The Value of Self-report Measures as Indicators of Driving Behaviors among Young Drivers

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ABSTRACT

Although much of the knowledge in transportation psychology has been gained by means of self-report measures, there is still a dispute regarding the usefulness and validity of such instruments. This series of two studies employed multivariate statistical models to examine associations between self-report and objective measures in two samples of young drivers. Study 1 (n=151) compared scores on the Multidimensional Driving Style Inventory (MDSI), a self-report questionnaire tapping four broad driving styles, with the naturalistic driving recorded by an in-vehicle data recorder (IVDR). Study 2 (n=80) compared responses to the Reckless Driving Habits Scale, assessing the frequency with which drivers commit a set of risky behaviors, with driving measures collected by a simulator. This study also examined the personality trait of sensation seeking, as well as gender and driving experience. In Study 1, the analysis revealed positive associations between high scores on the risky and hostile driving styles measured by the MDSI and risky behaviors measured by the IVDR, as well as inverse correlations between the latter and high MDSI scores on the anxious and careful driving styles. Similarly, in Study 2 associations were found between the self-reported frequency of reckless driving habits and several risky behaviors measured by the driving simulator. In addition, risky behaviors correlated with the sociodemographic variables and sensation seeking. The two studies, therefore, show that self-report measures are reliable tools for assessing driving behaviors for purposes of research, evaluation, and intervention.
INTRODUCTION

Studies in transportation psychology have traditionally employed self-report measures to examine personality, motivations, cognitions, and perceptions on the one hand, and driving behavior, driving styles and skills, and involvement in traffic violations and crashes on the other. Nevertheless, the usefulness and validity of such instruments is often questioned, in particular when the aim is to capture risky driving behaviors (1). Self-report measures have several advantages: (i) they are easy to administer to large samples and simple to complete; (ii) they constitute a standardized way of collecting data; and (iii) they are cheaper and allow for easier access to the data than objective options, such as driving simulators, in-vehicle data recorders (IVDRs), and instrumented cars (2). The weakness of these instruments, however, lies in the possibility of self-serving biases, recall biases, and shared residual variance with other self-report measures, leading to less than ideal and trustworthy reports on one’s own driving behavior and crash involvement (3, 4). In other words, the extent to which self-report measures represent real driving may sometimes be in doubt (2, 5, 6, 7).

In this paper, we reanalyze data from two studies that used different self-report measures, namely the Multidimensional Driving Style Inventory (MDSI, 8) and the Reckless Driving Habits Scale (9), as well as different objective measures for collecting behavioral data, i.e., risky driving events rate recorded by an IVDR in the first study, and risky driving measures scored by a driving simulator in the second. Both studies were previously used to investigate issues relating to young drivers but did not address the specific question of the connection between self-report and objective measures (10, 11, 12, 13, 14). Examining the associations between these measures will not only help to establish the validity of the MDSI and the Reckless Driving Habits Scale in particular, but, more importantly, will make it possible to determine the value of self-report measures of driving behavior in general.

The results of previous examinations of the associations between self-report and objective measures have been inconclusive, with some studies reporting positive correlations and others finding no significant associations. One group of studies found positive correlations between self-reports of road crashes and traffic offenses on the one hand, and official police records on the other (1, 15, 16, 17). Other studies looked at the associations between the self-report Manchester Driver Behavior Questionnaire (DBQ, 18) and crash involvement, and found a robust correlation between the questionnaire’s violations factor and crash rates, and weaker correlations between the errors and lapses factors and crash involvement (18, 19). DBQ violations were also associated with a greater tendency to accept shorter gaps on turns across traffic in a driving simulator experiment (20), as well as with higher speed as measured in a simulator (2, 4). However, another study examining the associations between DBQ scores and simulated driving found only one significant correlation, showing that drivers with higher violations tended to brake less heavily (21).

Similarly, MDSI scores were found to correlate with performance measures collected in a driving simulator experiment (22, 23). More specifically, participants with lower critical passing gaps scored higher on the MDSI angry and hostile driving style (23). Higher critical passing gaps were found for drivers scoring higher on the anxious and the patient and careful styles. In addition, speed and number of completed passing maneuvers, and to a lesser extent critical gaps, correlated significantly with higher scores on the reckless and careless driving style (22).

