# Impulsivity and self-regulation: A dual-process model of risky driving in young drivers in Iran

Mohammaderfan Memarian[a, *1], Lambros Lazuras[b], Richard Rowe[c], Mohammad Karimipour[D]

[a] Department of psychology and education sciences, Shahid Beheshti university, Iran
[b] Department of Psychology Sociology and politics, Sheffield Hallam University, UK
[c] Department of Psychology, University of Sheffield, UK
[d] Department of Psychological medicine, Institute of Psychiatry Psychology and Neuroscience (IOPPN), King's College London, UK

## Abstract

The dual-process model of risky driving (Lazuras, Rowe, Poulter, Powell, & Ypsilanti, 2019) suggested that regulatory processes mediate the effect of impulsivity on risky driving. The current study aimed to examine the cross-cultural generalisability of this model to Iranian drivers, who are from a country with a markedly higher rate of traffic collisions. We sampled 458 Iranian drivers aged 18 to 25 using an online survey measuring impulsive processes including impulsivity, normlessness and sensation-seeking, and regulatory processes comprising emotion-regulation, trait self-regulation, driving self-regulation, executive functions, reflective functioning and attitudes toward driving. In addition, we used the Driver Behaviour Questionnaire to measure driving violations and errors. Executive functions and driving self-regulation mediated the effect of attention impulsivity on driving errors. Executive functions, reflective functioning, and driving self-regulation mediated the relationship between motor impulsivity and driving errors. Finally, attitudes toward driving safety significantly mediated the relationship of both normlessness and sensation-seeking with driving violations. These results support the mediatory role of cognitive and self-regulatory capacities in the connection between impulsive processes and driving errors and violations. Overall, the present study confirmed the validity of the dual-process model of risky driving in a sample of young drivers in Iran. Implications for educating drivers and implementing policies and interventions based on this model are discussed.

**Keywords:** Risky driving, Young drivers, Driving violations, Driving errors, Impulsivity, Sensation-seeking, Self-regulation

## 1. Introduction

Road traffic crashes (RTCs) are currently the eighth leading cause of death for all ages and the leading cause of death for children and young adults globally. The income level of countries is strongly associated with road traffic deaths, as the average rate of death is 27.5 per 100,000 in low-income countries, while 8.3 deaths per 100,000 in high-income countries; and more than 90% of road traffic deaths occur in low- and middle-income countries (World Health Organization, 2018, 2021). One way to prevent and reduce road traffic injuries and fatalities is to understand the processes that underlie risky driving behaviour. Over the last few decades, several interventions have aimed to reduce fatalities by educating drivers (Cutello et al., 2020; Jordan et al., 2015). Understanding influential factors that may lead to (or prevent) road traffic crashes can provide a foundation for the development of driving safety interventions, including education, in-vehicle technology, and law enforcement.

Previous investigations have suggested that self-reported aberrant driving behaviour is associated with involvement in road traffic crashes (de Winter & Dodou, 2010). Reason et al. (1990) categorised risky driving behaviours into driving errors and violations, suggesting different psychological origins for each behaviour class. Errors are defined as “failure of planned actions to achieve their intended consequences” (e.g., underestimating the speed of an oncoming vehicle when overtaking). Violations are “deliberate deviations from those practices believed necessary to maintain the safe operation of a potentially hazardous system” (e.g., become impatient with a slow driver in the outer lane and overtake on the inside, pp. 1315-1316). This distinction between different types of risky driving behaviour has been repeatedly confirmed and expanded into more specific factors such as aggressive and ordinary violations (Aberg & Rimmo, 1998; Lajunen et al., 2004; Martinussen et al., 2013; Parker et al., 1995). Findings from a large-

[*] Corresponding author.
[1]Email adresses: memar.erfan@gmail.com (Mohammaderfan Memarian), L.Lazuras@shu.ac.uk (Lambros Lazuras), r.rowe@sheffield.ac.uk (Richard Rowe), mohammad.karimipour@kcl.ac.uk (Mohammad Karimipour)

scale naturalistic driving study (Dingus et al., 2016) further support the distinction between driving errors and violations. Dingus et al. focused on four categories of driving behaviour that relate to road traffic crashes. The category "momentary driver judgement errors" reflected speeding and aggressive driving, and was conceptually similar to the driving violations identified by Reason et al. (1990), while the three other categories were close to driving errors (e.g., vehicle manoeuvre and operation errors, emotions or fatigue impacting driver's performance, driver distractions). After comparing episodes of alert, attentive and sober driving behaviour and crash videos, driving-specific performance errors (e.g., improper braking, right of way error) had the highest contribution to crash risk. An 11-fold increase of crash risk was attributed to driver judgement errors, the category closest to driving violations (e.g., speeding and aggressive driving behaviours).

In recent years, a considerable body of research has been dedicated to explaining what leads to aberrant driving behaviours, resulting in RTCs. Studies focusing on demographic factors have shown that age is associated with risky driving behaviour and crash rates; and the characteristics related to risky driving behaviours vary among different age groups (Brown et al., 2017). Rhodes & Pivik (2011) found that young drivers (age 16-20) were more frequently engaged in risky driving behaviours than adults (age 25-45). The per-mile crash rate is ten times higher for teens than that of older drivers, highlighting the role of age and possibly driving experience in traffic casualties (McKnight & McKnight, 2003). This evidence clarifies the importance of considering age and developmental stage of drivers in risky driving studies and in the development of prevention strategies. Several studies have also identified gender differences in risky driving behaviours. Compared to female drivers, males have reported more frequent road traffic violations, while females have reported more driving errors (Aberg and Rimmo, 1998; Bachoo et al., 2013; de Winter and Dodou, 2010). González-Iglesias et al. (2012) additionally found that male drivers report higher crash involvement and received more traffic fines compared to female drivers independently from driving mileage. This evidence suggests that risky driving behaviours vary between males and females. A study across 9 European countries showed that, compared to females, male drivers have more permissive attitudes towards disrespecting road traffic rules, and were less concerned about their personal car crash risk (Cordellieri et al., 2016). Taken together, the extant empirical evidence highlights the importance of controlling for gender in studies of risky driving behaviour. In addition to demographic characteristics, driver's personality characteristics, as well as affective and cognitive processes have been identified as risk factors for risky driving (Scott-Parker & Weston, 2017; Smorti & Guarnieri, 2016).

In order to inform intervention efforts, we need to understand the processes that mediate the effects of personality characteristics on behaviour behind the wheel. Progress from detecting underlying factors toward procedural mediation models of risky driving seems necessary to better understand these behaviours. Lambert et al. (2014) reviewed studies applying the dual-system (executive and socio-emotional) model of cognitive development in risky adolescent driving. The executive system refers to cognitive functions leading to the regulation of one's thoughts and actions; and the socio-emotional system reflects sensitivity to socio-emotional cues and rewards (e.g., peer pressure). This model suggests that adolescents may be more vulnerable to different types of risk-taking (including risky driving) as their socio-emotional system develops earlier than their executive system, which regulates the socio-emotional system. This results in insufficient regulation of the socio-emotional system, especially in highly emotional situations. Lambert et al. (2014) concluded that there is initial support for the dual-systems model in risky adolescent driving, while there are major limitations in these studies (e.g., not measuring individual differences in executive function).

Lazuras et al. (2019) proposed a dual-process model that distinguishes between impulsive and regulatory processes that relate to aberrant driving behaviour in young drivers. Originating in the study of human reasoning (Evans, 2008), dual-process theorists generally categorise psychological processes based on whether they are unconscious, rapid, automatic, and high capacity, or conscious, slow, effortful, and deliberative. One of the dual-process categorisations is the distinction between impulsive processes consuming less cognitive effort and mainly relying on intuition (system 1), in contrast to system 2 processes which are characterised by reflective and analytical thinking, require a higher level of goal-directed and conscious cognitive effort, and are more deliberately controlled. System 2 processes mainly have a regulatory function in controlling impulses and emotional arousal, nevertheless this capability is not limited to system 2 processes, especially in implicit forms of regulation (Evans, 2008). System 1 processes, such as impulsivity and sensation-seeking, had been previously associated with aberrant driving behaviour (Pearson et al., 2013; Wishart et al., 2017). However, Lazuras et al. (2019) demonstrated that self-regulatory (system 2) processes could mediate the relationship between impulsive processes and aberrant driving behaviours. Specifically, the relationship between motor impulsivity and normlessness with driving errors, lapses, and violations was mediated by attitudes toward driving safety; and these indirect effects were stronger for driving violations. Also, trait self-regulation mediated the relationship between non-planning impulsivity, normlessness, and sensation-seeking with driving errors. Numerous studies have investigated the relationship of different impulsive and regulatory processes with risky driving behaviour (Bıçaksız & Özkan, 2016; Sani et al., 2017; Šeibokaitė et al., 2017), nevertheless, the dual-process model explains these observations by classifying them as emotional/impulsive (system 1) and regulatory/cognitive (system 2) processes, suggesting that regulatory processes mediate the relationship between impulsive processes and risky driving.

