) who have been actively driving for the past year participated in the study. The assessment instruments were: Sociodemographic Form, Mindful Driving Attitudes Scale (MDAS), Driver Behavior Scale (DBQ), Prefrontal Cortex Functions Scale (PCFS) and the Five Facet Mindfulness Questionnaire - Short Form (FFMQ-S). Path analysis was conducted to identfy the pathways from mindfulness to positive and negative driver behaviors. The results showed that the fit of the data to the model was quite good. In other words, while mindfulness predicts prefrontal functions, prefrontal functions predict mindful driving attitudes, and mindful driving attitudes significantly predict positive and aberrant driver behaviors. In addition, the sequential mediating effects of other variables from mindfulness to positive and abberrant driver behaviors were also found to be significant. In other words, prefrontal cortex functions and mindful driving attitudes significantly mediate the path from mindfulness to aberrant driver behaviors. Also, prefrontal cortex functions and mindful driving attitudes significantly mediate the path from mindfulness to positive driver behaviors. These findings suggest that a driver candidate training enriched with mindfulness practices could be used to train safer drivers.

**Keywords:** traffic safety, mindful driving attitudes, driving behaviors, driver training, mindfulness, prefrontal cortex functions

**Bilgece farkındalık ile sürücü davranışı arasındaki ilişkide prefrontal korteks işlevleri ve bilgece farkındalıkla sürücülük tutumlarının ardışık aracılık etkisi**

**Öz**
Trafik kazalarının nedenlerine bakıldığında sürücülere bağlı ögeler başı çekmektedir. Bu nedenle de trafik güvenliğinin geliştirilmesi için sürücü faktörünün incelenmesi önemlidir. Bu araştırmanın amacı, bilgece farkındalığa dayalı (prososyal) sürücü tutumları, prefrontal korteks işlevleri, bir kişilik özelliği olarak bilgece farkındalık ve sürücü davranışları arasındaki ilişkileri incelemektir. Çalışmaya, son bir yıldır aktif araç kullanan 528 (% 62 erkek ve % 36.9 kadın) sürücü katılmıştır. Veri toplama aracı olarak; Sosyodemografik Form, çalışmanın temel değişkenlerinden olan ve trafik adabını/prososyal tutumları ölçen Bilgece Farkındalıkla Sürücülük Tutumları Ölçeği (BFSTÖ), Sürücü Davranışları Ölçeği (SDÖ), Prefrontal Kortex İşlevleri Ölçeği (PKİÖ) ve Beş Faktörlü Bilgece Farkındalık Ölçeği- Kısa Form (BFBFÖ-K) kullanılmıştır. Çalışmada, bilgece farkındalıktan olumlu ve olumsuz sürücü davranışlarına giden yolları belirlemek amacıyla yol analizi yapılmıştır. Sonuçlar, verinin modele uyumunun oldukça iyi düzeyde olduğunu göstermiştir. Diğer bir deyişle, bir kişilik özelliği olarak bilgece farkındalık, prefrontal korteks işlevlerini; prefrontal korteks işlevleri, bilgece farkındalıkla sürücülük tutumlarını yordamakta; bilgece farkındalıkla sürücülük davranışları ise olumlu ve sorunlu sürücü davranışlarını anlamlı olarak yordamaktadır. Ayrıca, kişilik özelliği olan bilgece farkındalıktan olumlu ve sorunlu sürücü davranışlarına giden diğer değişkenlerin sıralı aracı etkileri de anlamlı bulunmuştur. Başka bir ifadeyle, bir kişilik özelliği olarak bilgece farkındalıktan sorunlu sürücü davranışlarına giden yolda, prerontal korteks işlevleri ve bilgece farkındalıkla sürücülük tutumları anlamlı olarak aracılık eden değişkenler olarak çıkmıştır. Ek olarak, kişilik özelliği olan bilgece farkındalıktan olumlu sürücü davranışlarına giden yolda da prefrontal korteks işlevleri ve bilgece farkındalığa dayalı sürücü tutumları anlamlı olarak aracılık etmektedir. Bu bulgulardan yola çıkarak, bilgece farkındalık egzersizleriyle zenginleştirilmiş bir sürücü eğitiminin daha güvenli sürücülerin yetiştirilmesinde katkısı olacağı düşünülmektedir.

**Anahtar kelimeler:** trafik güvenliği, bilgece farkındalıkla (mindful) sürücü tutumları, sürücü davranışları, sürücü adayı eğitimi, bilgece farkındalık, prefrontal korteks işlevleri

## INTRODUCTION

*"Man drives as he lives."*
*(Tillman and Hobbs, 1949, p.329)*

Road traffic injuries represent a persistent and growing threat to global public health. Every year, millions of lives are affected by road crashes—either through fatalities, serious injuries, or long-term disabilities. According to the World Health Organization (WHO, 2023), road traffic crashes are now the 12th leading cause of death globally for people of all ages. More alarmingly, road traffic injuries are the leading cause of death among children and youth aged 5 to 29 years, making this issue not only a public health crisis but also a significant barrier to sustainable development and human capital investment. Despite advancements in vehicle safety technologies and road infrastructure, disparities in traffic safety laws, enforcement,

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and emergency care continue to widen the gap between high-income and low- and middle-income countries—where over 90% of road traffic deaths occur. Exceeding the speed limit, driving under the influence, non-use of helmet (adult), non-use of seat-belts, distracted driving are among the most important risk factors highlighted in the report (WHO, 2023). Approximately half of all road traffic deaths and an even greater proportion of serious traffic-related injuries occur in urban areas, where high population density and mixed traffic conditions increase the risk of crashes (Dimitriou and Gakenheimer, 2012). "Human factors" are one of the leading contributors to road traffic craches. For example, Dingus et al. (2016) stated that the role of human error in traffic crashes is 90%, despite all the developments in technology, automotive industry, the improvements related to vehicles and roads (intelligent transportation systems, adaptation of artificial intelligence to vehicles, etc.). Therefore, understanding driver behavior is crucial.