Studies have also examined associations between responses to self-report instruments and measures of actual driving. In a recent study, DBQ factor scores were found to correlate with various driving behaviors observed during real highway driving in an instrumented
vehicle, which collected vehicle performance data, audio and video recordings of the driver and surrounding roadway, and physiological and eye-tracking information. It was found that drivers with high violations scores tended to drive somewhat faster, had more sudden unidirectional accelerations, had larger standard deviations of steering wheel angle, changed lanes more frequently, and spent more time in the left lane, while older drivers also had more hard braking events (24). Another recent study, however, found correlations between DBQ violations and naturalistic driving speed only in daylight conditions, but not in the night time, and no correlations with the other DBQ scales (2). Nor were any significant correlations found between DBQ scores and recorded on-road speed in an instrumented vehicle among novice drivers (25).

The results of studies examining the associations between self-report scales and the objective IVDR measure of kinematic risky driving (using The Naturalistic Teen Driving Study data, 26) have similarly been inconsistent. Although at various phases of one study (27), significant positive correlations were found between responses to both the Checkpoints Risky Driving Scale (C-RDS) and risky driving subscale of the DULA Dangerous Driving Index (DDDI, 28) on the one hand, and the kinematic risky driving score on the other, no significant associations emerged in an auto-regressive cross-legged analysis. In another study (29), DDDI scores were related to maximum speed observed in a simulator, and to an aggregated score of simulated driving behaviors.

Two important points can be derived from the literature. First, more research is needed to determine the relations between self-report instruments assessing driving behavior and objective measures such as police records, simulated driving, and actual driving. Secondly, more sophisticated statistical analyses are needed to better establish the associations between the two modes of measurement.

Furthermore, a variety of psychological characteristics have been shown to correlate with measures of risky driving. For example, several studies have found sensation seeking, which involves searching for new and complex experiences and sensations and a tendency to take physical, social, legal, and financial risks in order to achieve such experiences (30), to be related to reckless driving, including excessive speed, frequent overtaking, reckless lane changing, and driving under the influence of drugs or alcohol (4, 31, 32), as well as to MDSI factors (8, 33). In addition, associations have consistently been reported between anger, which refers to a tendency to feel negative emotions, such as hostility, frustration and bitterness (34), and aggressive and risky driving (4, 13, 35, 36), as well as between anger and a higher DBQ violations score (37). A further relevant characteristic is anxiety, that is, the propensity to feel threatened and fearful in various situations (38), which has been found to be related to higher scores on all the DBQ factors (39), to higher MDSI anxious driving style and lower careful style (33), and to higher risky driving (e.g., 40, 41, 42). Participants lower on trait anxiety have also been shown to commit more simulator-based speed violations (2). Finally, impulsivity, defined as the tendency to act on cravings and urges rather than on delayed gratification (43), has been positively associated with risky driving (29), including high speed, aggressive driving (35), driving anger (21), and higher DBQ errors (44).

Risky driving has also been associated with several sociodemographic and driving history variables, such as gender, age, and driving exposure. Among the major characteristics that have been shown to predict risky driving are lower age and male gender (e.g., 45): young male drivers tend to commit more violations and to be more aggressive on the road than female drivers and older drivers (e.g., 45, 46, 47). In addition, women score higher on the anxious driving style, whereas men score higher on the reckless style (9, 48). Aggressive and
hostile driving is also positively related to higher driving exposure (e.g., 29, 49), and is more endorsed by men than women, and by younger drivers, whereas the anxious and the careful driving styles are more endorsed by women (47). Risky driving is also related to less driving experience (e.g., 50). Finally, the MDSI reckless and anxious styles are most closely associated with a history of dangerous driving (previous involvement in car crashes and traffic violations), while the careful style reflects more well-adjusted and safer driving (8).

