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Designing a Driver's Hazard Perception Test Based on the Neural Brain Images Analysis (fMRI)

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Abstract

Background: Studies show that weakness in hazard perception is a major cause of traffic accidents, leading to high consequences.
Objectives: This study aimed to design a valid and reliable driver's Hazard Perception Test (HPT) based on neural imaging, reaction time, and miss rate in two groups of experienced and inexperienced drivers.
Methods: Different roads, including urban, intercity, and rural, were filmed from drivers' visual angles to examine the real road conditions. All videos were screened according to some quality factors. Then, hazard onset was determined for screened videos. The validity of the test was performed in three steps. Miss rates and reaction times to hazardous situations were measured. In the second step, 35 selected videos were broadcasted to 16 experienced and 16 novice drivers on a functional magnetic resonance imaging (fMRI). Finally, using 18 videos with statistically significant differences in neuro-cerebral neuronal activity, miss rate and reaction time were picked up for driver's HPT.
Results: The mean differences in reaction time, miss rate, and active neurons in the task of perceiving hazards in two groups of drivers were equal to 1.58 seconds, 29.55%, and 5248 neurons, respectively. There was a significant correlation between active neurons and miss rate ($r = 0.556$, $P < 0.001$). Eventually, the 18-videos of the valid test became HPT software.
Conclusions: Application of this valid test is suggested for assessing the hazard perception of drivers, particularly those who are responsible for transporting staff and goods in the studied country.

Keywords: Hazard Perception Test, Driving, Functional Magnetic Resonance Imaging (fMRI)

1. Background

Driving remains one of the riskiest activities globally. According to the World Health Organization (WHO), approximately one million and thirty-five thousand people die each year worldwide because of traffic accidents and road injuries. Driving is the eighth top cause of death for all age groups globally (1). While 48% of road accidents occur in developing countries, 90% lead to death in these countries (2, 3), emphasizing a higher risk of traffic accidents in developing countries. Iranian legal medicine organization reported 0.33% injuries and 0.00184% deaths due to traffic accidents in 2021. The annual averages of deaths and injuries caused by road accidents have been 17,226.5 and 320,987.5, respectively, over the last ten years (ie, from 2010 to 2020) (4).

According to the results of investigations, human error accounts for 75% of traffic accidents (5). Also, 40% of road accidents occur for novice drivers who have been licensed for less than a year (6). These data indicate that current controls on the risk of unsafe behaviors are not effective enough in Iran, and focusing on safe driving behaviors can be the best strategy to prevent traffic accidents in this country. After assessing the traffic accidents, Treat et al. stated that 52.1% of driving errors are decision-making errors, including incorrect assessment, erroneous assumption, improper maneuver, speeding, failing to signal, and improper distance. Fifty-six percent of driving errors are cognitive errors like inattention, distraction, and not being mentally alert. Only 11.2% of errors belong to functional errors like over-movement, fluster, freezing, and lack of control over navigation (7). Based on the Cognitive Levels of Rasmussen model (skill, rule, and knowledge-based behavior; SRK) and its relationship with human errors in driving, it can be argued that experience is an essential factor in traffic accidents (8). By introducing the SLM (slip, lapse, and mistake-based errors) model in 1990, Reason emphasized that two distinct psychological mechanisms of errors (unintentional) and violation (intentional) mediate unsafe behaviors in driving. It was asserted that decision-based errors are the most common causes of accidents (9). The Reason's findings were also supported by subsequent research (10, 11). Wickens mentioned the lack of situational awareness in mistakes due to lack of knowledge or experience as well as the limitations of the five senses of humans. Lapses are caused by impaired working memory mechanisms in the brain. However, slips are caused by weaknesses in the motor cortex of the brain and peripheral nerves (12).

Since the largest share of driver errors was related to decision-making and cognition, the situational awareness theory was predominantly adverted. According to this theory, a driver's performance in dangerous situations is a function of decision-making. Decision-making is itself a function of situational awareness, which includes three stages of processing information and component perception, component communication, and prediction (13). Situational awareness (SA) forms the central mechanism for the establishment of driving Hazard Perception Tests (HPTs) (14, 15).

Driving hazard perception depends on the driver's ability to detect dangerous situations and respond appropriately (16). Traffic accidents analysis confirmed that novice drivers have a larger share of both the likelihood of crashes occurring and the severity of the consequences than experienced drivers (17, 18). These two fundamental findings have led to the hypothesis that there is a link between driving hazards perception and road accidents (19, 20). Assuming there is such a connection, it is essential to investigate tools like HPTs that can both predict the car accidents risk and reduce the risk of crashes.