Although this dual-process model sheds light on understanding aberrant driving by revealing the mediating role of self-regulatory processes, the generalisability of this model is unknown. Mortality rates of car crashes vary by country and region; there is a substantial gap between European Countries such as the United Kingdom and Asian or African countries. Iran, a lower middle-income country in Western Asia, has an estimated road traffic death rate of 20.5 per 100,000 population when the corresponding rate in the United Kingdom is 3.1 (The World Bank, 2021; World Health Organization, 2018). This gap might reflect differences in the processes underlying crash involvement across cultural contexts. The extant evidence also suggests that self-regulatory processes can differ across cultures and countries. For instance, Easterners are less likely to engage in hedonic emotion regulation after experiencing negative events, a difference explained by cultural beliefs about the utility of negative emotions (Miyamoto et al., 2014). Similarly, Tsai & Lau (2013) suggested that cultural sensitivity might play a role in how Easterners and Westerners regulate their emotions, altering how distressed the person would be as an outcome of the regulatory process. Thus, the first aim of this study is to investigate the generalisability of the dual-process model of risky driving proposed by Lazuras et al. (2019) in an eastern country, which may differ in risky driving attitudes and regulatory mechanisms, as compared to UK drivers. To achieve this goal, we have chosen young Iranian drivers to provide a different culture to test the robustness of the dual-process model of risky driving.

The impulsive and regulatory processes in the Lazuras et al. (2019) model included a broad range of factors. The system 1 processes included more automatic, emotionally-driven and impulse-related factors (impulsivity, sensation-seeking and normlessness) previously shown to be related to aberrant driving behaviour (Iversen and Rundmo, 2002; Pearson et al., 2013; Wishart et al., 2017). Normlessness originates in the work of Kohn and Schooler (1983) and refers to the degree one respects social norms and values and adheres to them in their behaviours. Normlessness was used by Chen (2009) to study risky driving behaviours and was related to risk-taking attitudes toward driving violations. On the other hand, the system 2 processes in the dual-process model of risky driving (Lazuras et al., 2019) included cognitive-driven and reflective factors, mainly functioning as a regulatory process for impulses and emotional arousal (emotion regulation, self-regulation, attitudes to driving safety). Evidence suggests that negative attitudes toward driving safety are related to risky driving and driving violations (Iversen and Rundmo, 2004; Mohamed and Bromfield, 2017). Difficulties in emotion regulation aggravate risky driving behaviours, especially driving errors (Sani et al., 2017). We included the same factors from the Lazuras et al.(2019) model in the system 1 processes and expanded the system 2 processes by incorporating executive functions, reflective functioning, and driving-specific self-regulation. Driving-specific self-regulation focuses on regulatory behaviours and capacities in driving, while general emotion regulation and self-regulation represent broader and more general regulatory processes. Evidence suggests that risky driving outcomes are more strongly associated with driving-specific self-regulation than general self-regulation (Lazuras et al., 2022). Given this preliminary evidence, in the present study we included driving self-regulation as a regulatory factor in system 2 processes.

There is a strong link between different regulatory capacities and core cognitive processes, namely executive functions. There are three basic domains of executive functions, each including multiple functions: the information updating EF which is closely related to working memory, response inhibition, and mental shifting. Different facets of executive functions (EF) enable successful self-regulation (Hofmann et al., 2012); and contribute to regulation in a broad range of behaviours such as eating behaviour (Dohle et al., 2018). Different components of EF are associated with driving behaviour. In a simulated driving task, teen drivers who performed worse in a series of EF tasks made more errors in the driving simulation (Mäntylä et al., 2009).

Although the working memory updating facet of EF was the main predictor of driving performance in this study, other facets such as inhibitory control have been associated with aberrant driving behaviours (Tabibi et al., 2015). The meta-analysis by Walshe et al. (2017) confirms the commonly reported association between EF and aberrant driving and suggests that working memory and inhibition seem to be the primary facets of EF related to risky driving. Executive functions were not among the capacities included in Lazuras et al.'s (2019) dual-process model. Considering the critical role of EF in regulatory processes and the evidence suggesting the association between EF and risky driving, we included EF as a regulatory (system 2) process, possibly underlying multiple regulatory components in the model. Reflective functioning (also known as mentalization) is the capacity to reflect on and interpret mental states (e.g., attitudes, feelings, desires) of the self and others (Fonagy et al., 2016). Reflective functioning was associated with emotion regulation, and better mentalizing capacity was associated with adaptive strategies of emotion regulation (Schwarzer et al., 2021). Better executive function capacities in facets such as working memory were associated with better capacity for reflective functioning (Rutherford et al., 2018). There is a theoretical overlap between reflective functioning and mindfulness (Falkenström et al., 2014), and Murphy & Matvienko-Sikar (2019) found that mindfulness protects against risky driving. Even though reflective functioning has been empirically and theoretically associated with regulatory processes related to risky driving, studies focusing on reflective functioning in risky driving are rare. Since reflective functioning has a reflective nature and has been associated with regulatory capacities, we included reflective functioning as a system 2 variable to investigate further the regulatory role of reflective functioning in risky driving behaviours.

Considering the necessity of assessing the dual-process model of risky driving in a different culture and the evidence indicating the relationship between regulatory processes and risky driving, we investigated the association between regulatory processes and risky driving in Iranian drivers; and followed by investigating the mediatory role of regulatory processes in the relationship between impulsive processes and risky driving, while controlling for gender. Lazuras et al. (2019), found the indirect effects of system 1 (impulsive) processes via attitudes toward driving safety were stronger on driving violations than errors. This fits with Mohamed and Bromfield's (2017) finding that positive driving safety attitudes mitigate the likelihood of speedy and aggressive driving behaviours, whereas attitudes do not have a significant effect on driving errors. This association between attitudes toward driving and violations portrayed the "risky drivers" subtype in the study by Lucidi et al. (2010), indicating that these drivers experienced more crashes and showed higher levels of negative attitude towards driving safety. We hypothesised that attitudes toward driving safety are negatively associated with driving violations and mediate the relationship between system 1 (impulsive) processes and driving violations. Considering that Lazuras et al. (2019) found that the indirect effects of system 1 processes via self-regulation were stronger on driving errors than violations, we further hypothesised that cognitive and regulatory capabilities among system 2 processes (e.g., EF, self-regulation) are negatively associated with driving errors, and mediate the effect of system 1 (impulsive) processes on driving errors.

## 2. Method

### 2.1. Participants

A total of 458 Farsi-speaking young adults aged 18-25 participated in the study. To establish if respondents were completing the questionnaire without paying attention to the questions, we embedded an attention checker item which requested participants to provide a specific response (i.e., somewhat disagree). Overall, 34 participants were removed from our sample due to failing to provide the correct response to the said item and we continued with 424 remaining responses. The remaining participant's mean age was 21 years (SD= 1.9), and 63% identified as males. Their average kilometres travelled per week was 101.7 (SD= 192.9), and the mean time since obtaining their driving license was 2.5 years (SD= 1.8). One hundred and fifty-one (36%) of the participants responded positively to the question "Have you ever been involved in a car crash as the driver?".

## 2.2. Translations

We thoroughly translated the risky driving behaviour (Driver Behaviour Questionnaire),[2] normlessness, attitudes towards driving safety, and driving self-regulation measures, following the procedure suggested by the ITC test translation and adaptation guidelines (Hambleton, 2001). These guidelines were developed to respond to the common shortcomings in translation procedures (e.g., single translators) and include four sections: context, test development and adaptation, administration, and documentation/ score interpretations. Existing translations were used for all other measures.