**The Current Study**

The current investigation sought to assess the usefulness of self-report scales for predicting risky driving behavior. Two studies were conducted, each comparing the responses to a self-report instrument with an objective measure of behavior on the road. In Study 1 naturalistic driving was recorded by an IVDR, and in Study 2 driving measures were collected in a simulator. Both methods present an opportunity to study observed driving behavior and reactions to various road situations without running the risk of self-report biases (e.g., 29, 32, 51).

The self-report instrument employed in Study 1 was the MDSI (8), assessing four broad driving styles: (1) the *reckless and careless style*, referring to deliberate violations of safe driving norms and thrill seeking while driving, and characterized by high speed, illegal passing, and so on; (2) the *anxious style*, relating to feelings of alertness and tension, along with ineffective relaxation activities when driving; (3) the *angry and hostile style*, that is, expressions of irritation, rage, hostile attitudes and acts on the road, and a tendency for aggressive behavior, such as cursing or flashing lights at other drivers; and (4) the *patient and careful style*, an adaptive style that includes planning ahead, attention to the road, patience, courtesy, calmness, and obedience to traffic regulations. Study 2 employed the *Reckless Driving Habits Scale* (9), which assesses the frequency with which drivers commit a set of risky behaviors. Previous studies have found the score on this scale to be positively related to the reckless and careless driving style (e.g., 9).

In both studies, the data sets were derived from a sample of young drivers, who constitute the riskiest driver population (52). In addition, multivariate models were used to examining correlations between the two modes of measurement. A multivariate model was chosen because the risky driving behavior has been shown to be related to multiple variables, and this method allows for examination of their concurrent contribution. Traditional analysis of univariate correlations ignores possible confounding effects across variables and, therefore, the effects of variables not explicitly captured in the analysis are not reflected in the results.

**STUDY 1**

Study 1 examined the associations between scores on the MDSI (8) and actual on-road driving behavior as measured by IVDRs (see, e.g., 32, 51) in a sample of young male drivers. Consistency between the two measures was analyzed by estimating a model of the number of risky events per driving time unit as a function of the self-reported driving styles, under the assumption that significant parameter estimates for the latter would demonstrate the correspondence between the different modes of measurement.

**Method**

**Participants**

The sample consisted of 151 young male drivers between 17.0 and 21.5 years of age ($M=17.55$, $SD=0.68$), who were drawn from 242 families participating in a longitudinal study of a broader scope (for details, see 11). For all the young drivers in the current study, driving
behavior was observed by recording their driving maneuvers with an IVDR over the course of 12 months, and driving style was assessed by means of the MDSI after nine months following licensure. In the original study, the families were divided into four conditions: (i) feedback provided only to the young driver; (ii) feedback provided to the entire family; (iii) feedback provided to the entire family and a training program administered to the parents pertaining to parental guidance and training; and (iv) feedback not provided at all as a control group. The group was controlled for in the statistical model used in the present study to ensure that any associations emerging between driving styles and the IVDR risk score were significant beyond the effect of the study conditions.

**Instruments**

An IVDR was mounted on the family vehicle primarily used by the young male driver. Driver identification for each trip was obtained by means of a personal magnetic identification key. Maneuver identification was performed by the IVDR according to pattern recognition algorithms that classified 20 types of events by five categories (braking, accelerating, turn-handling, lane-handling, speeding) and three risk levels (moderate, intermediate, high). Feedback consisted of post-trip on-line consultation in which a green/yellow/red color scheme (corresponding to the moderate/intermediate/high-risk level) was displayed for the trips of the day. Details about the IVDRs and the feedback can be found in Toledo et al. (51), Prato et al. (32), and Farah et al. (11).

The driving behavior of the young drivers was assessed during the period of 9 to 12 months after licensure. This made it possible to observe driving behavior when the young drivers had developed a relatively stable driving style (e.g., 53). Furthermore, it meant that driving behavior was recorded at a time consistent with the administration of the self-report instrument, specifically during the first six months of solo driving following the three months of compulsorily accompanied driving required by the Israeli Graduated Driver Licensing program at the time of data collection.