In general, risk perception test studies can be categorized into the following domains. First, design and development of various tests in the form of photos, videos, animations, etc., second, retrospective and prospective studies to find a connection between risk perception test scores and accident risk. Third, assessing the relationship between risk perception scores and independent factors such as distraction, disorders, fatigue, speed, risk perception psychology, performance differences, age experience, and so on (20-24).

The basic challenge in this field is the design and implementation of a valid HPT because this tool must have psychological characteristics such as ecological validity. A number of HPTs have become behaviorally valid, reliable, and customized in different countries, in which drivers must anticipate the potential hazards in traffic videos filmed from the driver's visual angle with a car camera. The main issue in these tests is that the hazards must be chosen from a familiar environment, and drivers should be aware of accident scenarios (25).

In addition to ecological validity, behavioral contrast (reaction time and miss rate between experienced and novice drivers) is the main criterion for selecting videos for the test (26, 27). Gharib et al. examined differences in neural activity and functional communication in the driving hazards perception task between novice and experienced drivers using functional magnetic resonance imaging (fMRI) brain image processing. The results indicate that experienced drivers have higher neural activity and more situational awareness than novices. They claimed that the contrast of neuronal activities between experienced and novice drivers is an effective criterion for the development of a driver's hazard perception test (28). Therefore, it would be more valid if a test could create more contrast in neuronal activity, reaction time, and miss rate between experienced and novice drivers.

2. Objectives

This study aimed to design and implement a computer-based risk perception test with a new neuropsychological validity criterion (contrast of neural activity between novice and experienced drivers) as well as ecological and functional validity.

3. Methods

3.1. Participants

In the first stage of this study, a number of Iranian licensed drivers were chosen from Tehran and Mashhad (the two biggest cities in this country) between 2020 and 2021. Participants were selected based on responding to a public advertisement in a university's faculties, driving schools, and social media. Initially, 183 subjects (112 novices and 71 experienced drivers) agreed to participate, after explaining the procedure of the study to them. G*Power software (version 3.1) was used to determine the sample size. Based on the purpose of this study, the difference between two independent means (two groups) test was selected among the statistical tests. The input parameters were included the effect size d = 0.8; α err prob = 0.05; power (1-β err prob)

= 0.95, and allocation ratio N2/N1 = 1 in the software. Consequently, the sample size of each group was determined as 42 subjects. Consequently, the calculated sample size for each group was 42 subjects.

To ensure the adequacy of the sample size and considering the possible drop out of the subjects, the final sample size for each group (ie, novice and experienced drivers) was determined to be 50 persons. The novice drivers included 39 males and 11 females, while the experienced group contained 40 males and ten females. The novice drivers with a mean age of 23.46 ($\pm$ 4.84) years had more than six months and less than one year of driving experience, while the experienced drivers (mean age 37.74 $\pm$ 6.35) had ten years or more of driving experience. For the next stage, only male drivers, 15 novice drivers (22.13 $\pm$ 2.38), and 16 experienced drivers (41.44 $\pm$ 5.83) participated in the fMRI risk perception task test voluntarily.

Before performing the test, a physician examined all drivers. Participants of this part were selected using the simple random method. The inclusion criteria included having normal vision (without glasses or corrected with glasses), visual acuity and sensitivity, normal sleep, no alcohol consumption in the last 24 hours, and a minimum of six months period of driving license acquisition for novice drivers and more than ten years of driving license acquisition for experienced drivers. The study was approved by the IRCCS MUMS Ethics Committee, and all the participants signed the written informed consent (Ethics code: IR.MUMS.FHMPM.REC.1400.089).

3.2. Driving Hazard Perception Videos

A full HD portable digital car camera with high resolution (1920 $\times$ 1080) was installed inside a sedan vehicle on the windscreen of the car in the driver's visual angle. Then, different roads in three provinces of Tehran, Razavi Khorasan, and Mazandaran, including urban roads, intercity, and rural roads, were filmed from April-September 2020. All records were performed during daylight hours, generally under a clear sky and dry roadway conditions in different environments (eg, streets, rural roads, residential ways, and limited access to highways). In total, filming took place for 100 hours. Among them, a 150-minutes set of silent video clips were picked up in which a driver had to perform an emergency reaction such as slowing down, stopping, and turning left or right. This step of the study was carried out based on the most important psychological features of the risk perception test developed by Scialfa and Horswill (29, 30).

To select the appropriate scenarios for making risk perception test clips, accident data with fatalities and injuries were evaluated from 2006 to 2016. The data was collected from Iranian legal medical organization and traffic police. Figure 1 presents various groups of traffic collision and their percentages. However, from driver's point of view, the most important hazard source was pedestrians, followed by motorcyclists and cyclists, heavy vehicles and buses, other vehicles, and animals. In this step, 64 short clips from 5 risk sources were selected by consulting eight risk perception experts and behavioral psychologists. Drivers watched the clips, the miss rate (the percentage of missing the hazard scenes of the videos), and reaction time of drivers of both groups in hazardous situations were measured for 64 videos. Then, 35 video clips (out of 64) on a reaction time and miss rate picked up. The criteria for this screening were significant reaction time between two groups of experienced and novice drivers and a miss rate of less than %15 for experienced drivers (26). To choose the final videos for the driver's HPT, the significant deference of neural activity in each video was added to reaction time and miss rate. For doing so, fMRI was used.