## 2.3. Measures

*Impulsivity*: Was measured with the Abbreviated Impulsiveness scale (ABIS, Coutlee et al., 2014), which contains 13 items forming three subscales: Attentional (e.g., "I don't pay attention"), motor (e.g.," I say things without thinking"), and non-planning (e.g.," I am future-oriented") impulsivity. Responses are coded on a 4-point Likert scale (1= rarely/never, 4= almost always). A mean score is calculated for each subscale, with higher scores indicating higher impulsiveness. In the present study, the internal consistency (Cronbach's α) for each subscale was satisfactory (ABIS attention α= 0.63, ABIS non-planning α= 0.68, ABIS motor α= 0.64 ).

*Sensation-seeking*: Was measured with five items based on the NEO personality inventory (Costa & McCrae, 1992). Responses were coded on a 5-point Likert scale from 1= strongly disagree to 5= strongly agree. A mean score was computed, and higher scores reflected higher sensation-seeking. Two items ("I act in a direct way" and "I act wild and crazy") were removed to improve the internal consistency of the scale. The final 3-item measure had acceptable internal consistency (α= 0.61).

*Normlessness*: Was measured with the mean of three items (e.g., "It is alright to do anything you want as long as you keep out of trouble"). These items were based on Kohn & Schooler's (1983) normlessness scale. Responses were coded on a 5-point Likert scale from 1= strongly disagree to 5= strongly agree, and higher scores reflected normlessness. Internal consistency was satisfactory (α= 0.76).

*Emotion regulation*: Was measured with the brief version of the Difficulties in Emotion Regulation Scale (DERS-18, Victor & Klonsky, 2016) based on the original DERS questionnaire (Gratz & Roemer, 2004). Responses are coded on a 5-point Likert scale, from 1= almost never (0-10%) to 5= almost always (91-100%). After reverse-scoring three items, a sum score is computed with higher scores indicating greater difficulties in emotion regulation. The DERS-18 had excellent reliability in previous research (Victor & Klonsky, 2016), and the internal consistency reliability for the total score was satisfactory in the present study (α= 0.76).

*Self-regulation*: Trait self-regulation was measured with the 31-item Short Self-Regulation Questionnaire (SSRQ, Carey et al., 2004). The SSRQ has a single factor structure reflecting overall self-regulation in the original study. Responses were recorded on a 5-point Likert scale from 1= strongly disagree to 5= strongly agree, and a sum score was computed, with higher scores indicating higher overall self-regulation. The internal consistency reliability was excellent (α=0.92).

*Attitudes towards driving safety*: Were assessed with the measure developed by Iversen (2004). This 16-item scale measures attitudes toward violations of traffic rules and different aspects of road safety (e.g., "Many traffic rules must be ignored to ensure traffic flow," "punishments for speeding should be more restrictive"). Responses were coded on a 5-point Likert scale from 1= strongly agree to 5= strongly disagree, and a mean score was computed, with higher scores reflecting positive attitudes toward driving safety. This measure was used by Lazuras et al. (2019) to assess attitudes toward driving safety and had high internal consistency in the study mentioned above. This measure had satisfactory reliability in the present study (α= 0.65).

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[2] Various versions of The Driver Behaviour Questionnaire have been translated and used in Iranian samples before (Oreyzi & Haghayegh, 2010; Parishad et al., 2020). Nevertheless, we re-checked the translation and addressed the issues (e.g., considering right-hand to left-hand driving in the translation of items) by following the ITC test translation and adaptation guidelines.

*Driving self-regulation*: Self-regulatory behaviours during driving (e.g., "I have trouble controlling my speed when I'm driving") were measured with the 17-item Driving Self-Regulation Questionnaire (DSRQ-17, Lazuras et al., 2022). Responses were coded on a 5 point Likert scale from 1= strongly disagree to 5= strongly agree, and a sum score was computed, with higher scores reflecting less driving self-regulation. We removed one item to improve internal consistency reliability ("I usually think before I act when I'm driving"). The final internal consistency was satisfactory ($\alpha$= 0.84). We explored the factor structure of this scale by using principal axis factoring with promax rotations and examined the scree plot. The scree plot suggested a single factor structure. The correlations between the DSRQ and general self-regulation ($r= 0.56$, $p< .01$) and emotion-regulation ($r= 0.52$, $p< .01$) indicated the concurrent validity of the driving self-regulation questionnaire, while correlations with different facets of impulsivity (see Table 1) provided evidence for the discriminant validity of the DSRQ.

*Executive functions*: Was assessed by a 14-item measure based on The Dysexecutive Questionnaire-Revised (DEX-R, Simblett et al., 2017). This questionnaire measures everyday and common manifestations of EF problems (e.g., "I find it hard to complete tasks or activities without structure or direction"). Responses are coded on a 5-point Likert scale from 0= never to 4= very often. A sum score is computed, with higher scores reflecting greater executive functioning problems. The internal reliability was strong in the present study ($\alpha$= 0.83).

*Reflective functioning*: Was measured by the Reflective Functioning Questionnaire (RFQ-8, Fonagy et al., 2016). Reflective functioning is the capacity to reflect on internal mental states (e.g., feelings, goals) concerning self and others. This 8-item measure comprises two subscales that reflect certainty (RFQc) and uncertainty (RFQu) about mental states of self and others. Responses are recorded on a seven-point Likert scale from 1= completely disagree to 7= completely agree. To compute the certainty and uncertainty score, all items are treated as polar-scored items. For instance, "People's thoughts are a mystery to me" is coded 3-2-1-0-0-0-0 (3= strongly disagree) to compute the certainty score and coded 0-0-0-0-1-2-3 (3=strongly agree) to compute the uncertainty score. The total score for each subscale is the mean score of all items. The internal consistency reliability for this measure in the present study was acceptable ($\alpha$ for RFQc= 0.77, $\alpha$ for RFQu= 0.62).

*Risky driving behaviour*: Was measured with the 27-item version of the Manchester Driver Behaviour Questionnaire (DBQ, Lajunen et al., 2004). Responses were recorded on a six-point Likert scale from "Never" to "Nearly all the time." The validation study of the 27-item version indicated a four-factor structure of aggressive violations (e.g., "Sound your horn to indicate your annoyance to another road user"), ordinary violations (e.g., "Disregard the speed limit on a residential road"), errors (e.g., "Brake too quickly on a slippery road or steer the wrong way in a skid"), and lapses (e.g.," Hit something when reversing that you had not previously seen") based on UK, Finnish, Dutch samples. Nevertheless, Lajunen et al. (2004) emphasise taking cultural factors into account when applying this instrument in another country or language. For example, Dotse and Rowe (2021) found a two-factor structure in Ghanaian drivers which contained errors and violation factors, but 5 error items loaded with the violations and one violation was included in the errors factor. Therefore we explored the factor structure of the DBQ in the Iranian context in this study.

### 2.4. Design and procedure

We used a cross-sectional survey design to assess impulsive processes (impulsivity, sensation-seeking, normlessness), regulatory processes (emotion regulation, self-regulation, driving self-regulation, attitudes towards driving safety, reflective functioning, executive functions), and driving behaviour. We recruited participants through public invitations, mostly on social media (e.g., Instagram), asking them to complete an online driving behaviour survey hosted on Google Forms. We did not limit time for completing the survey, and participants usually took around 20 minutes. Participants were first led to an explanation page. They were informed about the study purpose and given the right to withdraw at any point without any negative consequences. They were assured regarding confidentiality and anonymity of their responses. Participants provided informed consent via selecting an option in the online survey indicating their agreement to proceed before starting the questionnaires. Ethics approval was granted by the ethics board of Shahid Beheshti University of Iran (Ethical approval ID: IR.SBU.REC. 1399.082).

### 2.5. Analysis

IBM SPSS Statistics for Windows, Version 23.0 (IBM Corp., Armonk, NY., USA) was used for all analyses. We used an exploratory factor analysis to establish the factor structure of the DBQ. In order to examine validity, we tested whether the identified factors predicted crash involvement using logistic regression. Having established the factor structure of the DBQ, we investigated the predictors of the identified factors using hierarchical regression. Age, KM travelled per week, system 1 processes (sensation-seeking, impulsivity sub-measures, normlessness) were entered in the first stage of the hierarchical regression. System 2 processes (attitudes towards driving safety, self-regulation, emotion regulation, executive functions, reflective functioning, driving self-regulation) were added in the second stage of the regression. DBQ subscales usually show moderate correlations (DeWinter & Dodou, 2010). In each regression, one of the DBQ categories (errors and violations) was entered as the outcome variable, and the other DBQ variable was controlled by being entered as a predictor in the first stage of the regression. We considered possible mediated relationships based on the regression results and formulated these relationships based on theoretical background. The PROCESS macro was used to investigate the direct and indirect effects on the outcome variables (Hayes, 2017). The number of bootstrap samples was 5000 for all the mediation analyses. We controlled for gender and the other DBQ outcome in all of the mediation models.

