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A model for evaluating drivers' mean speed: using psychological and driving simulator data.

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Abstract

Driving speed has always played an important role in safety. Many variables influence the driver's behavior to choose the speed, one of which is the individual's psychological variables. In this study, the direct and indirect relationship of a series of psychological variables (latent variables) on the mean speed and the relationship of the latent variables with each other have been investigated. For this purpose, two questionnaires of aggressive drivers and DBQ were used. Also, a driving simulator was used to record the mean speed of the driver . The number of participants was 71 (38% women and 62% men) who were selected randomly from the city of Tehran through the use of advertisements. one proposed model that includes 8 hypotheses was modeled using the structural equation model (partial least square method) that hypotheses were significant at the 99% level. And the results showed that there is a direct relationship between attitude with hostile behavior (H1), hostile behavior with risky violation (H3) , hostile behavior with Self-willed violation (H4), risky violation with Self-willed violation (H5) and Self-willed violation with Inexperience violation/error (H6). subjective norm have inverse relationship with risky violation (H2). Also, people who have a high Self-willed violation usually drive at a high speed (H7). The maximum value of the impact coefficient was recorded as 0.57, which is specifically associated with the sixth hypothesis.

1. Introduction

For a long time, speed has been regarded as a critical key element in road traffic: excessive speeds cause to a significant portion of traffic accidents. According to evidence, human activity is the most prevalent element in more than 85% of all traffic accidents [1]. One of the dangerous behaviors of humans is exceeding the recommended speed. According to studies, every 1 km/h increase in mean traffic speed resulted in a 3% rise in the occurrence of accident collisions and a 4-5% increase in fatal crashes [2], [3].

Driving behaviour has frequently been the subject of traffic Questionnaire (DBQ) in 1990, which comprised of 50 items detailing various driving faults and transgressions. Since the studies of Reason et al. 1990 and shi et al. 2010 the popularity of DBQ has risen significantly and there are several DBQ versions[4], [5]. Several research used these tools to evaluate the association between driving behavior and road accidents. Winter and Dodou evaluated 174 studies use of DBQ[6]. Zimbardo time perspective inventory and NEO-FFI, Linkov mixed driving simulator participant operating data with a set scenario to investigate the connection between operating speed and responsibility[7]. Steinbakk The UPPS-impulsivity scale was used to analyze the association between speed choosing behavior and personality factors of various drivers in the workplace[8]. Chevalier was conducted to examine how well elderly drivers with cognitive impairment are able to control their speed while driving, and the findings demonstrated the effect of cognitive decline on the driving speed of older individuals[9]. Based on the field driving experiment, Eboli According to the mean speed, 50th percentile operating

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speed, and 85th percentile operating speed, the participant was classified as safe, unsafe, and possibly dangerous[10]. Additionally, the concept of sensation-seeking was explored, which refers to an individual's inclination to seek out and enjoy activities that are exciting, as well as their willingness to try new experiences that may or may not be perceived as dangerous [11]. High sensation seekers have been found to be less influenced by road features in their speed preferences [12].

As argued by Summala (1974), drivers get into traffic with many reasons that, among other things, are impacted by their personalities. Self-report questionnaires are commonly used to investigate the relationship between personality and specialized driving performance [13]–[16]. Linkov et al. used a driving simulator to design three driving situations with varying speed limitations in order to assess the relationship between driver personality and speed (N=41). They reported an important relationship between speed and conscientiousness, which was consistent with the results of earlier surveys. [7]. Zicat et al. used driving speed indicators on a simulator to evaluate driving ability, and the results revealed a significant correlation between anxious, angry personality characteristics and the speed of young drivers (N=151) [17]. Personal features and habits of the driver will influence their behaviour when confronted with a risky circumstance while driving (N=27) [18]. Drivers were classified based on their degree of "aggressiveness" based on their driving behavior (see for example [19]). Aggressive drivers have a driving style that combines high speed with frequent and abrupt changes in instantaneous speed, resulting in sudden acceleration and deceleration. Various researchers have conducted substantial study in this topic. studies were evaluated effect of aggressive driving behavior (hostile and instrumental), theory of planned behavior and driver's personality (anger and rage) on dangerous driving [20]–[22]. According to their results, people with high aggressive behavior and high attitude, had high level of dangerous and risky driving. The Pennsylvania Department of Transportation defines aggressive driving as “the operation of a motor vehicle in a manner that endangers or is likely to endanger persons or property”. The US National Highway Traffic Safety Administration (NHTSA) defines aggressive driving as actions that include not only exceeding the posted speed limit or driving too fast for the conditions, but also to other driving behavior such as lane changing and improper signaling (failing to signal intent, using an emergency lane to pass, or passing on the shoulder, cutting into another car's path).; Tailgating (driving too close to the back of another car); driving in the wrong lane (moving too slowly in the passing lane, leading other drivers to undertake more frequent lane changes) [10].