The MDSI (8) was used to assess the young drivers’ driving style. The 44-item questionnaire relates to four general driving styles: (i) reckless and careless driving, which leads to deliberately violating road safety norms; (ii) anxious driving, which reflects a sense of alertness, tension, and distress behind the wheel; (iii) angry and hostile driving, or irritability and aggressive actions on the road; and (iv) patient and careful driving, which indicates a well-adjusted driving style. Drivers responded to the series of statements about their feelings, thoughts, and behaviors while driving on a 6-point Likert scale ranging from 1 (not at all) to 6 (very much). As Cronbach’s alpha for the four dimensions were reasonable (0.81 for reckless and careless driving, 0.84 for anxious driving, 0.78 for angry and hostile driving, 0.77 for patient and careful driving), each driver’s responses on the relevant scales were averaged to produce four driving style scores, with a higher score indicating a higher level of the particular style.

**Model**

Associations between the self-report measure of driving styles and actual driving behavior were investigated by means of a model examining correlations between the risk indices of the young male drivers and the four self-assessed driving styles (while controlling for the intervention in the original study). The risk index of driver $i$ was expressed as the logarithm of the ratio between the number of events and the driving time. Given that (i) the number of events is a count variable, (ii) heterogeneity exists across drivers, and (iii) the samples are small, count data models were estimated within a full hierarchical Bayesian framework.
The base form of the two Poisson-based models was expressed as:

$$ E_i \sim \text{Poisson}(\lambda_i) $$

\[
\log(\lambda_i) = \log(d_i) + \alpha + \beta X_i + \nu_i = \\
\log(d_i) + \alpha + \beta_{\text{MDSI_reck}} \cdot \text{MDSI_reck}_i + \beta_{\text{MDSI_anx}} \cdot \text{MDSI_anx}_i \\
+ \beta_{\text{MDSI_angry}} \cdot \text{MDSI_angry}_i + \beta_{\text{MDSI_patcar}} \cdot \text{MDSI_patcar}_i \\
+ \beta_{\text{feedb2}} \cdot \text{feedb2}_i + \beta_{\text{feedb3}} \cdot \text{feedb3}_i + \beta_{\text{male}} \cdot \text{male}_i + \nu_i
\]  

(1)

(2)

where \( i \) is the driver, \( E_i \) is the number of events weighted according to their risk level, \( \lambda_i \) is the expected Poisson event rate, \( d_i \) is the driving time, \( X_i \) is a vector of explanatory variables, \( \alpha \) is a constant term to be estimated, \( \beta \) is a vector of parameters to be estimated, and \( \nu_i \) is a random term that captures the heterogeneity across drivers. The explanatory variables include: driver \( i \)'s scores on the four MDSI dimensions (i.e., \( \text{MDSI_reck}_i \) for the reckless and careless style, \( \text{MDSI_anx}_i \) for the anxious style, \( \text{MDSI_angry}_i \) for the angry and hostile style, \( \text{MDSI_patcar}_i \) for the patient and careful style); the dummy indicators \( \text{feedb2}_i \) and \( \text{feedb3}_i \), indicating that driver \( i \) was administered the second or third study condition respectively, with the fourth being the reference case and the first being found not significant by model specification testing. The model in eq. 2 is the result of an iterative process of statistical testing that is not presented here for reasons of brevity.

Bayesian estimation of a Poisson-gamma model made it possible to estimate intercept \( \alpha \) and the elements of vector \( \beta \) to reveal the relationship between observed driving and the self-report measure of driving style. The parameter for driving time was constrained to be equal to one in order for the model to normalize the number of events by the driving time of driver \( i \). Bayesian estimation involved the definition of the following priors (see 54): a uniform prior for intercept \( \alpha \); highly non-informative normal priors with zero mean and 100,000 variance for the parameters \( \beta \); and a non-informative gamma prior \( \text{Gamma}(\phi, \phi) \), where \( \phi \) was assigned to a non-vague hyper prior \( \text{Gamma}(0.1, 1.0) \) for the term \( \exp(\nu_i) \). The model was estimated by using the Markov Chain Monte Carlo (MCMC) method under the full hierarchical Bayesian framework in the open-source software package Openbugs (55).

Results and Discussion

Sample characteristics

The results for the young male drivers on the two modes of measurement are presented in Table 1.