## 3. Results

### 3.1. DBQ factor analysis

Our exploratory factor analysis used principal axis factoring analysis with promax rotation, allowing emerging factors to correlate. A Kaiser-Meyer-Olkin value of 0.86 and a significant Bartlett's test of sphericity ($\chi2(351)= 2431.5$, $p< .001$) confirmed the suitability of the data for factor analysis. A scree plot indicated that 2 factors should be extracted. The two-factor solution explained 30% of the variance; there were no cross-loading items (>.3 on both factors) and all items loaded onto one factor at .3 or greater except for "Cross a junction knowing that the traffic lights have already turned against you", that did not load at 0.3 or greater onto either factor. We dropped this item and repeated the factor analysis, resulting in a satisfactory two-factor structure, explaining 31% of the variance. Sixteen items that are usually classified as errors loaded on the first factor, and 10 items usually classified as violations loaded on the second factor. There was a moderate correlation between factors according to Cohen's conventions, $r= .39$, $p< .001$ (Cohen, 1992).

### 3.2. The relationship between the DBQ and crash involvement

We used binary logistic regression to investigate the relationship of DBQ errors with the likelihood of crash involvement. The first model included gender[3], age, KM travelled per week and driving experience as covariates. The overall model was significant, $\chi2(5)= 59.37$ , $p<.001$, Nagelkerke $R^2=0.18$, and correctly classified 72% of the cases. Driving experience (odds ratio (OR)=1.56, 95% confidence interval (CI)=1.22, 2.00, $p< .001$) and driving errors (OR=1.05, 95% CI=1.02, 1.09, $p< .01$) significantly predicted likelihood of crash involvement.

The analysis process was the same for investigating the relationship between violations and the likelihood of crash involvement. The overall model was significant, $\chi2(5)= 89.15$, $p<.001$, Nagelkerke $R^2=0.26$, and correctly classified 71% of the cases. Consistent with the above analyses, driving experience (OR=1.51, 95% CI=1.18, 1.93, $p< .01$) was a significant predictor. Driving violations (OR=1.13, 95% CI=1.09, 1.18, $p< .001$) was also a significant predictor in this analysis.

[3] We investigated the relationship between gender and the likelihood of crash involvement in another binary logistic regression. The model was not statistically significant, ($\chi2(1)= 1.4$ , $p= .23$, Nagelkerke $R^2=0.005$) and gender did not predict the likelihood of crash involvement (OR= 0.78, 95% CI=0.51, 1.18, $p= .23$).

### 3.3. Correlations

Correlations among all the variables (including age and KM travelled per week) are presented in table 1. There were a number of small to medium correlations, including many consistent with the study hypotheses. For instance, problems in executive functions was positively correlated with errors ($r= .43$, $p< .05$), violations ($r= .26$, $p< .05$), and system 1 measures such as attention ($r= .55$, $p< .05$), motor ($r= .37$, $p< .05$) and planning impulsivity ($r= .33$, $p< .05$), while negatively correlated with system 2 measures such as attitudes toward driving safety ($r= -.24$, $p< .05$) and self-regulation ($r= -.63$, $p< .05$). These relationships were analysed further using hierarchical regressions and mediation analysis as described below.

Table 1. Descriptive statistics and Inter-correlations among all variables

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Age | - | 0.13** | 0.01 | 0.05 | -0.01 | -0.02 | -0.04 | 0.01 | 0.01 | -0.06 | -0.03 | 0.04 | -0.02 | -0.01 | 0.02 | 0.15* |
| 2. KM per week | - | - | -0.1* | 0.00 | -0.01 | 0.09* | 0.00 | 0.1* | 0.14** | 0.02 | 0.00 | -0.02 | 0.04 | 0.02 | 0.05 | 0.29** |
| 3. Attitudes towards driving safety | - | - | - | 0.19** | -0.26** | -0.19** | -0.13** | -0.29** | -0.54** | -0.18** | -0.24** | 0.25** | -0.1* | -0.38** | -0.22** | -0.44** |
| 4. Self-regulation | - | - | - | - | -0.73** | -0.5** | -0.6** | -0.08 | -0.28** | -0.64** | -0.63** | 0.54** | -0.35** | -0.56** | -0.36** | -0.16** |
| 5.Attention impulsivity | - | - | - | - | - | 0.45** | 0.57** | 0.19* | 0.28** | 0.51** | 0.55** | -0.49** | 0.3** | 0.56** | 0.32** | 0.19** |
| 6. Motor impulsivity | - | - | - | - | - | - | 0.31** | 0.23** | 0.24** | 0.4** | 0.37** | -0.42** | 0.42** | 0.4** | 0.3** | 0.19** |
| 7.Planning impulsivity | - | - | - | - | - | - | - | 0.1* | 0.21** | 0.3** | 0.33** | -0.33** | 0.11* | 0.4** | 0.21** | 0.12* |
| 8. Sensation-seeking | - | - | - | - | - | - | - | - | 0.3** | 0.09* | 0.15** | -0.17** | 0.13** | 0.23** | 0.09* | 0.26** |
| 9. Normlessness | - | - | - | - | - | - | - | - | - | 0.25** | 0.32** | -0.24** | 0.15** | 0.47** | 0.27** | 0.39** |
| 10.Emotion regulation | - | - | - | - | - | - | - | - | - | - | 0.69** | -0.56** | 0.41** | 0.52** | 0.33** | 0.16** |
| 11.Executive functions | - | - | - | - | - | - | - | - | - | - | - | -0.58** | 0.41** | 0.53** | 0.43** | 0.26** |
| 12.Reflective functioning (certainty) | - | - | - | - | - | - | - | - | - | - | - | - | -0.56** | -0.47** | -0.37** | -0.2** |
| 13.Reflective functioning (uncertainty) | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.24** | 0.19** | 0.07 |
| 14.Driving self-regulation | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.48** | 0.36** |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 15. Driving errors | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | 0.39** |
| 16. Driving violations | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Mean | 21.04 | 101.79 | 2.82 | 115.57 | 2.05 | 1.9 | 1.97 | 3.16 | 2.23 | 40.8 | 21.5 | 7.64 | 5.02 | 32.91 | 10.26 | 8.62 |
| SD | 1.9 | 192.9 | 0.49 | 18.37 | 0.52 | 0.51 | 0.63 | 0.88 | 0.97 | 12.17 | 8.52 | 5.41 | 3.93 | 9.13 | 6.5 | 6.13 |

*Note*. **p< .01, *p< .05

### 3.4. The role of impulsivity and regulatory processes in Errors

We used a two-step hierarchical multiple regression to investigate the effects of age, KM travelled per week, impulsivity (system 1) and regulatory (system 2) processes on each DBQ outcome (errors, violations). The first step included all the impulsive processes, age, KM travelled per week. Given the moderate correlation between errors and violations, violations were also entered as a covariate in the first stage. The second step included all regulatory (system 2) processes. This order of entering the variables was planned to highlight the possible mediation of the effects of system 1 components by aspects of system 2. The first set of predictors accounted for 24% of the variance in errors ($F(8,415)= 17.2$, $p< .001$). As shown in Table 2, attention impulsivity, motor impulsivity, and violations were independently associated with errors. Entering the regulatory processes at Step 2 increased predicted variance to 32% and the change in the variance explained was statistically significant, $\Delta R^2= 0.09$, $F(7,408)= 8.37$, $p< .001$. As presented in Table 2, executive functions, certainty in reflective functioning, and driving self-regulation effects were statistically significant in the second stage, while attention and motor impulsivity were no longer significant.