Some scholars found a relationship between traffic accidents and risk perception scores as examined and confirmed by different tests in various countries (31-33). Besides, Congdon and Wells accentuated the prospective relationship between risk perception test scores and the risk of traffic accidents (34, 35). Horswill stated that hazard perception scores could predict active traffic accidents (non-park or fixed obstacle) for up to one year (36). Moreover, there was a statistically significant relationship between reaction time in the hazard perception tests and driving skills in predicting, paying attention, and safety on public roads (37-41). Therefore, these studies support the fact that hazard perception tests can predict the risk of accidents and traffic accidents to some extent in real conditions. Indeed, other studies confirmed that there is a significant difference between the risk scores of novice and experienced drivers and attributed this issue to greater awareness of the situations among experienced drivers (17, 18, 22-24, 38).

Hazard perception skill is commonly used conceptually as situation awareness. Situation awareness means a driver who scores higher on the hazard perception test has a better representation of the observed traffic environment and can actively use this mental representation to predict possible outcomes in any situation. Hazard perception skills are also likened to read the road skills, in the sense that drivers who are skilled in hazard perception can detect and pay attention to the warning signs of a haz-

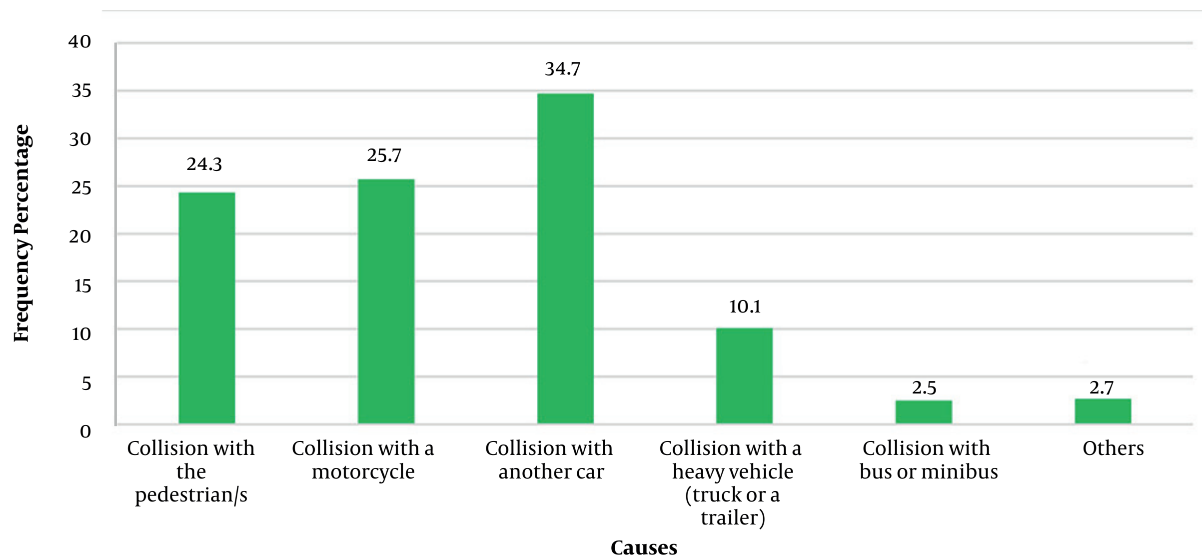

Figure 1. Frequency distribution of traffic accident causes according to Iranian data

ardous situation. It allows them to actively identify potentially hazardous situations and react to them earlier (30).

The validity of the study was determined according to, first, matching the scenarios of the hazard perception test with assessed accident scenarios on different roads, including urban, main roads, highways, freeways, intercity, and rural roads. Second, the significant differences between performances of novice and experienced drivers in the hazard perception test, which was done in three steps. Finally, the selection of final videos was based on three criteria, which were differences in means of miss rate, reaction time, and neural brain function.

3.3. Visual Acuity and Sensitivity Test

Visual acuity and sensitivity test was carried out based on the FrACT-Freiburg Visual Acuity Test (FrACT) developed by Michael Bach in 1996. It includes Acuity C and Contrast C, which its validity is reported (42). A Persian version of Stroop software was used to determine the function of visual attention (43). Besides, Farnsworth D-15 Dichotomous Color Vision Test was applied monocular in two stages (44). All examinations were performed on a 22-inch monitor at an eye distance of 40 cm. The illumination level was 300 Lux provided by a combination of daylight and artificial light sources.