Driver behavior is simply defined as "what the driver does" (Evans, 2004). Driver behaviors include aberrant behaviors such as lapses, errors and violations in traffic, as well as positive behaviors like trying to help and being polite to other road users in traffic (Reason et al., 1990; Ozkan and Lajunen, 2005). Errors can be defined as "the failure of planned actions to achieve their intended consequences" and are not intentional behaviors (e.g., misjudging the speed of an oncoming vehicle when overtaking; Parker and Manstead, 1996). Violations are deliberate deviations from those practices believed necessary to maintain the safe operation of a potentially hazardous system (Reason et al., 1990). For instance, they include disregarding the speed limit, not stopping even though the traffic light is red, or driving especially close to the car in front in order to signal its driver to move over. Lapses, which only cause embarrassment and discomfort to the actor, include items such as switching on the headlights when intending to switch on the windscreen wipers (Reason et al., 1990). The relevant literature shows that among these behaviors, violations are especially associated with crash involvement (Parker et al., 1995; Reason et al., 1990).

As studies in the literature show, driver behavior is also influenced by culture (Boyce and Geller, 2002; Fuller, 2011; Hennessy, 2011; Lonero and Clinton, 1998; Ozkan and Lajunen, 2011). In addition, especially since the 2000s, a new model including interdisciplinary analysis and interpretation became dominant in studies which investigate traffic and road safety. In this model, it is seen that culture, especially traffic culture, is associated with traffic safety (Ozkan and Lajunen, 2011). Traffic culture can be conceptualized as an artifact of cultural heritage, and the current environmental conditions, including the socio-economic and political climate (Ozkan and Lajunen, 2015). Therefore, the definition of "safe driver" may also vary depending on the characteristics of the culture in which people live.

It can be assumed that prosocial traffic attitudes like values and norms are also related to traffic culture. In other words, prosocial traffic attitudes can be conceptualized as internalizing and following traffic regulations without the fear of traffic police or the fines and exhibiting habitual behaviors that require mutual communication and understanding in traffic (Hatipoglu and Yasak, 2016). Numerous studies in the literature have investigated the role of prosocial attitudes in promoting safe driving behaviors and they suggest that individuals who exhibit greater concern for the well-being of others are more likely to engage in risk-reducing practices on the road (Ge et.al, 2021; Kaye et.al, 2022). One study found that drivers with high prosocial tendencies consistently exhibit safer and more cooperative behavior, even under conditions of heavy traffic. These drivers were more likely to maintain safe distances and adapt appropriately to changing traffic conditions. On the other hand, drivers with low prosocial attitudes were found to maintain smaller transverse distances between vehicles in high-density traffic, a behavior that may significantly increase the likelihood of collisions and lane-change conflicts (Ge et.al, 2021).

In the current study, it is assumed that the concept of "mindful driving attitudes", which by definition includes concepts such as empathy, benevolence, responsibility, and tolerance, would be representative of prosocial behaviors and would be related to trait mindfulness and prefrontal cortex functions. In the related literature, minfulness is defined as a much more inclusive concept than "awareness", which is related to consciousness. The term mindfulness is explained as being able to stay in the present moment, observing whatever comes to mind or experienced in the body without judgment and with compassion. Through mindfulness, attention is directed to whatever is happening in the body, in the mind, or in the external environment at that moment. In summary, minfulness is a process in which the content of these mind-body observations is accepted with curiosity, understanding, and compassion, without judgment, analysis, or reaction (Kabat-Zinn, 2003). It is stated that people with higher trait mindfulness scores have higher levels of personal control, empathy, sense of autonomy, better regulatory functions, higher self-esteem, life satisfaction, rigor, clearer and better perception of personal competence, and optimism (Bowlin and Baer, 2012). In a review study examining the relationship between mindfulness and road safety, it was revealed that mindfulness exercises which help in increasing minfulness as a trait would be beneficial in preventing distracted driving (Koppel et al., 2019). Another study found that people with higher trait mindfulness were less likely to engage in aberrant driver behaviors such as violations, aggressive driving, errors, lapses, and phone use (Murphy and Matvienko-Sikar, 2019). In addition, higher trait mindfulness was found to have a negative relationship with abberrant driver behaviors such as driving anger and following the other driver too closely (Stephens et al., 2018).

Based on the above literature, the current study introduces two other variables hypothesized to be related to driver behaviors. These are mindful (prosocial) driving attitudes and prefrontal cortex functions. There is an abundance of research showing that mindfulness is linked to executive functions and has an impact on the functional integrity of the prefrontal cortex (Keng et al., 2011; Lyvers et al., 2013). Studies investigating the role of the brain in interpersonal communications such as understanding an-

other person's perspective, empathy, resolution of moral relationships, conscience, gratitude, guilt, shame, and fear also showed that the prefrontal cortex has an important role in all these processes (Barrasso-Catanzaro and Eslinger, 2016; Siegel, 2007; Seigel, 2009). Other complex cognitive functions such as attention, memory, decision making, reasoning, planning, foresight, and problem solving are also regulated by the prefrontal cortex. It can be said that the role of the prefrontal cortex in human behavior is very vital because of its relationship with the regulation of mind-body functions, effective communication, response flexibility, emotional regulation, insight, fear reduction, intuition and conscience (Siegel, 2007). The related literature shows that there is a relationship between the prefrontal cortex functions and social and agressive behaviors, and lack of empathy (Sterzer et al., 2007). In addition, studies using brain imaging techniques have revealed that there is a robust relationship between mindfulness practices and prefrontal cortex activity. Studies also showed that profrontal cortex functions are associated with emotion regulation and mindfulness (Hisli Sahin et al., 2023; Creswell et al., 2007; Lutz et al., 2014). Based on the above literature the main purpose of the current study is to investigate the relationship between prosocial driving attitudes, conceptualised in this study as mindful driving attitudes, trait mindfulness, prefrontal cortex functions, and positive and abberrant driver behaviors.