Table 2. Hierarchical regression model predicting driving errors

| | Step 1 | | Step 2 | |
|---|---|---|---|---|
| Independent variable | **β** | t | **β** | t |
| Sensation-seeking | -0.08 | -1.78 | -0.07 | -1.75 |
| Age | -0.01 | -0.28 | 0.00 | 0.02 |
| KM traveled per week | -0.06 | -1.32 | -0.03 | -0.69 |
| Attention impulsivity | 0.16** | 2.92 | -0.02 | -0.43 |
| Motor impulsivity | 0.15** | 3.22 | 0.09 | 1.76 |
| Planning impulsivity | 0.01 | 0.30 | -0.02 | -0.49 |
| Normlessness | 0.09 | 1.88 | 0.01 | 0.34 |
| DBQ violations | 0.33*** | 6.71 | 0.26*** | 5.30 |
| Attitudes toward driving safety | - | - | 0.05 | 1.10 |
| Self-regulation | - | - | -0.02 | -0.26 |
| Emotion dysregulation | - | - | -0.04 | -0.74 |
| Executive functions | - | - | 0.18** | 2.98 |

| | | | | |
|---|---|---|---|---|
| RFQ (Certainty) | - | - | -0.13* | -2.24 |
| RFQ (Uncertainty) | - | - | -0.04 | -.80 |
| Driving self-regulation | - | - | 0.26*** | 4.58 |

*Note*. ***p< .001, **p< .01, *p< .05

RFQ= reflective functioning, DBQ= Driver behaviour questionnaire.

We used the SPSS PROCESS macro (Hayes, 2017) to model the direct and indirect effects indicated by the hierarchical regression. In this bootstrapping approach, confidence intervals of the indirect effects that do not contain zero indicate mediation. Continuous variables that define products were mean-centred prior to these analyses. Since there was a moderate correlation between errors and violations, we controlled for violations.

We investigated whether executive functions and driving self-regulation mediated the relationship between attention impulsivity and errors. We used a sequential pathway model (Figure 1), following the evidence suggesting executive function has a critical role in successful self-regulation, indicating that different facets of executive functions underlie the self-regulatory processes (Dohle et al., 2018; Hofmann et al., 2012). Executive functions and driving self-regulation each mediated the relationship between attention impulsivity and errors. Attention impulsivity was indirectly related to errors through the sequential pathway of executive functions and driving-self regulation.The standardised and unstandardized coefficients, standard errors, and confidence intervals are presented in table 3.

Table 3. Direct and indirect effects of attention impulsivity on driving errors

| | Executive functions (M1) | | Driving self-regulation (M2) | | Driving errors (Y) | |
|---|---|---|---|---|---|---|
| | 95%CI | β | 95%CI | β | 95%CI | β |
| Attention impulsivity (X) | 7.18, 9.77 | 0.52*** | 4.87, 7.89 | 0.36*** | -1.52,0.98 | -0.02 |
| Executive functions (M1) | - | - | 0.2,0.39 | 0.27*** | 0.1,0.25 | 0.21*** |
| Driving self-regulation (M2) | - | - | - | - | 0.12,0.28 | 0.28*** |
| X → M1 → Y | | | | | 0.74,2.11 | 0.12 |
| X → M2 → Y | | | | | 0.71, 1.94 | 0.1 |
| X → M1 → M2 → Y | | | | | 0.24,0.83 | 0.04 |
| Total effect | | | | | 1.99, 4.11 | 0.24*** |
| Total indirect effect | | | | | 2.44,4.26 | 0.26 |
| Gender (total effect) | | | | | -2.8, -0.46 | -0.12 |

Note. ***p< .001, **p< .01, *p< .05.

Confidence intervals of the indirect effects that do not contain zero indicate mediation.

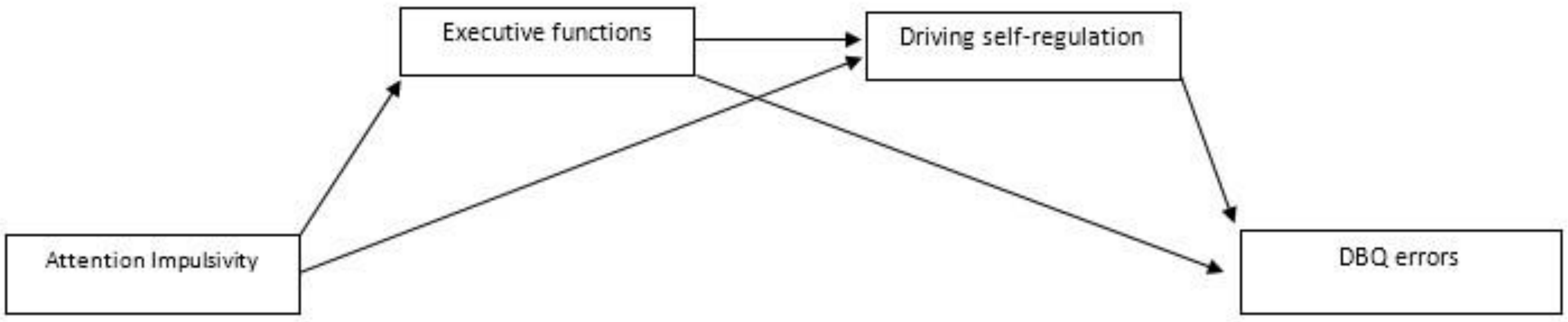


Figure 1. Model of direct and indirect effects of attention impulsivity on errors

We investigated the direct and indirect effects of motor impulsivity on errors via executive functions, reflective functioning, and driving self-regulation. As Figure 2 shows, the indirect effects were structured to be sequential; general cognitive processes such as executive functions and reflective functioning were modelled to be parallel mediators and prior to the specific process of self-regulation in driving. Executive functions and driving self-regulation each mediated the relationship between motor impulsivity and errors. Motor impulsivity was indirectly related to errors through the sequential pathway of executive functions and driving self-regulation, and the sequential pathway of reflective functioning and driving self-regulation. The standardised and unstandardized coefficients, standard errors, and confidence intervals are presented in table 4.

Table 4. Direct and indirect effects of motor impulsivity on driving errors

| | Executive functions (M1) | | Reflective functioning (M2) | | Driving self-regulation (M3) | | Driving errors (Y) | |
|---|---|---|---|---|---|---|---|---|
| | 95%CI | β | 95%CI | β | 95%CI | β | 95%CI | β |
| Motor impulsivity (X) | 4.01,6.95 | 0.33*** | -5.18,-3.34 | -0.4*** | 1.61, 4.59 | 0.17*** | -0.25,1.99 | 0.06 |
| Executive functions (M1) | - | - | - | - | 0.23,0.44 | 0.31*** | 0.05,0.21 | 0.17** |
| Reflective functioning (M2) | - | - | - | - | -0.46,-0.13 | -0.17** | -0.21,0.03 | -0.07 |
| Driving self-regulation (M3) | - | - | - | - | - | - | 0.1, 0.24 | 0.24*** |
| X → M1 → Y | | | | | | | 0.25, 1.29 | 0.05 |
| X → M2 → Y | | | | | | | -0.1, 0.93 | 0.03 |
| X → M3 → Y | | | | | | | 0.21, 0.95 | 0.04 |
| X → M1 → M3 → Y | | | | | | | 0.14, 0.57 | 0.02 |
| X → M2 → M3 → Y | | | | | | | 0.08, 0.38 | 0.01 |
| Total effect | | | | | | | 1.98,4.15 | 0.24*** |
| Total indirect effect | | | | | | | 1.51, 2.97 | 0.17 |
| Gender (total effect) | | | | | | | -3.22, -0.88 | -0.15 |

Note. ***p< .001, **p< .01, *p< .05.

Confidence intervals of the indirect effects that do not contain zero indicate mediation.