In terms of observed driving behaviors, the event rates per hour averaged 2.765 (\( SD=4.014 \)), and showed highly asymmetric distributions, with skewness equal to 5.439. Calculating the risk index as the natural logarithm of this rate (51) yielded a mean of -3.639 (\( SD=1.080 \)), with the tail tending toward negative values and a skewness of -0.167. Kolmogorov-Smirnov tests for the young drivers (\( D_{151.0,0.05}=0.457 > D_{151.0,0.05}=0.111, \text{n.s.} \)) refuted the assumption of a normal distribution of the natural logarithm of the event rates, thus confirming the suitability of a count data model, rather than a hierarchical regression model, for assessing risky driving. In terms of driving style, the young male drivers reported exhibiting the four styles in the following descending order: reckless and careless; anxious; angry and hostile; patient and careful.
TABLE 1 Driver Characteristics

<table>
<thead>
<tr>
<th>Variable</th>
<th>mean</th>
<th>st.dev.</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of events (unit)</td>
<td>101.510</td>
<td>146.109</td>
<td>2</td>
<td>1081</td>
</tr>
<tr>
<td>Driving time (h)</td>
<td>37.651</td>
<td>27.396</td>
<td>6.275</td>
<td>145.435</td>
</tr>
<tr>
<td>Event rate (unit/h)</td>
<td>2.765</td>
<td>4.014</td>
<td>0.057</td>
<td>37.999</td>
</tr>
<tr>
<td>Feedback to young drivers</td>
<td>0.258</td>
<td>0.439</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Feedback to entire family</td>
<td>0.225</td>
<td>0.419</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Parental training</td>
<td>0.517</td>
<td>0.501</td>
<td>0.000</td>
<td>1.000</td>
</tr>
<tr>
<td>MDSI – reckless and careless a</td>
<td>2.235</td>
<td>0.643</td>
<td>1.180</td>
<td>4.100</td>
</tr>
<tr>
<td>MDSI – anxious a</td>
<td>1.761</td>
<td>0.461</td>
<td>1.000</td>
<td>3.860</td>
</tr>
<tr>
<td>MDSI – angry and hostile a</td>
<td>2.206</td>
<td>0.945</td>
<td>1.000</td>
<td>5.200</td>
</tr>
<tr>
<td>MDSI – patient and careful a</td>
<td>4.998</td>
<td>0.575</td>
<td>2.500</td>
<td>6.000</td>
</tr>
</tbody>
</table>

Note: a scale 1-6

Model estimates

The MCMC method allowed for estimation of the posterior means and standard deviations of intercept $\alpha$, parameters $\beta$, and the standard deviation of the error term $\nu$, representing heterogeneity. Two chains were simulated with different initial values, with 25,000 initial iterations discarded as burn-ins to reach convergence, and the next 75,000 iterations used in the calculations. The results appear in Table 2.

As Table 2 indicates, a high rate of risky events per driving unit correlated with reckless and careless driving as well as with angry and hostile behavior on the road, while a low rate was associated with the anxious and the patient and careful driving styles. Calculating the average effects of the increase of one unit in the means of the drivers’ responses over the four dimensions of the MDSI revealed comparable effects for the reckless and angry driving styles and slightly larger effects for the anxious and careful styles. Moreover, the posterior mean of the standard deviation of $\exp(\nu)$ was significantly different from zero, thus suggesting the importance of taking into account the heterogeneity across drivers to avoid biased estimates.

The results of Study 1 thus revealed consistency between actual driving behavior measured by an IVDR and self-reported driving style: the rate of risky events recorded by the IVDR correlated positively with the risky and hostile driving styles and negatively with the anxious and careful driving styles. These findings not only reconfirm the validity of the MDSI as an assessment tool but also serve to validate the use of self-report measures in general as good proxies for behavior.