## METHODS

### Participants

A total of 528 people aged between 18-65 ($M$ = 36.47, $SD$ = 13.03), who had driver's license and had been driving for at least one year, participated in the study. As shown in Table 1, 332 (62.9%) of the participants are male, 195 (36.9%) are female. The mean period for which participants held a driving license was 12.96 years ($SD$ = 11.37). In addition, 62.5% of the participants were college graduates; 82.5% defined their socioeconomic status middle. In addition, 54.2% reported driving almost every day, and 36% reported that they drove an average of 1000-5000 km. per year.

### Measures

***Sociodemographic Form*** This form, prepared by the researchers, is intended to determine sociodemographic characteristics such as age, gender, marital status, educational level, and perceived socioeconomic status, years of driving, prequency of driving, and involvent in crashes.

***Driver Behaviours Scale (DBQ)*** The scale was developed by Reason et al. (1990) to determine the type and frequency of the errors, lapses, and violations drivers make. The Turkish adaptation of the 28-item scale was carried out by Sumer et al. (2002). They found a two-factor structure: Errors (α = .79) and violations (α = .86). Ozkan and Lajunen (2005), on the other hand, after adding some more items, made it into a 42-item scale and found a third dimension naming it positive driver behaviors (Cronbach's alpha = .84).

**Table 1. Summary Statistics of Drivers' Demographic Information and Driver Features** *(N = 528)*

| | N | % |
|---|---|---|
| Gender | | |
| Male | 332 | 62.9 |
| Female | 195 | 36.9 |
| Others | 1 | 0.2 |
| Age (years) | | |
| 18-30 years | 220 | 41.7 |
| 31-40 years | 92 | 17.4 |
| 41-65 years | 216 | 40.9 |
| Education level | | |
| Primary school | 13 | 2.5 |
| Junior high school | 20 | 3.8 |
| High School | 101 | 19.1 |
| Undergraduate | 330 | 62.5 |
| Postgraduate | 64 | 12.1 |
| Socio-economic status | | |
| Low | 30 | 5.7 |
| Middle | 450 | 82.5 |
| High | 47 | 8.9 |
| Unknown | 1 | 0.2 |
| Kilometers driven in the last year | | |
| < 1000 km | 89 | 16.9 |
| 1000-5000 km | 190 | 36.0 |
| 5001-15000 km | 138 | 26.1 |
| >15000 km | 111 | 21.0 |
| Driving Frequency | | |
| Per day | 286 | 54.2 |
| About 3 to 4 days a week | 109 | 20.6 |
| About 1 to 2 days a week | 74 | 14.0 |
| A few times a month | 38 | 7.2 |
| Very rarely | 18 | 3.4 |
| Unknown | 3 | 0.6 |
| Crash involvement within the past 3 years | | |
| Yes | 121 | 22.9 |
| No | 406 | 76.9 |
| Unknown | 1 | 0.2 |
| Traffic fines (last 3 years) | | |
| Yes | 212 | 40.2 |
| No | 315 | 59.7 |
| Unknown | 1 | 0.2 |

In the context of driving behavior, errors and violations are considered to be two separate forms of aberration (Reason et al., 1990; Özkan et al., 2005; Youssef et al., 2023). Errors are defined as unintentional actions that result from lapses in attention and memory, or misjudgment during driving tasks. In contrast, violations refer to intentional breaches of traffic rules and deliberate disregard for safe driving norms. Although these two dimensions have distinct psychological underpinnings and may require different remediation strategies—such as skill training for errors and attitudinal or legal interventions for violations—they are both conceptually grouped under the broader construct of aberrant driving behavior (Reason et al., 1990; Özkan et al., 2005; Youssef et al., 2023). In line with this theoretical framework, we treated errors, lapses and violations as components of a single aberrant driving behavior dimension in the current study. The internal consistency of this composite measure was found to be acceptable, with Cronbach's alpha coefficient of .86. Thus, in the current study, the DBQ was handled in the path

analysis as comprising of two dimensions: positive driver behaviors and aberrant driver behaviors. The internal consistencies of the subscales were found to be satisfactory, with Cronbach's alpha coefficients ranging from .62 to .86.

***Mindful Driving Attitudes Scale (MDAS)*** This is a self-report scale developed by Yasak et al. (2022a) after the Turkish Ministery of Education approached the first author requesting a booklet that would be used in the driver candidate training programs. They were specifically interested in teaching prosocial driving attitudes. The researchers, after investigating the related literature, found that empathy, communication, basic values, responsibility, respecting rights of others, and warning each other were the variables that should be included in this program and prepared a booklet to be used in the training (Hatipoglu and Yasak, 2016). They were also interested to see how these variables were perceived by the public. So, they conducted a pilot study which was published in 2019 (Hatipoğlu and Yasak, 2019). Based on this pilot study, the MDAS was developed and published in 2022 (Yasak et al., 2022a). The MDAS is a 4-point Likert type self-report scale consisting of 33 items. Higher scores indicate prosocial driver attitudes. The scale consists of 4 factors: "basic values" (16 items), "empathy and communication" (8 items), "respecting rights of others" (7 items), and "warning each other" (2 items). Cronbach's alpha coefficients range from .60 to .80. For the current study, these values ranged from .60 to .89.