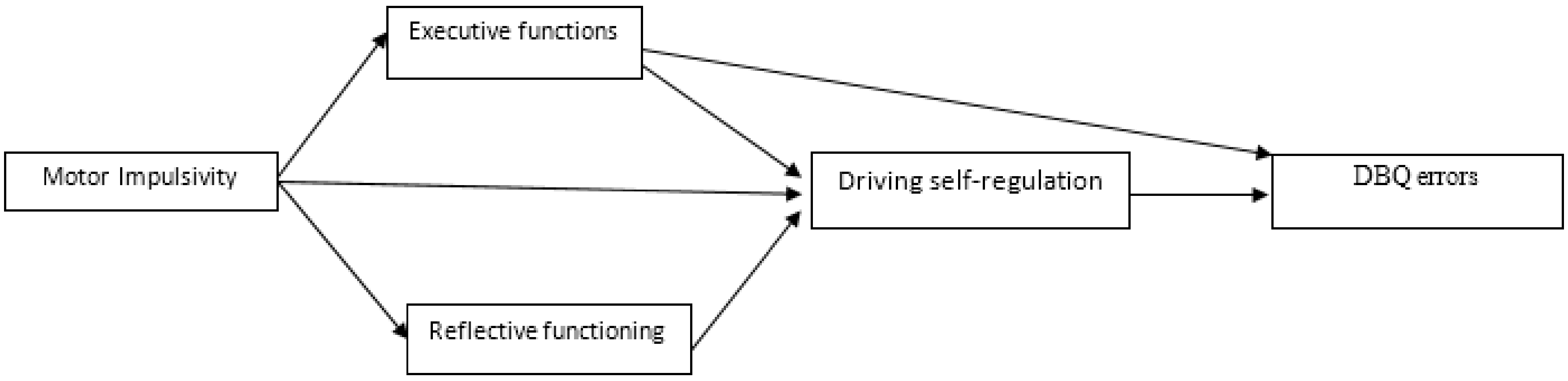


Figure 2. Model of direct and indirect effects of motor impulsivity on errors

### 3.5. The role of impulsivity and regulatory processes in violations

Similar to the errors analysis procedure, we first used a hierarchical regression to examine the effects of age, KM travelled per week, impulsive (system 1), and regulatory (system 2) processes on violations. The first set of predictors accounted for 31% of the variance ($F(8, 415)= 25.18$, $p< .001$). As presented in Table 3, the effects of age, sensation-seeking, KM travelled per week, normlessness, and errors on violations[4] were statistically significant. Including the regulatory processes in the second step adjusted the explained variance to 37%, and the change in the variance explained was statistically significant, $\Delta R^2= 0.06$, $F(7,408)= 6.22$, $p< .001$. In the second stage, the effects of sensation-seeking, age, KM travelled per week, errors, and attitudes toward driving safety on violations were statistically significant, while the effect of normlessness was no longer statistically significant. We followed this regression by investigating the suggested indirect effects on violations. Table 5 summarises the results of this hierarchical regression.

Table 5. Effects and coefficients of violations hierarchical regression

| Independent variable | β | t | β | t |
|---|---|---|---|---|
| Sensation-seeking | 0.13** | 3.14 | 0.09* | 2.14 |
| Age | 0.11** | 2.81 | 0.11** | 3.03 |
| KM traveled per week | 0.21*** | 5.11 | 0.21*** | 5.29 |
| Attention impulsivity | 0.02 | 0.36 | -0.03 | -0.51 |
| Motor impulsivity | 0.00 | -0.1 | 0.02 | 0.43 |

[4] To investigate whether the non-significance of impulsivity measures resulted from inter-correlations between the sub-components, we used a total score for impulsivity in an additional analysis. The effect of the total impulsivity score on violations was not statistically significant.

| | | | | |
|---|---|---|---|---|
| Planning impulsivity | -0.01 | -0.27 | 0.00 | 0.06 |
| Normlessness | 0.23*** | 5.3 | 0.08 | 1.6 |
| DBQ errors | 0.29*** | 6.71 | 0.24*** | 5.3 |
| Attitudes toward driving safety | - | - | -0.26*** | -5.58 |
| Self-regulation | - | - | 0.05 | 0.79 |
| Emotion dysregulation | - | - | -0.04 | -0.77 |
| Executive functions | - | - | 0.11 | 1.78 |
| RFQ (Certainty) | - | - | 0.01 | 0.22 |
| RFQ (Uncertainty) | - | - | -0.05 | -1.04 |
| Driving self-regulation | - | - | 0.1 | 1.77 |

*Note*. ***p< .001, **p< .01, *p< .05

RFQ= reflective functioning, DBQ= Driver behaviour questionnaire.

We investigated the direct and indirect effects of normlessness on violations through attitudes toward driving safety (Figure 3). Attitudes toward driving safety mediated the relationship between normlessness and violations. The standardised and unstandardized coefficients, standard errors, and confidence intervals are presented in table 6.

Table 6. Direct and indirect effects of normlessness on driving violations

| | Attitudes toward driving safety (M1) | | Driving violations (Y) | |
|---|---|---|---|---|
| | 95%CI | **β** | 95%CI | **β** |
| Normlessness (X) | -0.29,-0.21 | -0.51*** | 0.3,1.48 | 0.14** |
| Attitudes toward driving safety (M1) | - | - | -4.63,-2.29 | -0.27*** |
| X → M1 → Y | | | 0.55,1.26 | 0.14 |
| Total effect | | | 1.25,2.31 | 0.28*** |
| Gender (total effect) | | | 1.85, 3.91 | 0.22*** |

Note. ***p< .001, **p< .01, *p< .05
Confidence intervals of the indirect effects that do not contain zero indicate mediation.

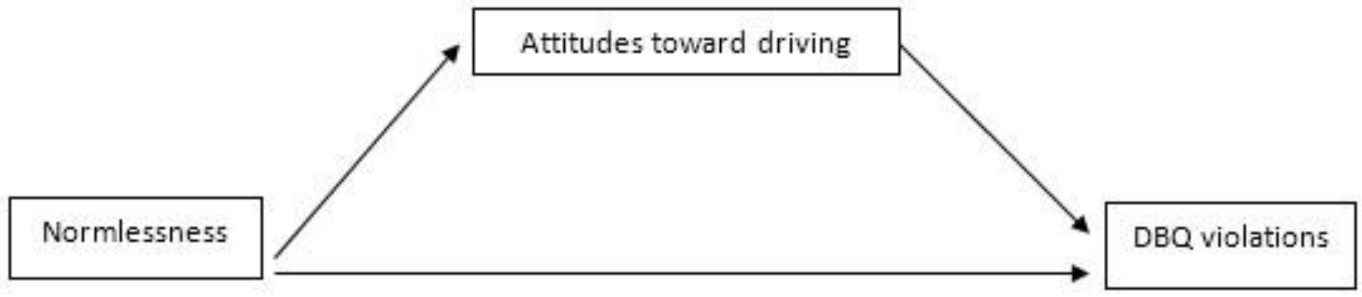


Figure 3. Model of direct and indirect effects of normlessness on violations

We examined the mediating role of attitudes toward driving safety in the relationship between sensation-seeking and violations (Figure 4). Attitudes toward driving safety mediated the relationship between sensation-seeking and violations. The standardised and unstandardized coefficients, standard errors, and confidence intervals are presented in table 7.

Table 7. Direct and indirect effects of sensation-seeking on driving violations

| | Attitudes toward driving safety (M1) | | Driving violations (Y) | |
|---|---|---|---|---|
| | 95%CI | β | 95%CI | β |
| Sensation-seeking (X) | -0.2,-0.1 | -0.27*** | 0.45,1.58 | 0.14** |
| Attitudes toward driving safety (M1) | - | - | -4.87,-2.78 | -0.3*** |
| X → M1 → Y | | | 0.33,0.88 | 0.08 |
| Total effect | | | 1.03,2.18 | 0.23*** |
| Gender (total effect) | | | 2.27, 4.34 | 0.26*** |

Note. ***p< .001, **p< .01, *p< .05

Confidence intervals of the indirect effects that do not contain zero indicate mediation.

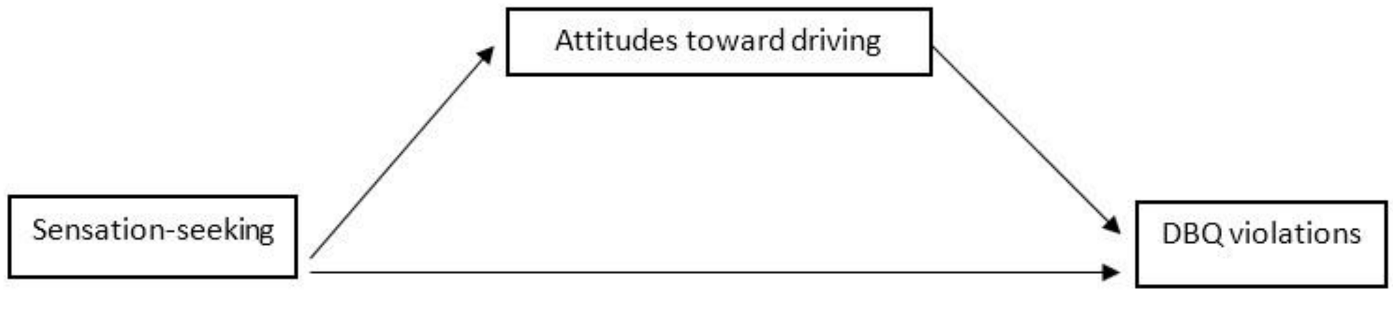


Figure 4. Model of direct and indirect effects of sensation-seeking on violations