Speeding is seen as a big issue in all countries. There are several studies in the literature that look into speeding as a cause of accidents. As an example, the study of Cabral, Mendonça, and Cabral intends to contribute to the prevention of accidents caused by speeding, and to assist the driver in maintaining a more regular driving and regulated pace through the use of multisensory information[23]. They concentrate their efforts on young drivers. On the other hand, the study proposed by Chevalier focused on the speeding behavior of elderly drivers [9]. They studied whether a decrease in speeding is part of the self-restrictive driving behavior seen in older drivers with poor cognitive and visual function. Ulleberg and Rundmo As for risk perception was found that it is adversely correlated with risk-taking behavior, with individuals with a greater risk perception reporting lower hazardous behaviors[24]. Positive attitudes toward speeding and a decreased perception of dangers are likely to explain greater desired speeds in work zones. The driver's regular driving style can predict how they would respond in future traffic situations.

Other variables have demonstrated that personality traits have both direct and indirect influence on driving behavior [7], [8], [25]. However, it has to be seen if the hypothesized association between personality characteristics and driving results is reliant on the existence of a specific context. Thus, the current study sought to investigate both the direct and indirect impacts of personality factors on desired speeds.

The suggested research model is shown in Figure 1 and in section 2-2, an explication is provided for each of the variables present in the model.

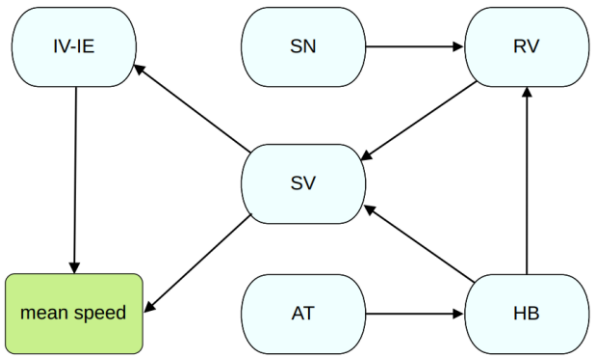

Fig. 1: Proposed model

2. Methodologhy

The main approach of this study is the impact of psychological variables on drivers' behavior to choose the mean speed. For this aim, a route has been designed in the driving simulator, and mean speed has been extracted for analysis by participants driving on this route. Also, by using a questionnaire, we collected their psychological factors. Finally, the direct and indirect effects of these factors on driving mean speed have been investigated by using the proposed model. The analysis tools will be described in the next subsections.

2.1 Data collection

For this study, 71 participants (44 men and 27 women) were selected from Tehran city. An advertisement was prepared for the selection of participants, which was published both in the virtual space and in public places. 71 people were randomly selected from those who announced their readiness. Table 1 shows the descriptive statistics of the participants.

Table 1: Descriptive statistic of the sample

	Frequency	Percentage	Cumulative Percent
Gender			
Female	27	38.0	38.0
Male	44	62.0	100.0
Age			
20<X<25	13	18.3	18.3
26<X<30	18	25.4	43.7
31<X<35	16	22.5	66.2
36<X<40	5	7.0	73.2
X>40	19	26.8	100.0
Education			
illiterate	1	1.4	1.4
High school diploma	17	23.9	25.4
university	53	74.6	100.0
Driving history			
x<1	2	2.8	2.9
1<X<2	2	2.8	5.7
3<X<5	10	14.1	20.0
6<X<10	11	15.5	35.7
X>10	45	63.4	100.0

2.1.1 Questionnaire

In this study, the aggressive driving questionnaire [26] and the driving behavior questionnaire of the Shai [5] have been used. We used Attitude, Subjective norm, and Hostile Behavior factors from the aggressive driving questionnaire, and Risky violation, Self-willed violation, Inexperience violation/error factors from the Shai questionnaire in our model. The factors and their propositions are presented in Table 2.