***Prefrontal Cortex Functions Scale (PCFS)*** The PCFS, developed by Sahin and Ozsoy (2017), is a 29-item self-report scale rated on a 5-point Likert to measure the executive and regulatory prefrontal cortex functions based on the Interpersonal Neurobiology approach. The scale was found to have a five-factor structure: Bodily regulation ($\alpha$ = .80), fear management and intuition ($\alpha$ = .80), empathy and response flexibility ($\alpha$ = .76), insight ($\alpha$ = .78), and conscience ($\alpha$ = .67). Several studies using the scale reported reliability scores ranging between .67 and .93. (Duman and Hisli-Sahin, 2018; Erguler and Durak-Batigun, 2020; Hisli Sahin et al., 2023; Kaya and Eldogan, 2018; Hisli-Sahin and Varlık-Özsoy, 2017; Isık and Incedere, 2016). In the current study, Cronbach's alpha coefficients of the subdimensions of the scale ranged between .75 and .90.

***Five Facet Mindfulness Questionnaire - Short Form (FFMQ-S)*** The 39-item FFMQ-S was developed by Baer et al. (2006). In another study, it was found that the 20-item short form of the scale was as valid and reliable as the original (Tran et al., 2013). In this study, the short form of the scale adapted to Turkish by Ayalp and Hisli-Sahin (2018) was used. As a result of the adaptation study, 5 factors were determined. These factors are regulating attention ($\alpha$ = .85), observing without judgement ($\alpha$ = .76), observing the mind and the body without being affected ($\alpha$ = .71), sensory awareness ($\alpha$ = .69), and naming emotions ($\alpha$ = .69). In the current study, Cronbach's alpha coefficients of these factors ranged from .70 to .89.

### Procedure

After obtaining the approval of the ethics committee (Protocol No: 486; Date: March 1st, 2021) from the Çankırı Karatekin University, the data collection phase was carried out between February and April 2022. The data was collected online by using the sample of convenience technique, through the use of Surveey.com system. In order to control for the order effect, besides the Demographic Information Questionaire, all of the other scales were given to the participants in different combinations. The participation was voluntary and the data was kept strictly confidential. Participants completed the questionnaires in about 20 minutes.

### Data Analysis

Correlation analyses, path analysis, and serial mediation analysis were conducted. Statistical analyses were performed using SPSS-23 and AMOS-21 statistical programs. Before conducting the analyses, the dataset was reviewed, and outliers that were outside of the the normal distribution in both directions were excluded from the dataset, leading to the fulfilment of the -2 and +2 criteria for Skewness and Curtosis (George ve Mallery, 2010). Therefore, the parametric statistics were run for the remaining 528 participants.

## RESULTS

### Descriptive Statistics on Scales

The means, standard deviations and score ranges of the scale using the study are given in Table 2.

### Relationships Between Variables

A Pearson correlation analysis was performed to determine the relationships between driver behaviors and other variables. The results are given in Table 3.

Table 3 reveals that as age and years of driving increase, positive driver behaviors increase and aberrant driver behaviours decrease. There is also a positive and significant relationship between the number of crashes and aberrant driver behaviors ($r$ = .10, $p$ < .01). The relationship between all subscales and total scores of the FFMQ-S (except for the observing without judgment subscale) and positive driver behaviors ranged from .10 ($p$ < .01) to .26 ($p$ < .001). In addition, the relationship between the FFMQ-S and aberrant driver behaviors ranged from -.09 ($p$ < .05) to -.36 ($p$ < .001).

Significant relationships were also found between the PCFS total and subscale scores and positive driver behaviors, ranging from .41 ($p$ < .001) to .18 ($p$ < .001). Similarly, the PCFS was found to have significant negative relationships with aberrant driver behaviors, ranging from -.38 ($p$ < .001) to -.16 ($p$ < .001). Additionally, significant positive relationships ranging from .23 ($p$ < .001) to .40 ($p$ < .001) were found between the MDAS total and subscale scores and positive driver behaviors. The relationships between mindful driving attitudes and aberrant driver behaviors were found to range between -.14 ($p$ < .001) and -.55 ($p$ < .001). In addition, the relationships between the PCFS and

**Table 2. Means, SDs, and Score Ranges for All Scales**

| | M | M* | SD | Score range | Cronbach's alpha |
|---|---|---|---|---|---|
| MDAS-Total | 111.25 | (3.37) | 11.95 | 67-132 | .88 |
| Basic values | 55.12 | (3.44) | 6.55 | 27-64 | .89 |
| Empathy and communication | 28.02 | (3.50) | 3.42 | 16-32 | .68 |
| Respecting rights of others | 22.51 | (3.21) | 4.13 | 10-28 | .73 |
| Warning each other | 5.60 | (2.80) | 1.85 | 2-8 | .60 |
| DBQ | | | | | |
| Lapses | 6.20 | (0.80) | 4.51 | 0-26 | .65 |
| Errors | 6.47 | (0.80) | 4.94 | 0-26 | .62 |
| Violations | 12.40 | (1.03) | 8.16 | 0-44 | .80 |
| Aberrant driving behaviors | 25.01 | (0.89) | 14.46 | 0-88 | .86 |
| Positive driving behaviors | 49.55 | (3.54) | 9.25 | 14-70 | .68 |
| PFCFS-Total | 109.03 | (3.76) | 15.11 | 56-145 | .90 |
| Bodily regulation | 17.22 | (3.44) | 3.91 | 5-25 | .75 |
| Fear management and intuition | 29.61 | (3.70) | 4.92 | 13-40 | .76 |
| Empathy and response flexibility | 21.99 | (3.67) | 4.31 | 7-30 | .81 |
| Insight | 14.93 | (3.73) | 2.91 | 5-20 | .75 |
| Conscience | 25.27 | (4.21) | 3.78 | 10-30 | .69 |
| FFMQ-S- Total | 69.25 | (3.46) | 9.25 | 42-98 | .75 |
| Regulating attention | 14.26 | (3.57) | 4.05 | 4-20 | .89 |
| Observing without judgement | 12.07 | (3.01) | 3.79 | 4-20 | .82 |
| Observing the mind and the body without being affected | 14.17 | (3.54) | 3.07 | 5-20 | .76 |
| Sensory awareness | 14.14 | (3.54) | 3.28 | 4-20 | .70 |
| Naming emotions | 14.62 | (3.66) | 3.14 | 4-20 | .73 |