## 4. Discussion

The current study extended Lazuras et al.'s (2019) dual-process model of risky driving by including executive functions as a critical regulatory factor and investigating the model in the culturally different context of young Iranian drivers. First we tested whether the DBQ usefully measured aberrant driving behaviour in this Iranian sample. Our exploratory factor analysis revealed a coherent two factor structure that distinguished between driving errors and violations. This confirms the widely supported distinction between driving errors and violations (Aberg & Rimmo, 1998; Martinussen et al., 2013). The two-factor structure is along the lines of the factor structure found by Dotse & Rowe (2021) in Ghanaian drivers, while different from the four-factor structure reported by Lajunen et al. (2004). The cultural differences between the population of Lajunen et al. 's (2004) study (European countries) and lower-middle income countries such as Iran or Ghana (Dotse & Rowe, 2021) might explain the observed differences in the DBQ factor structures, and call for more cross-cultural examinations of risky driving behaviour. Further evidence about the validity of the DBQ was provided by the analysis showing significant associations between driving errors, violations, and crash involvement, matching the conclusions of de Winter & Dodou's (2010) meta-analysis. This association was stronger for violations. These results support the use of the Driver Behaviour Questionnaire to measure aberrant driving in Iran that is compatible with other studies that have addressed this question (Özkan et al., 2006). González-Iglesias et al. (2012) found gender differences in crash involvement while controlling for mileage. In the current study, gender did not predict crash involvement but driving experience was a significant predictor. This difference may be related to cultural differences between the samples from the study by González-Iglesias et al. (2012) and the current study, and suggest further investigation of the role of gender in crash involvement in drivers in Iran. Additionally, the current study focused on young drivers aged between 18 and 25 (M= 21 , SD= 1.9) while the participants in the study by González-Iglesias et al. (2012) aged between 20 and 73 years (Males: $M$ = 40.14 , $SD$ = 12.39; females: $M$ = 39.06 , $SD$ = 10.77).

According to the dual-process model of risky driving (Lazuras et al., 2019), the relationship between system 1 processes (emotional factors such as impulsivity, sensation-seeking, normlessness) and risky driving behaviour is mediated by system 2 processes (regulatory processes such as self-regulation, attitudes toward driving safety). In other words, higher impulsive (system 1) traits increase the chances of risky driving behaviours by reducing regulatory (system 2) processes. Generally, the results of the present study corroborate the dual-process model of risky driving. Nevertheless, the differences in specific direct and indirect relationships from (Lazuras et al., 2019) and the role of executive functions in these effects are notable and interesting.

### 4.1. Dual-process model of risky driving: errors

In the present study, the relationship between attention impulsivity and driving errors was mediated by executive functions, driving self-regulation, and the sequential pathway through executive functions and driving self-regulation (Figure 1). The relationship between motor impulsivity and driving errors was mediated by executive functions and driving self-regulation. Motor impulsivity was associated with driving errors through the sequential pathway of executive functions and driving self-regulation, and reflective functioning and driving self-regulation. Lazuras et al. (2019) found motor impulsivity was indirectly associated with driving errors as well. This relationship was mediated by attitudes toward driving safety in the UK model, while executive functions, reflective functioning, and driving self-regulation mediated this relationship in the present study. In addition to this indirect association, motor impulsivity was directly associated with errors in the UK study, whereas all of the associations between impulsivity sub-measures and risky driving behaviour were mediated by regulatory processes in the present study. In the UK study, self-regulation mediated the association between planning impulsivity, normlessness, and sensation-seeking with driving errors, and normlessness was associated with driving errors through attitudes toward driving safety. It is possible that accounting for regulatory processes not included in the UK study, mainly executive functions- a core cognitive process- and a specific driving self-regulation measure contributed to these differences. Moreover, in their cross-cultural study on risky driving, (Özkan et al., 2006) found different patterns of risky driving between "dangerous" driving environments (e.g., Iran) and "safe" countries such as the UK, which may be relevant to the differences observed in the present study.

The present findings corroborate existing evidence about the association between motor impulsivity and driving errors. In a systematic review, Bıçaksız & Özkan (2016) investigated the relationship between impulsivity and risky driving, and stated that it is not feasible to conclude which dimension of impulsivity is mainly related to risky driving behaviours. Motor impulsivity, which reflects uninhibited action (Coutlee et al., 2014), was associated with driving errors in the present study and in the study by Lazuras et al. (2019). Motor impulsivity has been associated with inhibitory control (Caswell et al., 2013) and Tabibi et al. (2015) found that behavioural inhibition significantly predicted aberrant driving behaviours, including driving errors. A considerable body of evidence highlights the role of executive functions in driving behaviours. For instance, in a driving simulation study on teenage students, Mäntylä et al. (2009) found that lower performance in an EF task was associated with more frequent driving errors. In a review study, Walshe et al. (2017) concluded that inefficient EFs were associated with risky driving behaviours, specifically with a higher number of driving errors in young drivers. Furthermore, crash involvement was associated with lower ability in specific facets of executive functions, such as working memory. Our findings provide further evidence on the contribution of executive functions in different regulatory capacities (e.g., driving self-regulation) and consequently in driving errors.

In recent years, novel models based on the critical role of executive functions in risky driving among young adults have gained more prominence. For example, Lambert et al. (2014) proposed that insufficient regulatory capacities fail to down-regulate the socio-emotional system, leading to risky driving in teens. This model is comparable to our dual-process model of risky driving: first of all, both models suggest that regulatory processes play a vital role in down-regulating factors directly contributing to risky driving. Lambert et al. (2014) emphasise executive functions as the primary regulatory factor. While our results support the role of executive functions in predicting driving errors, it is important to consider that in addition to the direct relationships, there was an indirect association between EF and errors through driving-self regulation in both of the models predicting errors. This sequential relationship corroborates the past findings that different facets of executive functions enable successful self-regulation (Hofmann et al., 2012) and contribute to self-regulation in different categories of behaviour (e.g., driving). Second, the rewarding social context (e.g., presence of peers) is the main risk factor in the dual-system model of risky driving proposed by Lambert et al. (2014), while our dual-process model focuses on emotional processes and traits (system 1) as risk factors in young drivers. Our results imply that impulsive traits are generally related to driving errors, and regulatory processes (e.g., executive functions) mediate this relationship. Rewarding social contexts such as the presence of peers may act as a trigger in young drivers with higher impulsive (system 1) traits.

There was an additional indirect relationship between motor impulsivity and driving errors mediated by the sequential pathway of reflective functioning and driving self-regulation. Certainty in reflective functioning refers to the extent to which one is certain about the mental states (e.g., feelings, goals, desires) of the self and others (Fonagy et al., 2016). Even though excessive levels of certainty can point out a non-genuine stance of mentalization, this specific facet, and mentalization in general, have been related to higher levels of mindfulness (Falkenström et al., 2014; Fonagy et al., 2016). This relationship has even raised arguments on a theoretical overlap between mentalization and mindfulness (Falkenström et al., 2014). Studies investigating the role of mentalization in risky driving are rare; however, in a study by Murphy & Matvienko-Sikar (2019) mindfulness protected drivers against risky driving behaviours such as errors and lapses, ordinary violations, and mobile phone use while driving. Similarly, Terry and Terry (2015) found that college students reporting higher mindfulness reported fewer cell-phone-related near accidents. Based on the relationship and theoretical overlap between mindfulness and reflective functioning and the protective role of mindfulness against risky driving behaviours, reflective functioning may have a similar function. Nevertheless, more research is needed to better understand the relationship between overlapping regulatory processes such as reflective functioning, mindfulness, and perspective-taking and their role in predicting risky driving behaviour.

### 4.2. Dual-process model of risky driving: violations

In the present study attitudes towards driving safety mediated the associations of normlessness and sensation-seeking with violations. Normlessness and sensation-seeking were both directly associated with driving violations (Figure 1). The present findings are in line with Lazuras et al. (2019) whereby the relationship between normlessness and violations was mediated by attitudes toward driving safety. Moreover, attitudes toward driving safety mediated the relationship between motor impulsivity and violations in the UK dual-process model study; and motor impulsivity was directly associated with violations, whereas we found no direct or indirect relationships between impulsivity sub-measures and driving violations in the present study. Based on our current knowledge, studies investigating the relationship between sensation-seeking and impulsivity with risky driving in Iran are lacking, as most have focused on one of these variables (for instance, Rahemi et al., 2017; Barati et al., 2009). Further research investigating the role of impulsivity and sensation-seeking in risky driving behaviour in Iran can help us understand this difference better.