3.4. Procedure

Participants were tested in a single session lasting two hours. In the first stage, the procedure of the study was explained in detail to every participant after obtaining informed consent. Next, visual and cognitive tests were performed. Then, each participant performed two practices and got feedback to ensure researchers that participants fully understood what they would do. Afterward, the participants observed the hazard perception videos for 60 minutes randomly. Finally, drivers performed the hazard perception task inside the fMRI, based on Gharib et al.'s study (28).

Images resulted from the hazard perception task were processed in an fMRI device by FSL software version 6. (FMRIB's Software Library, version 6.0). Brain extraction tools (BET) were used for pre-processing; and fMRI Expert Analysis Tool (FEAT) was applied for activity analysis of active neurons between groups and intergroup from the start of the stimulus to the end of each video (45). We also used the z-score to compare the significant differences in neural activities between the two groups.

3.5. Statistical Analysis

Data analysis was administered using SPSS (Statistical Package for the Social Sciences) version 22. Descriptive statistics, such as mean, standard deviation, and frequency distribution, were applied to describe the demographic characteristics of the two groups of novice and experienced drivers. The Kolmogorov-Smirnov test was used to determine the normality of the data. Since the data were normal ($P > 0.05$), parametric tests were used to an-

Table 1. The Demographic Characteristics, a Mean and Standard Deviation of Participants in Two Stages of a Driver's Hazard Perception Test [a]

Variables	Stage 1			Stage 2		
	Novice Drivers (46)	Experienced Drivers (46)	P-Value	Novice Drivers (15)	Experienced Drivers (16)	P-Value
Age (y)	23.46 ± 4.84	37.74 ± 6.35	< 0.001	22.13 ± 2.38	41.44 ± 5.83	< 0.001
Education (y)	15.2 ± 3	14.8 ± 2.5	0.07	12.81 ± 3.56	12.62 ± 1.85	0.51
Driving license acquisition (y)	1.24 ± 0.8	14.57 ± 8.96	< 0.001	0.3 ± 0.13	21.25 ± 6.42	< 0.001
Driving distance average (Km/week)	46.8 ± 26.47	196.0 ± 97.26	< 0.001	31 ± 56	837 ± 360.57	< 0.001
Color vision (correct answers)	14.63 ± 0.63	14.46 ± 0.67	0.193	14.63 ± 0.65	14.61 ± 0.5	0.6
Vision acuity (Log MAR)	1.70 ± 0.02	1.69 ± 0.02	0.269	1.69 ± 0.02	1.69 ± 0.01	0.42
Vision sensitivity (SF)	0.6 ± 0.016	0.59 ± 0.017	0.09	0.61 ± 0.02	0.58 ± 0.1	0.08
Visual attention						
Correct answers	443.94 ± 32.13	438.78 ± 43.34	0.478	449.2 ± 19.62	443.35 ± 44.9	0.47
Interference time (ms)	12.76 ± 17.34	16.62 ± 11.33	0.2	14.56 ± 9.29	9.76 ± 11.19	0.25
Miss rate (%)	35.41 ± 18.34	16.39 ± 10.37	< 0.001	39.67 ± 16.68	11.12 ± 8.36	< 0.001
Reaction time (s)	3.15 ± 0.48	1.72 ± 0.18	< 0.001	3.10 ± 1.45	1.52 ± 0.8	< 0.001

[a] Correlation is significant at the 5% level. The independent sample *t*-test analysis method were used for P-value.

alyze the data. The Independent-Samples *t*-test, for P-value < 0.05, was utilized to analyze the differences between the two groups concerning the following variables: age, education, visual acuity and sensitivity, visual attention, weekly driving distance, miss rate, and reaction time. In addition, the miss rate of two groups in various traffic conflicts was examined by the Independent-Samples *t*-test for P-value < 0.05.

4. Results

Demographic characteristics as well as visual and cognitive tests on novice and experienced drivers, participating in both stages, are given in Table 1. The miss rate and reaction time of novice drivers were significantly lower than experienced drivers. In the first stage, the mean value of miss rate in novice drivers was 35.41%; while it was 16.39% for experienced drivers. Moreover, the mean response time to the hazards of novice and experienced drivers was 3.15 ± 0.48 and 1.72 ± 0.18, respectively.