***Note.*** MDAS: Mindful Driving Attitudes Scale; DBQ: Driver Behaviours Scale; PFCFS: Prefrontal Cortex Functions Scale; FFMQ-S: Five Facet Mindfulness Questionnaire- Short Form. **The values in parentheses represent mean scores, calculated by dividing each scale's total score by its number of items.*

**Table 3. Bivariate Correlations Between Study Variables**

| | DBQ- Lapses | DBQ-Errors | DBQ-Violations | DBQ-Positive | DBQ-Aberrant |
|---|---|---|---|---|---|
| Age (years) | -.21*** | -.08 | -.17*** | .23*** | -.20*** |
| Education level | .05 | -.03 | .11** | .01 | .08 |
| Years of active driving | -.21*** | -.04 | -.06 | .20*** | -.12** |
| Crash involvement within the past 3 years | .04 | .04 | .13** | -.07 | .10** |
| PFCFS-Total | -.22*** | -.22*** | -.29*** | .31*** | -.31*** |
| Bodily regulation | -.10** | -.09** | -.15*** | .18*** | -.16*** |
| Fear management and intuition | -.20*** | -.16*** | -.13*** | .19*** | -.19*** |
| Empathy and response flexibility | -.16*** | -.18*** | -.27*** | .19*** | -.27*** |
| Insight | -.08 | -.13*** | -.19*** | .23*** | -.18*** |
| Conscience | -.24*** | -.27*** | -.39*** | .41*** | -.38*** |
| FFMQ-S- Total | -.35*** | -.29*** | -.26*** | .26*** | -.36*** |
| Regulating attention | -.33*** | -.22*** | -.22*** | .21*** | -.29*** |
| Observing without judgment | -.06 | -.08 | .05 | -01 | -.01 |
| Observing the mind and the body without being affected | -.24*** | -.15*** | -.21*** | .19*** | -.25*** |
| Sensory awareness | -.04 | -.07 | -.09* | .10** | -.09* |
| Naming emotions | -.28*** | -.25*** | -.25*** | .21*** | -.31*** |
| MDAS-Total | -.38*** | -.35*** | -.58*** | .36*** | -.55*** |
| Basic values | -.27*** | -.26*** | -.50*** | .30*** | -.46*** |
| Empathy and communication | -.38*** | -.35*** | -.42*** | .40*** | -.47*** |
| Respecting rights of others | -.29*** | -.28*** | -.46*** | .23*** | -.43*** |
| Warning each other | -.12*** | -.05 | -.15*** | .03 | -.14*** |

*$p < .05$, **$p < .01$, ***$p < .001$, ***Note.*** MDAS: Mindful Driving Attitudes Scale; DBQ: Driver Behaviours Scale; PFCFS: Prefrontal Cortex Functions Scale; FFMQ-S: Five Facet Mindfulness Questionnaire- Short Form.

all other scales ranged from .52 ($p < .001$) to -.39 ($p < .001$), while the relationships between FFMQ-S and all other scales were found to be .52 ($p < .001$) and -. 35 ($p < .001$).

Table 4 presents the bivariate correlations among the MDAS total score, its subscales (positive and aberrant driving behaviors), and other key study variables. As shown, MDAS total scores were positively correlated with positive driving behaviors ($r = .36$, $p < .01$) and trait mindfulness ($r = .33$, $p < .01$) and negatively correlated with aberrant driving behaviors ($r = –.55$, $p < .01$). These findings support the theoretical link between trait mindfulness and mindful driving attitudes. Additionally, age showed significant positive relationship with overall MDAS scores ($r = .26$, $p < .01$), indicating that older participants tend to report higher levels of mindful driving attitudes. As demon-

**Table 4. Bivariate Correlations Between MDAS Scores and Study Variables**

| | MDAS-Total | Basic values | Empathy and communication | Respecting rights of others | Warning each other |
|---|---|---|---|---|---|
| Age (years) | .26*** | .22*** | .28*** | .16*** | -.01 |
| Education level | -.15*** | -.17*** | -.01 | -.10** | -.13*** |
| Years of active driving | .15*** | .11** | .21*** | .10** | -.04 |
| Crash involvement within the past 3 years | -.21*** | -.20*** | -.11** | -.17*** | -.08 |
| PFCFS-Total | .45*** | .41*** | .33*** | .27*** | .22*** |
| Bodily regulation | .25*** | .23*** | .17*** | .14*** | .20*** |
| Fear management and intuition | .31*** | .28*** | .22*** | .18*** | .18*** |
| Empathy and response flexibility | .34*** | .33*** | .25*** | .20*** | .10** |
| Insight | .32*** | .27*** | .24*** | .19*** | .19** |
| Conscience | .51*** | .45*** | .38*** | .35*** | .20*** |
| FFMQ-S- Total | .33*** | .25*** | .33*** | .26*** | .07 |
| Regulating attention | .26*** | .18*** | .26*** | .25*** | .04 |
| Observing without judgment | -.06 | -.11*** | .07 | .02 | -.14*** |
| Observing the mind and the body without being affected | .27*** | .26*** | .20*** | .17*** | .09** |
| Sensory awareness | .15*** | .15*** | .11** | .06 | .08 |
| Naming emotions | .29*** | .23*** | .24*** | .17 | .15*** |

*$p$ < .05, **$p$ < .01, ***$p$ < .001. ***Note***. MDAS: Mindful Driving Attitudes Scale; DBQ: Driver Behaviours Scale; PFCFS: Prefrontal Cortex Functions Scale; FFMQ-S: Five Facet Mindfulness Questionnaire- Short Form.