Actual behavior in this study was assessed by a single risky driving score. In order to expand our investigation, in the next study we used simulated driving and looked at several aspects of risky driving behavior and their associations with a self-report measure examining young drivers’ tendency to take risks behind the wheel, as well as with a relevant personality trait. In addition, whereas the sample in Study 1 consisted solely of young men, both genders were represented in Study 2.
### TABLE 2 Estimates of the Poisson-Gamma Model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Variable</th>
<th>est.</th>
<th>st.dev.</th>
<th>sig.</th>
<th>average effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_{feedback}$</td>
<td>Feedback to entire family</td>
<td>-0.296</td>
<td>0.149</td>
<td>**</td>
<td>0.74</td>
</tr>
<tr>
<td>$\beta_{feedb3}$</td>
<td>Feedback to entire family and parental training</td>
<td>-0.238</td>
<td>0.132</td>
<td>*</td>
<td>0.79</td>
</tr>
<tr>
<td>$\beta_{MDSIreck}$</td>
<td>MDSI – reckless and careless</td>
<td>0.350</td>
<td>0.155</td>
<td>**</td>
<td>1.42</td>
</tr>
<tr>
<td>$\beta_{MDSIangry}$</td>
<td>MDSI – angry and hostile</td>
<td>-0.280</td>
<td>0.148</td>
<td>*</td>
<td>0.76</td>
</tr>
<tr>
<td>$\beta_{MDSIpatcar}$</td>
<td>MDSI – patient and careful</td>
<td>-0.663</td>
<td>0.170</td>
<td>**</td>
<td>0.52</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Intercept</td>
<td>0.127</td>
<td>0.936</td>
<td>*</td>
<td>1.14</td>
</tr>
<tr>
<td>$log(d_i)$</td>
<td>Exposure</td>
<td>1.000</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$sigma(exp(v))$</td>
<td>Heterogeneity</td>
<td>0.771</td>
<td>0.084</td>
<td>**</td>
<td></td>
</tr>
</tbody>
</table>

*statistically significant difference from zero (90% credible set shows the same sign)
**statistically significant difference from zero (95% credible set shows the same sign)

### STUDY 2

This study examined associations between the scores on the Reckless Driving Habits Scale (9), assessing the self-reported frequency of risky driving, and a set of risky driving behaviors measured in a driving simulator (e.g., 14). In addition, it examined the roles of the personality trait of sensation seeking and the sociodemographic variables of gender and driving experience. The analysis was performed by estimating a model of the four measures of simulated driving reflecting the tendency to take risks as a function of the self-reported measures, under the assumption that significant parameter estimates would demonstrate the correspondence between the different modes of measurement.

### Method

#### Participants

The sample consisted of 80 young drivers, 40 males and 40 females, between 18 and 21 years of age ($M=19.24$, $SD=0.75$) who volunteered to participate in a driving simulator experiment and complete a series of questionnaires. The participants were first familiarized with the driving simulator and driving commands, and then ran a driving scenario of 7.5 kilometers. Following their time on the simulator, they completed the questionnaires tapping sensation seeking, reckless driving habits, and sociodemographic characteristics. The total time required for each young driver to complete these tasks ranged from 15-20 minutes.

#### Instruments

Actual driving behavior was measured by an STISIM Drive simulator (56), which presents the driver with a 600 wide and 400 high field of view, a steering wheel, and pedals. The simulator was loaded with a predetermined driving scenario on a two-lane highway with narrow shoulders and traffic in both directions. Data was recorded every 0.1s, and a Matlab code was used to produce measures of a set of four driving behaviors: (i) average headway (m); (ii) average speed (m/s); (iii) time over the speed limit (s); and (iv) time in the opposite lane (s). Details of the simulator settings and the Matlab code can be found in Farah et al. (57).
Lower average headway, higher average speed, longer time over the speed limit, and longer time in the opposite lane were used as indicators of risky driving. On the basis of the literature, these measures were expected to correlate with the sociodemographic characteristics of gender, as well as with driving experience (i.e., time since licensure, kilometers driven per week, kilometers driven on weekdays and on weekends).

The Reckless Driving Habits Scale (9) was used to examine the self-reported frequency of reckless driving. The scale consists of 8 items, each presenting a typical type of risky driving that might endanger the life or well-being of the driver, passengers, pedestrians, and/or passengers of other vehicles (e.g., running a red light, not stopping at a stop sign, making a high-speed turn). Participants were asked to indicate how often they drive in the manner described on a 6-point scale ranging from 1 (never) to 6 (always). As Cronbach’s alpha was 0.85, each participant’s responses were averaged to produce a reckless driving habits score, with higher scores indicating a higher frequency of reckless driving.