In the second stage (after the screening of the first stage clips), the mean value of the miss rate of experienced drivers for 35 videos decreased significantly. The reaction time of novice and experienced drivers was 3.10 ± 1.45 and 1.52 ± 0.8, respectively. In both stages, the two groups of novice and experienced drivers had the same conditions in terms of education, vision sensitivity, and vision acuity (P-value < 0.05). Novice drivers were younger and drove significantly shorter distances per week compared to the experienced drivers, F (1,100) = 2.13, P-value = 0.13. In the second stage, the visual attention of each participant with two variables of reaction time and the total number of correct answers to the Stroop test is shown in Table 1. Among 64 videos, 11 were removed since the miss rate of experienced drivers in those videos was higher than 15%. Afterward, 39 (of 53) videos were chosen based on miss rate and reaction time in both groups. The results showed that the reaction time of novice drivers was significantly higher than that of experienced drivers. Four videos were also removed due to multiple risks with simultaneous onset time and duplicate hazardous sources. Finally, 35 videos from five hazardous sources were selected. Table 2 shows the characteristics of the 35 videos. It also demonstrates the differences in miss rate, the average reaction time, and the active neurons in hazard onset between novice and experienced drivers who participated in the second step of this research. The last column shows the contrast of active brain neurons in each video between experienced and novice drivers. Also, 101 voxels in the first video indicate a higher number of active neurons of experienced drivers than novice drivers for the hazard perception task in the fMRI.

The miss rate was correlated with the number of active neurons in experienced and novice drivers (r = 0.556, P = 0.001), while the miss rate and the number of active neurons did not have any significant correlation with reaction time. Eighteen chosen videos had a strong correlation in

Table 2. Traffic Conflict Categories and Their Frequencies in a Driver's Hazard Perception Test [a]

Hazardous Situations in front of Camera Car	In 64 Clips	In 35 Clips	In 18 Clips
Pedestrian movement	10 (15.6)	7 (20)	4 (22.2)
Move the bike and ride the motorcycle	9 (14.1)	7 (20)	3 (16.7)
Road construction	4 (6.3)	1 (2.85)	0 (0)
Fixed obstacle on the road	5 (7.8)	1 (2.856)	1 (5.6)
Right or left turn indicators of front car	6 (9.4)	3 (8.6)	2 (11.1)
Speed reducing or stopping of a front car	7 (10.9)	3 (8.6)	2 (11.1)
Cut in from right or left	8 (12.5)	4 (11.4)	3 (16.7)
Pull over and pull off	4 (6.3)	2 (5.7)	1 (5.6)
Animal on the road or sideway	11 (17.1)	7 (20)	2 (11.1)

[a] Values are expressed as No. (%).

all three criteria ($P > 0.05$). The final chosen videos are indicated by green color. To conclude, assessing 35 videos, experienced drivers had fewer miss rates, faster reaction time, and more active voxels than novice drivers in the hazard perception task. Table 3 shows the classification of traffic conflicts, which are noticeable events that would lead to an unacceptable consequence unless one of the involved parties reacts to avoid collision, such as slowing down, changing the direction, or accelerating.

In the first stage, the pedestrian movement toward the car was ten videos (out of 64; 15.62%). In the second stage, there were seven videos (20%), and four videos (22.23%) in the final stage. The movement of cyclists and motorcyclists towards the camera car was 14% in the first stage and 16.67% in the final stage. Therefore, the pedestrian movement toward the car and the movement of cyclists and motorcyclists toward the car was allocated the most dangerous situations in the final step of the test. Table 3. Shows the characteristics of the 35 videos. It also demonstrates the differences in miss rate, the average reaction time, and the active neurons in hazard onset between novice and experienced drivers who participated in the second step of this research.

The last column shows the contrast of active brain neurons in each video between experienced and novice drivers. One hundred and one voxels in the first video indicates a higher number of active neurons of experienced drivers than novice drivers for the hazard perception task in the fMRI.

The final video-based of the HPT were converted to a computer software that can be installed on the Windows operating system. Video images were displayed on a monitor with a 1280×1024 resolution.

Using SQL database, C # programming, and WPS technology, the 18-videos test was converted into software that can be installed on the Windows operating system. Figure 2 shows an overview of the different parts of the driving HPT software. Also, Figure 2A presents the main page for entering information into the software. By launching the software, the mentioned page allows the users to enter their information. Figure 2B shows a video view of what an applicant (driver) can see. When a driver reacted to a hazard, a red flag was displayed below the image as a feedback, while no feedback was given to individuals regarding the correctness of answers or scores. After completing the test, users can review their performance, the time-bound, scores, and the place and time of their reactions (Figure 2C). The users can also observe the training tips and safety behaviors in dangerous situations on this page. Figure 2D shows the final report of the test performance (a record) along with the dangerous situations and the earned scores for each video by a user.

5. Discussion

The current study developed a valid HPT, considering local, psychological, behavioral, and neuropsychological features. The test, then, became software, a computer program for the Windows operating system (Figure 1). Among many skills required in safe driving, a proper and timely perception of the hazards has a significant influence; therefore, various studies in the field of hazard perception have been done in recent years, such as those intended to design new tools, as well as training and evaluation of these tools (46-52).