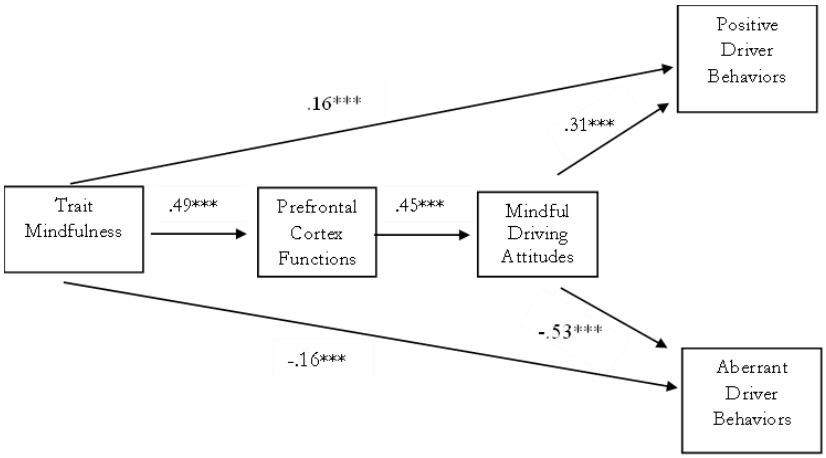


**Figure 1. Path Model**. ***Note***. *N= 528*. ***$p$ < .001. Standardized path coefficients among variables are presented. All path coefficients are statistically significant.

strated in Table 4, minful driving attitudes scores were significantly and positively correlated with driving experience ($r$ = .15, $p$ < .01), indicating that more experienced drivers tend to display higher levels of mindful driving attitudes. Conversely, higher levels of education ($r$ = -.15, $p$ < .01) and a greater number of traffic crashes ($r$ = -.21, $p$ < .01) were negatively associated with mindful driving attitudes, suggesting a decline in mindful (prosocial) driving attitudes in those contexts.

## Path Analysis

A path analysis was conducted to identify the pathways from mindfulness to positive and aberrant driver behaviors. A single-group path model was tested for the sample. Goodness of fit indices for the model are presented in Table 5. The proposed model is shown in Figure 1. Since the goodness of fit index values of the baseline model were acceptable, no error variance associations were made.

The model for the study sample revealed good fit values (see Figure 1). In this model, mindfulness was significantly associated with the prefrontal cortex functions ($\beta$ = .49, $p$ < .001) and prefrontal cortex functions were significantly associated with mindful driving attitudes ($\beta$ = .45, $p$ < .001). Mindful driving attitudes, on the other hand, were significantly associated with positive driver behaviors ($\beta$ = .31, $p$ < .001) and aberrant driver behaviors ($\beta$ = -.53, $p$ < .001). Additionally, mindfulness was also significantly associated with positive ($\beta$ = .16, $p$ < .001) and aberrant driver behaviors ($\beta$ = -.16, $p$ < .001).

## Serial Mediation Analysis

To test the serial mediating effects in the pathway from mindfulness to positive and aberrant driver behaviors, 95% bias-corrected confidence intervals (BC, CI) were calculated for the sample, using a bootstrapping method with 2000 resamples (Shrout and Bolger, 2002). Estimates, standard errors, and CIs of mediation models are presented in Table 5. Prefrontal cortex functions and mindful driving attitudes significantly mediated the relationship between trait mindfulness and aberrant driver behaviors ($B$ = -.14, CI[-.17, -.11], $p$ < .001). Additionally, prefrontal cortex functions and mindful driving attitudes

**Table 5. Model Fitness Index Values for the Sample**

| | $X^2$ | df | $X^2$/df | CFI | GFI | AGFI | RMSEA | NFI | IFI |
|---|---|---|---|---|---|---|---|---|---|
| Model | 19.80 | 4 | 4.95 | .97 | .98 | .94 | .08 | .97 | .97 |

***Note***. CFI: Comparative Fit Index, GFI: Goodness of Fit Index, AGFI: Adjusted Goodness of Fit Index, RMSEA: Root Mean Square Error of Approximation, NFI: Normed Fit Index, IFI: Incremental Fit Index.

significantly mediated the relationship between trait mindfulness and positive driver behaviors ($B$ = .07, CI[.05, .09], $p$ < .001).

**Table 6. Estimates of Indirect Effects**

| | B (SE) | Lower | Upper |
|---|---|---|---|
| M → PF → MDA → ADB | -.14***(.02) | -.17 | -.11 |
| M → PF → MDA → PDB | .07*** (.01) | .05 | .09 |

***Note***. M: Mindfulness, PF: Prefrontal Functions, MDA: Mindful Driving Attitudes, ADB: Aberrant Driver Behaviors, PDB: Positive Driver Behaviors. ***$p$ < .001.

## DISCUSSION

Safe drivers can be considered as among the most important factors for a sustainable safe traffic environment (Dingus et al., 2016; Farooq et al., 2019). Consequently, the training of driver candidates is undoubtedly curicial for safe driving. In this context, in Turkey (2015), Private Education Institutions affiliated with the Ministry of National Education carried out major revisions in their training curriculums (Hatipoglu and Yasak, 2016; Hatipoglu and Yasak, 2019). Prosocial driving attitudes was added into this curriculum as a new topic based on the requirements and the published regulations of the Ministry (Ministry of National Education, 2017). An investigation on the topic of prosocial driving attitudes revealed that the topic was studied very limitedly in the field of traffic safety, within the framework of empathy and altruism (Lucidi et al., 2019; Mallia et al., 2015; Nordfjærn and Simsekoglu, 2014; Simsekoglu, 2015; Ulleberg and Rudmo, 2003;). The current study aims to expand the concept of prosocial driving behavior a little further by relating it to mindfulness and prefrontal cortex functions, and naming it as mindful driving attitudes. It was hypothesized that mindfulness as a trait, prefrontal cortex functions and mindful driving attitudes would be related to driver behaviors.