2.1.2 Apparatus

In this research, the driving simulator of K.N.Toosi University of Technology was used, which is the first driving simulator manufacturing center in Iran (Figure 2). To this present time, the subject of research has been the focus of published literature that has employed the apparatus. [27], [28],[29]. The simulated route comprises a two-lane highway with an asphalt shoulder. Each lane measures 3.75 meters in width, and the total road length spans 2.5 kilometers. The speed limit imposed on the route stands at 80 kilometers per hour. Furthermore, all other parameters of the simulated route, including signs and symbols, have been simulated in accordance with those of the actual road. During the driving simulation, a hazardous situation is induced by the entry of a pedestrian into a traffic lane. Figure 3 shows the details of the simulation path. The data collection utilizing this device followed a protocol wherein the participant received preliminary instructions regarding the device. Subsequently, the participant proceeded to operate the device for a period of 2 minutes on a trial basis. Upon attaining familiarity with the device's surroundings, the primary test was initiated. It is worth mentioning that a few participants experienced dizziness during the course of operating the device, while some discontinued the test prematurely. As a result, their test results were deemed invalid and their corresponding data was excluded.

Fig. 2: Driving simulator

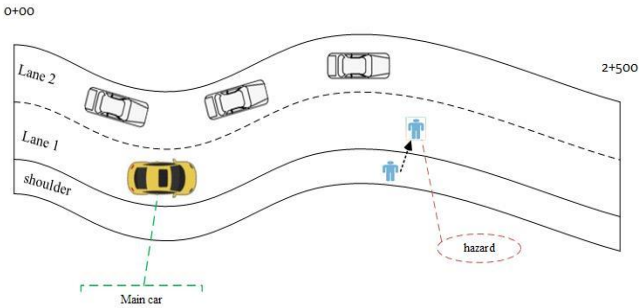

Fig. 3: driving simulated path

2.2 Hypotheses

2.2.1 Attitude (AT)

The first factor influencing people's intention to perform a behavior or not to perform a behavior is attitude and tendency which is also known as a personal factor. The purpose of attitude is a negative or positive evaluation of a person about performing or not performing a specific behavior. A person's attitude to perform a behavior may be positive, but another person's attitude toward it may be

negative. Attitude toward specific behavior refers to a person's belief to perform that behavior [30]. In this study, the first hypothesis is defined as:
Hypothesis 1: attitude has a positive effect on hostile behavior.

2.2.2 Subjective norm (SN)

The subjective norm refers to the expected perception of the individual that affects the individual. This behavior includes the effects or pressures of the social environment on the individual, which are increased by showing a certain behavior (either rewarded or punished). In other words, a subjective norm consists of one's beliefs weighted by the importance of other people's opinions about an attribute [30].
An example of a person's subjective norm might be to believe that it is good to wear a seat belt while driving since parents or friends suggest it, so the following hypothesis is suggested:
Hypothesis 2: subjective norm has direct relationship with risky violation.

2.2.3 Hostile Behavior (HB)

Hostile behavior is a behavior that makes the person feel better without solving the problem. The purpose of this behavior is to harm the person and anything that has caused frustration. In the field of driving, in extreme conditions, this behavior is part of road rage. Obviously, this dichotomy is not always clear. Honk at a pedestrian or motorist may be classified as hostile driving and instrumental driving [31]. Therefore, the following two hypotheses are proposed:
Hypothesis 3: hostile behavior has a direct relationship with the risky violation.
Hypothesis 4: hostile behavior has a direct relationship with the self-willed violation.

2.2.4 Risky violation (RV)

in which abnormal behavior is always planned, high-risk, and non-emotional. In certain situations, drivers opt to accept risks for the sake of convenience or profit [5]. Therefore, the following hypothesis is presented:
Hypothesis 5: The Risky violation has a positive effect on the Self-willed violation.

2.2.5 Self-willed violation (SV)

Drivers do not wish to incur risks in circumstances of self-willed violations, and they are not impacted by mood. They violate the law for the purpose of ease or comfort after confirming that there is no danger [5] .Therefore, the following hypothesis is presented:
Hypothesis 6: The Self-willed violation has a positive effect on the Inexperience violation/error.
Hypothesis 7: The Self-willed violation has a positive effect on the mean speed.

2.2.6 Inexperience violation/error (IV/IE)

These are inadvertent acts induced by a lack of expertise, unfamiliarity with the traffic environment, and the like [5]. Therefore, the following hypothesis is presented:
H8: The Inexperience violation/error has a positive effect on the mean speed.

2.2.7 Mean speed:

In this study, the mean speed is equal to the driver's mean speed from the beginning to the end of the simulated route.