According to hazard perception studies in different countries, on the one hand, HPT has been considered a

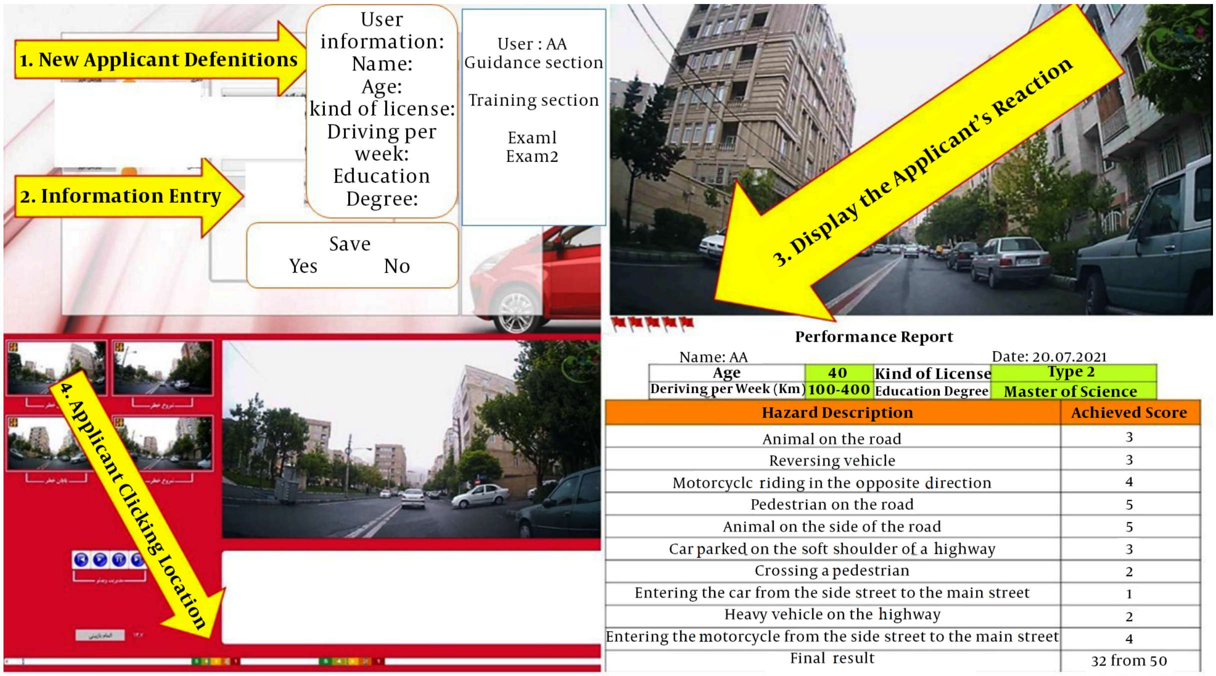

Figure 2. An overview of the different parts of the driving HPT software

predictor and differentiator between novice and experienced drivers; and, on the other hand, researchers have used the significant differences between novice and experienced drivers for validation of HPT (17, 22, 36, 53). Therefore, in most studies, the validation criterion of HPT was differences between novice and experienced drivers. The theoretical foundation of these studies is the theory of information processing defects in dangerous situations. This theory states that traffic accidents occur when individuals are unable to prevent a collision. The reason for this inability is that a safe decision is not made at the right time to avoid the accident. The inappropriate decision has two reasons; either the risk is not detected, or the diagnosis or response to the risk has done with a delay.

Assuming that people react the same way in a dangerous situation, whether behind a computer or a steering wheel, a test can be developed to predict and manipulate the risk of accidents. The traffic accidents data in our country have also shown a higher risk of accidents for novice drivers than for experienced drivers; 40% of road accidents occur for novice drivers who have been licensed for less than a year (6).

In other studies, HPTs were applied to predict traffic accidents considering that there is a relationship between scores of HPT and traffic accidents. Spicer is an example who did a retrospective study to find a relationship between traffic accidents and the HTP test (27). This theory was investigated by hazard perception tests implemented by Darby, Horswill, Boufous, and Cheng (31-33). Besides, Congdon, Wells, and Horswill did prospective studies to find a relationship between traffic accidents and hazard perception skills (34-36). The results of their studies confirm a significant difference between scores of novice and experienced drivers in the HPT with serious traffic accidents, leading to injuries as well as active accidents, occurring where a driver is driving a car, not a parked car.