The results revealed that besides the mentioned variables, age and education were found to be important variables to be considered. While age was related to both positive and aberrant behaviors, education was found to be related to violations. These findings are supported by other studies in related literature (Uzumcuoglu-Zihni, 2018; Mesken et al., 2002; Parker et al., 1995; Reason et al., 1990; Amado et al., 2004; Sumer and Ozkan, 2002; Yasak et al., 2002). Regarding the association between mindful driving attitudes and driving behaviors, the current study revealed significant relationships in expected directions, i.e., negative relationship with aberrant driver attitudes and positive relationship with positive driver behaviors. All of the subscales of the MDAS also had significant relationships in the expected direction with positive and aberrant driver behaviors, except the "warning each other" subscale. The relationship between this subscale and the positive driver behaviors was insignificant.

One of the remarkable findings of this study is the relationship between prefrontal cortex functions and driver behaviors (positive and aberrant). Our search in the related literature did not reveal any studies which touched the subject of prefrontal cortex functions and driver behaviors. Most of the studies were based on the relationship between safe driving and empathy, personality, anger, and mindfulness (Deffenbacher et al., 1994; Koppel et al., 2019; Lucidi et al., 2019; Nordfjærn and Simsekoglu, 2014). The current study revealed a robust relationship of driver behaviors with prefrontal cortex functions as a total and with all of its subdimensions like "bodily regulation", "fear management and intuition", "empathy and response flexibility", "insight", and "conscience" (see Table 3).

The second variable of the current study that was hypothesized to be related to driver behaviors is mindfulness. Our findings indicated significant positive relationship of mindfulness (total and three subdimensions: "regulating attention", "observing the mind and the body without being affected", and "naming emotions") with positive driver behaviors. However, "observing without judgement" subdimension did not have a significant relatioship with positive or aberrant driver behaviors. On the other hand, "sensory awareness" subdimension had significant but very low correlations with driver behaviors in the expected direction (negative relationship with violations and aberrant driver behaviors and positive relationship with positive behaviors) (see Table 3).

The third variable, mindful driving attitudes, representing prosocial driving attitudes was also found to be related to driver behaviors. As expected, mindful driving attitudes (total and subscales) were found to have robust relatonships with driver behaviors. The correlations were negative with aberrant driver behaviors and positive with positive driver behaviors with the exception of "warning each other" subdimension which did not have a relationship with any of these behaviors.

Since prosocial driving behavior was the major variable of a project that was previously proposed to the first author by the Ministery of National Education, in the current study, mindful driver attitudes are treated as both an independent and a dependent variable. Table 4 shows the values after correlating this variable with the demographic variables such as age, education level and years of driving. The findings showed positive and significant strong relationship between age and minful driving behaviors like "basic values", "empathy and communication", "respecting rights of others", and "warning each other." This is an understandable result when considering maturity factor due to age (Murphy and Matvienko-Sikar, 2019; Meital Navon-Eyal and Ben-Ari, 2020; Shope and Bingham, 2008) and development of the prefrontal cortex which is also involved in regulating empathic behaviors and emo-

tions until late twenties (Seigel, 2007). Similar points can be repeated to explain the positive and significant relationship between years of driving—which can be considered an indicator of experience—and mindful (prosocial) driving behaviors: as years of driving experience increase, mindful (prosocial) driving behaviors also increase.

However, the relationship between education and mindful driving behaviors presents a different and unexpected finding. Table 4 reveals that as level of education increases, total mindful driving behaviors, along with the subdimension of "basic values", "respecting rights of others", and "warning each other" decrease. This is an intriguing finding that may be explained in the contex of the Turkish culture. It is not an uncommon experience to witness incidents in big cities, where some people with higher education feel entitled to be above traffic rules, or even all rules. This may also be related to the inconsistencies related to the application of legal rules by the law enforcement authorities or inconsistencies in the quality of education between educational institutions.

Furthermore, we also found significant and strong positive relationships between mindful driving attitudes and prefrontal cortex functions. The subdimensions, such as "body regulation", "fear management and intuition", "empathy and response flexibility", "insight", and "conscience", all were related to the "basic values", "empathy and communication", "respecting the rights of others", and "warning each other" subdimensions of mindful driving (prosocial) attitudes measured by the MDAS. This is an important finding, considering the neuroplasticity of the brain and the trainability or the development of the prefrontal cortex through either mindfulness practices and/or child rearing practices based on secure attachment. In other words, if mindful (prosocial) driving is essential for road safety, then besides the driver candidate training programs, there are other dimensions like brain development and child rearing practices that should be taken into consideration on a macro level.

There is a robust scientific literature on the importance of attachment (specifically secure attachment) styles between the caregivers (later between teachers) and young children. It has been shown in laboratory studies with animals and cross-sectional research with humans that secure attachment is closely related to prefrontal cortex development, which is the regulatory center of the brain and its functions (Schore, 2001). Secure attachment was also found to be related to both prefrontal cortex functions and trait mindfulness, as mediators toward predicting emotional regulation (Hisli Sahin et al., 2023).

Other very interesting findings of the current study are the relationships between trait mindfulness and almost all of its subdimensions, except "observing without judgement." The other dimensions like, "regulating attention", "observing the mind and the body without being affected", and "naming emotions" were all strongly associated with "mindful driving behavior." These findings are in parallel with previous studies on mindfulness, emotional regulation, and executive functions (Hisli Sahin et. al, 2023). There could be several reasons for the lack of an association between "observing without judgement"—an important dimension of mindfulness—and mindful driving attitudes; one possible explanation is the low reliability of the subscale used to measure it. It can also have a cultural explanation. In this culture, observing, developing opinions, and judging is a very common daily automatic behavior (Kağıtçıbaşı and Cemalcılar, 2016). Therefore, developing a mindful behavior like "observing without judgement" can be quite contrary to this automatization.