The Sensation Seeking Scale (30) was employed to assess the desire for thrill and adventure. In each of the 10 items, the young drivers were asked to select one of two contradictory statements relating to the tendency to participate in risky activities involving speed and defying gravity. Cronbach’s alpha for this scale was 0.78, and, therefore, each participant’s responses were averaged to produce a sensation-seeking score, with higher scores indicating a higher tendency to seek thrills.

Model

Four models were estimated to investigate the correlation between the four measures of driving behavior (i.e., average headway, average speed, time over the speed limit, time in the opposite lane) and the two self-report scales while controlling for the sociodemographic characteristics and driving experience.

In constructing the model, the following considerations were taken into account: (i) the correlations may be investigated by means of a linear regression; (ii) the young drivers display heterogeneous behavior that might be explained by unobserved factors; (iii) the sample size is small. Accordingly, a linear regression model was estimated within a full hierarchical Bayesian framework with the following specifications:

$$m_i = \alpha + \beta \mathbf{X}_i + \nu_i = \alpha + \beta_{\text{reck}} \cdot \text{reck}_i + \beta_{\text{sensseek}} \cdot \text{sensseek}_i + \beta_{\text{male}} \cdot \text{male}_i + \beta_{\text{lictime}} \cdot \text{lictime}_i + \beta_{\text{kmweek}} \cdot \text{kmweek}_i + \nu_i$$

where $i$ is the driver, $m_i$ is a measure of driving behavior, $\mathbf{X}_i$ is a vector of explanatory variables, $\alpha$ is a constant term to be estimated, $\beta$ is a vector of parameters to be estimated, and $\nu_i$ is a random term that captures the heterogeneity across drivers. The explanatory variables include: $\text{reck}_i$, driver $i$’s score on the Reckless Driving Habits Scale; $\text{sensseek}_i$, driver $i$’s score on the Sensation Seeking Scale; the dummy indicator $\text{male}_i$, equal to 1 if driver $i$ is male and 0 if she is female; the continuous variable $\text{lictime}_i$, expressing the time since licensure of driver $i$; and the continuous variable $\text{kmweek}_i$, representing the driving experience of driver $i$.

The model in eq. 3 is the result of an iterative process of statistical testing that is not presented here for reasons of brevity.

Bayesian estimation of the linear regression models made it possible to estimate intercept $\alpha$ and the elements of vector $\beta$ to reveal the relationship between simulated driving behavior and the two self-reported measures of risky driving. Bayesian estimation involved the definition of the following priors (see 54): a non-informative normal prior for intercept $\alpha$ and the parameters $\beta$ with zero mean and 0.00001 variance; and a non-informative uniform
prior between zero and 100 for the standard deviation of the error term \( \nu_i \). The model was estimated by multiplying the prior by the likelihood function and then sampling from the posterior distributions with a Gibbs sampler in the open-source software package Openbugs (55).

**Results and Discussion**

*Sample characteristics*

The results for the whole sample of young drivers on the various instruments are presented in Table 3.

In terms of the driving behaviors measured in the simulator, the results show that speed was high, ranging between 63.6 and 125.2 km/h and averaging 87.2 km/h. Moreover, an average of more than one minute was spent over the speed limit. In terms of the self-report measures, the young drivers indicated a low frequency of reckless driving, with responses at the lower end of the scale, and a moderate propensity for sensation seeking, with responses lying between the extremes of the scale.

![Table 3 Driver Characteristics](image)

**Model estimates**

The Gibbs sampler was run multiple times to guarantee convergence of the model. The posterior means and standard deviations of intercept \( \alpha \), parameters \( \beta \), and the standard deviation of the error term \( \nu_i \) representing heterogeneity are presented in Table 4. The simulation discarded the initial 25,000 iterations as burn-ins to attain convergence and used the next 75,000 iterations in the calculations.