On the other hand, the direct and indirect relationship between sensation-seeking and driving violations in the present study aligns with Zhang et al.'s (2019) systematic review, concluding that sensation-seeking was associated with risky driving and aggressive driving across different cultural contexts. Notably, Rahemi et al. (2017) investigated the relationship between sensation-seeking and risky driving behaviours in Iran and found a comparable pattern of results to the present study: multiple sub-scales of sensation-seeking were positively associated with risky driving, including aggressive and ordinary violations. Normlessness has been a significant predictor of risky driving in Ethiopian drivers (Disassa & Kebu, 2019), as it is plausible that this trait may be reflected in breaking traffic rules. Yang et al. (2013) also found sensation-seeking and normlessness significantly predicted ordinary violations. Normlessness was the only one to predict aggressive violations as well. The present study results confirm a comparable pattern of associations between normlessness and sensation-seeking with driving violations in Iranian drivers.

The dual-process model integrates the evidence on the role of sensation-seeking and normlessness in driving violations and the mediatory role of attitudes toward driving safety: normlessness indirectly influenced driving violations via attitudes towards driving safety in the UK dual-process model and the present study. In addition, sensation-seeking affected violations through attitudes towards safe driving in the present study. Mirzaei et al. (2014) found safer attitudes toward traffic regulations were the most critical predictor of a decrease in RTCs and modified the effects of knowledge and driver behaviour in a cross-sectional study of 2200 Iranian drivers. Mohamed & Bromfield (2017) also found that driving violations (speedy and aggressive driving) predicted crash involvement, and positive attitudes toward safe driving negatively affected speedy and aggressive driving in young Saudi Arabian drivers. This pattern suggests that even though there is a considerable difference in RTC mortality rates between lower-middle-income countries like Iran and the UK, the role of system 1 processes and mediatory role of attitudes toward driving safety might have similarities across countries. A study on Italian high school students (Lucidi et al., 2010) portrayed a "risky driver" cluster mainly evident by having more crashes, higher violations score on the Driver Behaviour Questionnaire, and more negative attitudes toward driving safety. In contrast, the "careful drivers" cluster portrayed drivers with lower violations scores, being involved in fewer crashes, and having more positive attitudes toward driving safety. This relationship might not be limited to young drivers. In a study on active drivers aged between 60-and 90, Lucidi et al. (2014) concluded that positive attitudes toward driving were negatively associated with risky driving (including violations). The extent to which this relationship persists in older drivers in Iran and other regions, remains unclear and can be further investigated in future studies.

### 4.3. Conclusion

The specific associations between risky driving behaviours, impulsive and regulatory processes have similarities and differences between Iran and the UK (Lazuras et al., 2019). Nevertheless, a dual-process approach of impulsive and regulatory processes seems applicable to understanding and explaining risky driving behaviours in young Iranian drivers. Dual-process paradigms can extend our understanding of the repeated relationships between risky driving and different risk and protective factors, by integrating these relationships in dual-process conceptualizations. The evidence suggesting that dual-process paradigms are helpful to understand risky driving behaviour has been growing in recent years (see the review by Lambert et al., 2014; Ross et al., 2016). The present study extends this growing prominence by applying the dual-process model of risky driving suggested by Lazuras et al. (2019) in Iran, a country with a different socio-economic context from most previous studies on this matter. In our study, cognitive capabilities (e.g., executive functions) mediated the relationship between impulsive processes and driving errors. On the other hand, attitudes mediated the relationship between impulsive processes and driving violations. This distinction can resemble the original distinction between risky driving behaviours; as Reason et al. (1990) stated: driving errors and driving violations are differentiated as they have different psychological origins and manifest distinct psychological mechanisms.

This distinction may have important practical implications in education and interventions, as procedures focusing on promoting a more positive attitude toward driving could differ from procedures emphasizing the examination and enhancement of cognitive capabilities. for instance (Özkan et al., 2006) mention media campaigns to promote positive driver behaviours. It is plausible to assume that focusing on positive attitudes toward driving safety could be one of the main focuses of such programs. Nevertheless, the effectiveness of such programs in reducing risky attitudes toward driving is questionable (e.g., Glendon et al., 2014). On the other hand, interventions can focus on regulatory functions (such as driving self-regulation), as there is preliminary support for the effectiveness of this type of program in areas like mindfulness-based training (Koppel et al., 2019).

### 4.4. Limitations

Although our study presented novel findings, there are certain limitations that need to be acknowledged. Firstly, we measured executive functions using the revised version of the Dysexecutive Questionnaire (Simblett et al., 2017). Even though the dysexecutive questionnaire has been used to measure problems in executive functions across several countries (Dimitriadou et al., 2020; Wakely et al., 2022), executive functions can be further assessed using experimental tasks, especially in relation to driving behaviour (see Mäntylä et al., 2009 for an example). Furthermore, this assessment could be more specific and include different components of executive functions, namely behavioural inhibition that has been associated with risky driving (Tabibi et al., 2015). We used self-report measures for risky driving behaviour, and a dichotomous question to assess crash involvement. Generally, self-reports may impose limitations such as socially desirable responding, nevertheless, the DBQ has been associated with objective measures of driving such as observed speed (Helman & Reed, 2015) and self-reported traffic crashes (see the meta-analysis by de Winter et al., 2015).

## Declaration of competing interest

The authors report no competing declaration of interest.

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## Appendix

### Driver behaviour questionnaire factor analysis table

Table 1. Results of the factor analysis with promax rotations

| | Factor 1 | Factor 2 |
|---|---|---|
| Errors | | |
| 1. Hit something when reversing that you had not previously seen. | .33 | |
| 2. Intending to drive to destination A, you "wake up" to find yourself on the road to destination B. | .37 | |
| 4. Get into the wrong lane approaching a roundabout or a junction. | .46 | |
| 5. Queuing to turn left onto a main road, you pay such close attention to the main stream of traffic that you nearly hit the car in front | .51 | |
| 6. Fail to notice that pedestrians are crossing when turning into a side street from a main road. | .49 | |
| 8. Fail to check your rear-view mirror before pulling out, changing lanes, etc. | .38 | |
| 9. Brake too quickly on a slippery road or steer the wrong way in a skid. | .32 | |
| 12. Switch on one thing, such as the headlights, when you meant to switch on something else, such as the wipers. | .53 | |
| 13. On turning left nearly hit a cyclist who has come up on your inside. | .43 | |
| 14. Miss "Give Way" signs and narrowly avoid colliding with traffic having right of way. | .45 | |
| 15. Attempt to drive away from the traffic lights in third gear. | .43 | |

| | | |
|---|---|---|
| 16. Attempt to overtake someone that you had not noticed to be signalling a right turn | .39 | |
| 19. Forget where you left your car in a car park. | .48 | |
| 22. Misread the signs and exit from a roundabout on the wrong road. | .51 | |
| 26. Realise that you have no clear recollection of the road along which you have just been travelling. | .46 | |
| 27. Underestimate the speed of an oncoming vehicle when overtaking. | .46 | |
| Violations | | |
| 3. Disregard the speed limit on a motorway. | | .69 |
| 7. Sound your horn to indicate your annoyance to another road user. | | .48 |
| 10. Pull out of a junction so far that the driver with the right of way has to stop and let you out. | | .44 |
| 11. Disregard the speed limit on a residential road. | | .73 |
| 17. Become angered by another driver and give chase with the intention of giving him/her a piece of your mind. | | .58 |
| 18. Stay in a motorway lane that you know will be closed ahead until the last minute before forcing your way into the other lane. | | .30 |
| 20. Overtake a slow driver on the inside | | .63 |
| 21. Race away from traffic lights with the intention of beating the driver next to you. | | .38 |
| 23. Drive so close to the car in front that it would be difficult to stop in an emergency. | | .50 |

| | |
|---|---|
| 25. Become angered by a certain type of a driver and indicate your hostility by whatever means you can. | .52 |

Note. For the sake of clarity, factor loadings less than 0.3 have been omitted.