Table 2: Constructs and measurement items with sources

Construct	Items	Sources adapted
Attitude	AT1: When someone in the form of a boss gives orders, I don't want to follow his orders. AT2: I often disagree with other people on many occasions. AT3: I like to raise my voice when I am angry.	[30]
Subjective norm	SN1: In the presence of family members, how bound are you to observe proper behavior while driving**?** SN2: In the presence of friends, how bound are you to observe proper behavior while driving**?** SN3: In the presence of strangers, how bound are you to observe proper behavior while driving**?**	[30]
Hostile Behavior	HB1: To what extent do you ignore the speed limit of the roads**?** HB2: How fast do you drive to arrive on time**?**	[30]
Risky violation	RV1: Drive fast to avoid a yellow light turning red RV2: Overtake on the right side RV3: Drive in the opposite lane the wrong direction RV4: When turning right, do not give way to bicycles	[5]
Self-willed violation	SV1: Ignore the requirement to use a direction indication lamp SV2: Take two lanes SV3: Driving while distracted SV4: Keep too close to the automobile in front of you	[5]
Inexperience violation/error	(IV-IE)1: Get into the incorrect lane (IV-IE)2: Failure to recognize give-away indicators (IV-IE)3: Misinterpretation of road signs (IV-IE)4: Turn left where turning left is forbidden	[5]

3. Results

71 participants whose descriptive statistics are shown in Table 1 have been used in this study.in this research, the structural equation model method has been used to analyze the proposed model. This model evaluates the relationships between the latent variables and their observable indicators (called the measurement model) and the relationships between the latent variables with each other (called the structural model). Also, in this model, measurement errors for observable variables are considered [32]. The structural equation model has two different methods: 1) covariance-oriented method, and 2) variance-oriented method. The partial least squares method as a variance-oriented method was chosen to investigate the hypotheses stated in this study since it has many advantages. This method is very suitable for studies with a small number of samples that do not require a normal distribution [33] . Also, this method is used to analyze complex models and fields that have not been extensively studied so far, because it has high statistical strength [34], [35]. As mentioned prior, this method is suitable for the present study. Based on the study [36], first, the model was measured and then the structural model was evaluated using SmartPLS 3.2.8 software [37], which will be explained below.

3.1 Measurement model

As mentioned, the measurement model examines the relationships between latent variables and their related observable variables .The results of this modeling are presented in Table ***3***. As it is clear from this table, all factor loadings are statistically significant and greater than 0.5 [32]. Cronbach's alpha should be greater than 0.6 [38], which is correct for all variables. For Convergent Validity, the Composite Reliability (CR) should be greater than 0.7 [33] and the Average Variance Extracted (AVE) should be greater than 0.5 [39]. According to Table 3, all variables have allowed values. According to [39], for divergent validity, the mean square root of the extracted variance for each latent variable should be greater than its correlation with other latent variables. In Table ***4***, the mean square root of the extracted variance (main diameter) is higher than the correlation values (bottom of the main diameter). Also, the Heterotrait-Monotrait (HTMT) ratio (above the main diameter) is lower than its maximum value of 0.9 [40].

Table 3: Reliability indices for the measurement model

Construct	Item	Factor Loading	α	CR	AVE
Attitude(AT)	AT1	0.722	0.53	0.758	0.513
	AT2	0.777			
	AT3	0.644			
subjective norm(SN)	SN1	0.656	0.725	0.834	0.63
	SN2	0.931			
	SN3	0.77			
Hostile Behavior(HB)	HB1	0.772	0.658	0.844	0.733
	HB2	0.932			
Risky violation (RV)	RV1	0.725	0.756	0.846	0.582
	RV2	0.813			
	RV3	0.854			
	RV4	0.642			
Self-willed violation (SV)	SV1	0.745	0.714	0.822	0.536
	SV2	0.739			
	SV3	0.753			
	SV4	0.691			
Inexperience violation/error (IV/IE)	(IV/IE)1	0.812	0.704	0.818	0.536
	(IV/IE)2	0.635			
	(IV/IE)3	0.864			
	(IV/IE)4	0.58			

Table 4: AVE, correlations and Heterotrait Monotrait (HTMT) ratio

	HB	IV-IE	RV	SV	AT	SN	Mean speed
HB	0.856	0.431	0.567	0.822	0.843	0.664	0.064
IV-IE	0.315	0.732	0.379	0.789	0.352	0.456	0.049
RV	0.430	0.265	0.763	0.800	0.866	0.448	0.107
SV	0.602	0.570	0.606	0.732	0.701	0.458	0.060
AT	0.530	0.192	0.532	0.432	0.716	0.679	0.102
SN	-0.531	-0.333	-0.391	-0.357	-0.482	0.794	0.040
Mean speed	-0.017	-0.040	0.090	0.046	0.045	-0.032	1.000

3.2 Structural model

At this stage, the bootstrap method with 5000 sub-samples was used to verify the research hypotheses. The modeling results are presented in Table 5.