Table 4 indicates a consistency between risky driving as measured in the simulator and the tendency to drive recklessly as measured by the two self-report scales. All four measures of simulated driving behavior correlated significantly with scores on the Reckless Driving Habits Scale in the anticipated directions. However, only two measures of risky driving behavior were significantly associated with sensation seeking: average speed and time spent over the speed limit, both of which were approximately double for participants high on sensation seeking than for those low on this personality trait. No significant correlations emerged between sensation seeking and headway or time spent in the opposite lane.
In respect to the sociodemographic and exposure variables controlled for, gender and experience were found to relate to risky driving as measured in the simulator. In line with the literature, young male drivers tended to exhibit more risky behavior than females in terms of both speeding and time spent over the central white line, and drivers with less experience maintained a shorter distance from other vehicles and spent more time over the speed limit. Moreover, the posterior mean of the standard deviation of $\nu$ was significantly different from zero, again indicating the importance of taking into account the heterogeneity across drivers to avoid biased estimates.

The results of Study 2, therefore, provide further evidence of the positive associations between self-report measures of driving behavior, particularly the Reckless Driving Habits Scale, and a measure of actual driving, in this case behaviors displayed in a simulator. Similar to Study 1, the multivariate analysis employed here demonstrated the correlations between the different modes of measurement while making it possible to control for the contribution of other variables that could be absorbed in univariate measures of correlation, and hence could bias the results of simple correlation methods.

**DISCUSSION AND CONCLUSIONS**

The current series of studies aimed at examining the associations between two self-report instruments regarding habitual driving behaviors and two objective driving measures: an in-vehicle recorder and a simulator. The results indicate that the scores on self-report instruments are consistent in a rational and predictable way with measures of actual driving in samples of young drivers. More specifically, the IVDR risky driving rate correlated positively with the risky and hostile driving styles and negatively with the careful and anxious styles measured by the MDSI. Similarly, positive correlations were found between young drivers’ reports on the frequency of their reckless driving and their performance in a driving simulator. Simulated driving was also found to correlate with the results of an instrument tapping sensation seeking, as well as with gender and driving experience. Thus, those with a higher tendency to seek thrills and adventure drove faster and spent more time driving over the speed limit, young males tended to drive more recklessly than young females, and more experienced drivers tended to take fewer risks when driving in the simulator. All these findings suggest that self-report measures may serve as good proxies for observation of actual driving behavior, as previously reported in the literature (e.g., 4, 20, 22, 24).
It is important to note that most previous studies used univariate correlations to examine the associations between self-report and behavioral measures, with few performing a multivariate analysis to eliminate the possibility of confounding effects that might inflate correlation values. For example, Simons-Morton et al. (26) found significant positive correlations between the C-RDS and a kinematic risky driving score, but no significant associations emerged between the two measures in an auto-regressive cross-legged analysis. In contrast, the current study employed a complex model to examine the associations between the different modes of measurement. The findings show that all four driving styles as measured by the MDSI correlated significantly with the IVDR risky events rate, and that the self-reported frequency of reckless driving, along with the personality trait of sensation seeking and the sociodemographic variables of gender and driving experience, correlated significantly with the aspects of risky driving measured in a simulator. The results of this multivariate analysis not only provide further validation of the MDSI and the Reckless Driving Habits Scale as assessment tools but also offer valuable evidence in support of the use of self-report measures to assess risky driving among young drivers.

Certain limitations of the current study should be noted. Firstly, the samples were non-representative and relatively small, with the latter consideration leading to the adoption of the Bayesian approach. Secondly, Study 1 consisted solely of young male drivers. Although females were represented in Study 2, future attempts to explore the role of the factors examined here would do well to use a larger, more heterogeneous sample that includes both genders.

To conclude, the current study employed different objective measures and self-report instruments, along with a complex model for data analysis, to explore the associations between self-report instruments and actual risky driving among young drivers. The results provide crucial evidence indicating the validity of using self-report measures to assess risky driving behaviors in this population, and to examine their associations with various personality traits, attitudes, cognitions, and other risky behaviors. Such instruments may reliably serve not only for research purposes, but also as diagnostic, evaluation, and intervention tools.

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