Another interesting thing that can be observed in Table 4 is the relationship between mindfulness as a trait and mindful driving attitudes. It is seen that event hough the total score of the FFMQ-S was significantly correlated with the total score of the MDAS, its correlation with the "warning each other" subscale of the MDAS was not significant. "Warning each other" subdimension of the mindful driving attitudes was not correlated with the "regulating attention" and "sensory awareness" dimensions of the FFMQ-S. These results might also have several explanations, including cultural factors. It is possible that in this culture, "warning each other" can be perceived as a socially intrusive or inappropriate behavior that can even evoke anger (Kağıtçıbaşı and Cemalcılar, 2016). It is also possible that this scale is not tapping very robustly to "warning each other" variable, indicated by its lower reliability coefficient. On the other hand, the FFMQ-S subdimension of "regulating attention" was found to be positively related with all three subdimensions of mindful driving attitudes. This subdimension consists of items such as "I am not easily distracted", "I have no difficulty in keeping my attention on what is happening at the moment", and "I am not easily distracted while doing a job." In the related literature, attention/distraction is seen as a complex and multifaceted issue involved in driver behavior (Ozturk, 2022). In a review article that examines the contributions of mindfulness practices to improve traffic safety, it is emphasized that these practices were found to be very useful, especially in reducing distracted driving (Koppel et al., 2019). In the current study, our findings on the relationship of trait mindfulness with mindful driving behaviors also indicate how these mindfulness practices which can help increase trait mindfulness can be used as one of the skills to be taugt to increase traffic safety. In other words, by including mindfulness practices in traffic safety education, especially in driver candidate training, individuals might improve their driving attention. According to the results of our study, the subdimensions of "regulating attention", "observing the mind and the body without being affected", "sensory awareness", and "naming emotions" are the four practices that should be emphasized during mindfulness training (Kabat- Zinn, 2003).

The main purpose of this study was to investigate the mediating role of prefrontal cortex (regulatory) functions and mindful driving attitudes in the relationship between trait mindfulness and aberrant and positive driver behaviors. For this purpose, a path analysis was conducted to identify pathways from trait mindfulness to positive and aberrant driver behaviors. The results showed that the fit of the data to the model is quite good. In other words, mindfulness significantly predicted prefrontal cortex functions, prefrontal cortex functions significantly predicted mindful driving attitudes, and mindful driving attitudes significantly predicted positive and aberrant driver

behaviors. In addition, the sequential mediating effects of these two variables on the path from trait mindfulness to positive and aberrant driver behaviors were also found to be significant. Based on these findings, we can assume that a traffic education enriched with mindfulness techniques emphasizing attention regulation, observing the mind and the body without getting affected by the triggers, sensory awareness and labeling emotions might produce safer drivers.

It can be noted that these findings, which are important in terms of driving behavior and therefore traffic safety, are the most important contribution of the study. In Turkey as well as in the world, driver candidate training is a consistently developing field. As we stated in detail in the introduction, the relevant Ministry in Turkey has made innovations in this regard. In the revised new curriculum for driver candidate education, mindful (prosocial) driving attitudes were added as a topic by the initiation of the researchers (Hatipoglu and Yasak, 2016). The current study, for the first time, provides scientific evidence highlighting the importance of mindful (prosocial) driving attitudes in relation to both positive and aberrant driving behaviors, within the context of trait mindfulness and prefrontal cortex functions. In conclusion, in the short run, we can say that increasing the duration of the revised driver candidate education and training with the incorporation of mindfulness techniques of "attention regulation", "observing without getting affected", "sensory awareness", and "labeling emotions" mindfulness skills can be very beneficial for increasing the practice of safe driving. In the long run, other revisions in educating parent candidates, preschool, elementary school teachers, and the public in general on the importance of "secure attachment" should also be considered.

There are several limitations of this study, one of them being the self-report nature of the data collecting instruments. The reliance on participants' self-perceptions and declarations may have led to subjective interpretations of the data. Another limitation is the risk of social desirability bias; individuals may tend to provide responses that are more socially acceptable or desirable, potentially deviating from their true attitudes or behaviors. Consequently, these limitations necessitate a cautious evaluation of the study's generalizability and the inferences drawn from its findings.

### Conclusions

One of the most important contributions of the study is to reveal the importance of mindful (prosocial) driving attitudes, along with prefrontal cortex functions and trait mindfulness. Therefore, further studies are needed to comprehensively understand the determinants contributing mindful driving attitudes as well as to identify and assess effective interventions aimed at enhancing traffic safety.

## DECLARATIONS

**Ethics Committee Approval**: Ethical approval for this study was obtained from Çankırı Karatekin University Ethics Committee (Protocol No: 486; Date: March 1st, 2021).

**Conflict of Interest**: The authors declare that they have no conflict of interest.

**Informed Consent**: Informed consent was obtained from all participants prior to their involvement in the study.

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**Data Sharing/Availability**: The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Authors' Contributions**: [1st author]: Conceptualization, writing-original draft, methodology, data analysis, writing-review and editing. [2nd author]: Methodology, data analysis, writing-review and editing. [3rd author]: Writing-original draft, data curation. [4th author]: Writing-review and editing. All authors have read and approved the final manuscript.

**Use of Artificial Intelligence**: During the preparation of this manuscript, OpenAI's ChatGPT-4 model was utilized by the authors for linguistic adjustments, such as checking grammar and spelling errors, improving sentence structures, and regulating the overall flow of the text.

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