In order to confirm the hypotheses of the research, the mentioned relationships should be significant. In other words, the P statistic for each relationship should be less than 0.05 and the T statistic should be greater than 1.96 or less than -1.96. The coefficient of each relationship shows the intensity of the independent variable's influence on the dependent variable. According to Table 5, all research hypotheses have been confirmed, the sixth hypothesis has

the highest and the eighth hypothesis has the lowest impact coefficient.

Table 5: Structural Model Results

Hypothesis	Path	Path Coefficient	STD	T Statistics	P Values	Result
H1	AT -> HB	0.530	0.029	18.424	0.000	Supported
H2	SN -> RV	-0.227	0.029	7.833	0.000	Supported
H3	HB -> RV	0.310	0.027	11.365	0.000	Supported
H4	HB -> SV	0.419	0.025	16.433	0.000	Supported
H5	RV -> SV	0.426	0.027	15.909	0.000	Supported
H6	SV -> IV-IE	0.570	0.029	19.899	0.000	Supported
H7	SV -> mean speed	0.103	0.039	2.636	0.009	Supported
H8	IV-IE -> mean speed	-0.099	0.038	2.602	0.010	Supported

4. Discussion and Conclusions

Human factors is examined on a wide range from driver's demographic characteristics to their personalities and behaviors. In this study, the aim is investigating the relationship between the latent variables of driving behavior and their direct and indirect effects on the average driving speed. Behavioral questionnaires and simulators have been used to collect data. Then, using the available factors, the model was defined in the form of 8 hypotheses, and its results are shown in section 4.

In this study, the person's attitude is not to do the task or disagree with the other's opinion (according to the meaningful questions related to the attitude). According to hypothesis 1, it shows that the more a person's attitude towards not doing a task or disagreeing with the opinions of others increases, the more hostile behavior one shows [24]. Regarding the subjective norm, people avoid risky driving when they drive with family or acquaintances. It is concluded that in order to respect the status of their acquaintances, they abandon a series of risky driving behaviors (second hypothesis) [20]. People who have highly hostile behavior drive dangerously and risky (third hypothesis)[22]. Also, people who have a high hostile behavior and people who have a high driving risk, their self-willed violations is also more and they commit violations for their own convenience. People with high-risk driving behavior are more prone to self-willed violation than people with hostile behavior (fourth and fifth hypothesis). In similar studies regarding the hostile behavior of people, it was shown that these people are aggressive and believe that they are able to control the vehicle in all conditions, and for this reason, they engage in risky behaviors[20].

According to the sixth hypothesis, it was proved that self-willed violation has a direct effect on inexperience errors, that is, people who have high self-willed violations in driving, do things they have no experience with. Also, people who have a high desire for error usually drive at a high speed (seventh hypothesis) These results are similar to the results of many previous studies in different fields [7], [17], [18], [20]. Regarding the eighth hypothesis, although it has become statistically significant, contrary to our hypothesis, the effect of inexperience error on the mean speed is negative (path coefficient is negative) and according to the value of the path coefficient (-0.099), this effect is not so great. It is suggested to investigate the effect of this factor on the mean speed in another study and compare it with our results. In view of these results, we suggest making drivers' more conscious of high speed and its results, especially, at the drivers' training centers, in addition to the lessons containing more qualified traffic information, other teaching and training lessons such as speed in traffic and results, and risky driver attitude in traffic and results should be added.

4.1 Limitations and future studies

There were some limitations in this study that are suggested to be considered in future studies.

The data that was gathered in this study was acquired during the occurrence of the COVID-19 disease, and the process of selecting participants presented considerable challenges. and it was very difficult to select the participants because many people were not ready to appear at the desired place and participate in this test due to the fear of the disease being contagious. It was very difficult and it is recommended that in future studies, the environmental conditions of the society should be such that there is no restriction for the selection of participants.

In this study, most of the participants (almost 80%) were not familiar with the driving simulator. In some cities, these simulators are used for driving training to obtain a license, so it is recommended to take this issue seriously and provide this platform in most cities so that the general public will familiar with this system and the accuracy of the information collected will increase for such studies.

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