There are various types of tests for driving licenses. The traditional one includes a paper-based test for theoretical concepts and a real road-driving test to determine practical skills. Currently, driving HPTs, such as video clips, pictures, animations, and simulations, are used in some developed countries as part of the driving certification and renewal process (19, 48-50). However, in developing countries such as Iran, studies on hazard perception effects on driving accidents are seldom, probably due to the lack of a valid perception test to be used in the certification process. Therefore, it is not possible to examine the relationship between accident risks and hazard perception scores. The current study can fill this gap by providing such information for the prediction and correction actions of traffic risks in Iran. Further studies can be conducted to evaluate any relationship between accident risks and HTP's scores.

There are several forms of driving HPTs, such as video clips, photos, animations, and simulators, validated by researchers in different countries (19, 20, 26). In most studies, the criteria for validity and reliability were the difference in reaction time or miss rate between experienced and novice drivers. Nevertheless, the present study considered both the behavioral criteria and the novel criterion of brain imaging. The study could differentiate the responses to the hazards in traffic videos in two stages between novice and experienced drivers. The confounding variables (eg, color vision, visual acuity and sensitivity, visual attention, and education) were eliminated in all steps of error rate, reaction time, and neuron activities exams during the HPT (Table 3). Previous studies have focused on behavioral validity criteria (miss rate and reaction time) between novice and experienced drivers. Nevertheless, there is an improvement in the current study by designing a three-step test and developing a validation method (comparison of neuron activities between novice and experienced drivers).

One fundamental challenge of the HPTs is the examining of the experienced and novice drivers considering a variety of hazardous situations as well as different roads conditions. Some studies emphasized more on the significant differences between the performance of experienced and novice drivers at the same roads (17, 47); while others focused on the diversity of dangerous situations on different roads (22, 48). The test used in this study enables researchers to consider both the diversity of dangerous conditions on different roads and performance differences (Table 3). One of the findings of the present study was a significant correlation between neuronal activity and error rate, which shows the importance of the recognition criterion of hazardous sources in the HPT (49). Insufficient knowledge of dangerous conditions is probably due to lower neurological activity and lower working memory of novice drivers, resulting in unsafe behavior and more accidents.

Studies indicate that hazard perception is the only skill that has a significant correlation with traffic accidents (19, 27). Wetton et al.'s study showed that the mental model of novice drivers is less immature and less developed than experienced drivers due to fewer neurological activities that require strengthening (20). In other words, novice drivers experience more serious traffic accidents in dangerous road situations due to a lower level of neurological activity and weakness in the identification of hazardous sources. The findings of this study support the training courses and driving HPT for novice drivers.

Not considering the gender and the age differences between novice and experienced drivers were among the limitations of this study. However, we considered other essential factors, including experience, duration of the license, driving history, and distance traveled per week. Concerning the relation between behavioral differences in hazard perception of experienced and novice drivers, studies such as Wetton et al., Scialfa et al., and Vlakveld support our findings (20, 26, 53). There were significant differences in average driving distance per time-bound and driving experience between the two groups (26); therefore, age differences were inevitable.

It was not possible to perform a female gender test due to the difficulty of finding female drivers, especially experienced ones who are volunteer to participate in this study. In addition, some studies in developed countries demonstrate no significant gender difference in hazard perception tasks (26, 54-56). However, there may be some differences in performances of HTP in women who live in developing countries. Therefore, it is advised to conduct further research in this regard.

5.1. Conclusions

The present study was carried out to design a driving HPT based on fMRI. The main outcome of this research was a brief, cheap, and customized series of traffic scenes that can be used extensively for HPTs of Iranian drivers. In total, eighteen reliable and valid video clips, which included various traffic scenarios, were prepared by controlling confounding factors such as age, visual attention, visual acuity, visual sensitivity, and color vision.

This hazard perception test can predict the behavior of drivers in real hazardous situations without endangering them. It is also applicable to evaluate the effectiveness of measures related to safe driving training and to improve drivers' perception of traffic hazards. In the UK, the test is estimated to reduce the number of death due to road accidents by 1,746 annually, and costs have been reduced by almost 85 £ million (27). Moreover, this test can be used as part of the driver's license and renewal process in Iran. Finally, it is a valuable tool for the evaluation of taxi, transport, and public transport drivers as well as drivers of transport services of companies and organizations.

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Footnotes

Authors' Contribution: Study concept and design: S. Gh., and M. M.; Analysis and interpretation of data: M. M., and S. Gh.; Drafting of the manuscript: S. Gh.; Critical revision of the manuscript for important intellectual content: Z. R., S. Gh., and M. M.; Statistical analysis: S. Gh..

Conflict of Interests: No potential conflict of interest relevant to this article was reported.

Data Reproducibility: The data presented in this study are openly available in one of the repositories or will be available on request from the corresponding author by this journal representative at any time during submission or after publication. Otherwise, all consequences of possible withdrawal or future retraction will be with the corresponding author.

Ethical Approval: This study is approved under the ethical approval code of IR.MUMS.FHMPM.REC.1400.089 (ethics.research.ac.ir/IR.MUMS.FHMPM.REC.1400.089)

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Informed Consent: The participants signed the written informed consent.

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Table 3. Features of Driving Hazard Videos in a Driver's Hazard Perception Test Based on fMRI

Video Number	Hazard Source	Road Type	Hazard Onset (s)	Miss Rate Difference (Experienced-Novice)		Mean Reaction Time Difference (Experienced-Novice)		Mean Activation Neurons Difference (Experienced-Novice)	
				Percent	P-Value	Second	P-Value	Voxel	P-Value
1	Pedestrian	Urban	5.51	12.5	0.39	2.29	0.001	101	0.13
2	Pedestrian	Urban	2.25	0	1	0.82	0.067	54	0.48
3	Changing the direction of a long vehicle	Intercity	5.43	20	0.1	2.1	0.001	92	0.09
4 [a]	Animal on the road	Rural	5.21	40	0.015	2.01	0.001	810	0.003
5 [a]	Reversing vehicle	Highway	5.52	33.5	0.037	2.47	0.001	476	0.01
6	Overtaking a car carrying goods	Intercity	4.08	47.7	0.009	1.03	0.077	137	0.28
7	Crossing a motorcyclist	Urban	4.17	14.3	0.433	1.82	0.001	55	0.61
8 [a]	Pedestrian	Urban	2.26	33.75	0.037	0.98	0.014	967	0.008
9 [a]	Crossing a construction vehicle	Highway	4.21	33.34	0.018	2.2	0.001	537	0.03
10	Animal on the road	Rural	4.3	19.4	0.33	1.16	0.043	81	0.35
11	Motorcycle in intersection	Urban	4.55	40.5	0.015	0.88	0.034	159	0.22
12	Animal on the road	Rural	4.3	27.5	0.11	1.93	0.001	79	0.57
13 [a]	Motorcycle riding in the opposite direction	Suburb	5.3	40	0.018	2.04	0.001	421	0.003
14 [a]	Pedestrian	Suburb	5.51	47.5	0.002	2.3	0.003	365	0.03
15 [a]	Animal on the side of the road	Rural	3.39	54.5	0.003	1.64	0.004	342	0.02
16	car in intersection	Urban	3.48	13.75	0.33	0.61	0.182	299	0.04
17	Animal on the road	Rural	5.71	20	0.1	1.66	0.005	0	0.97
18 [a]	Reversing vehicle	Suburb	5.21	33.5	0.037	2.69	0.001	308	0.043
19 [a]	Changing the direction of a long vehicle	Intercity	5.31	33.5	0.037	1.95	0.001	524	0.01
20	Pedestrian	Urban	3.18	27.5	0.11	1.06	0.126	143	0.39
21	Animal on the road	Rural	3.38	13.75	0.33	0.84	0.187	45	0.82
22 [a]	Crossing a car from one side of the street to the other	Urban	5.51	33.5	0.037	2.09	0.001	250	0.037
23 [a]	Motorcycle entry from the side of the road	Urban	3.89	42	0.032	1.49	0.012	524	0.001
24	Bus entry from the roadside ramp	Intercity	5.92	28.34	0.14	0.69	0.302	80	0.25
25 [a]	Car parked on the soft shoulder of a highway	Highway	3.39	48.34	0.012	1.35	0.001	412	0.001
26 [a]	Crossing a pedestrian	Urban	6.12	33.34	0.018	1.2	0.048	442	0.001
27 [a]	Entering the car from the side street to the main street	Urban	3.39	26.67	0.04	1.95	0.001	250	0.046
28 [a]	Redirection of a vehicle carrying the goods	Intercity	3.09	47.5	0.009	1.35	0.004	849	0.001
29	Entering the motorcycle from the side street to the main street	Urban	2.87	0	0.96	1.5	0.009	0	0.97
30	Cyclist	Urban	4.3	21.25	0.25	0.64	0.185	56	0.71
31 [a]	Pedestrian on the side of street	Urban	2.17	42	0.032	1.59	0.007	224	0.049
32	Animal on the road	Rural	4.6	21.5	0.22	2.33	0.001	220	0.045
33 [a]	Heavy vehicle on the highway	Intercity	4.87	42.5	0.029	2.32	0.001	182	0.07
34 [a]	Entering the motorcycle from the side street to the main street	Urban	2.57	40	0.014	1.7	0.001	400	0.01
35	Changing the direction of a car	Urban	2.08	0	1	0.71	0.221	125	0.38
Total	All	All	4.02	28.55	< 0.001	1.58	< 0.001	5248	< 0.001

[a] These rows of videos were selected for HTP.