Review Article

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Driving Hazard Perception Tests: A Systematic Review

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ABSTRACT

Objective: The present study was conducted to evaluate previous studies on hazard perception among road users.
Methods: A comprehensive search was conducted using electronic databases and search engines including Science Direct, PubMed, Scopus, Embase, Web of Science, Iranmedex, SID, Irandoc, and Google Scholar from January 2000 to September 2021. The search was performed using a combination of medical subject heading terms and keywords. Endnote software version 20.0 (Clarivate, Philadelphia, PA, USA) was used to organize the included articles. Thematic content analysis was used to analyze the findings. The entire review process was conducted by two authors, and unresolved challenges were discussed with other researchers.
Results: Findings of the study show that all of the tests could discriminate between inexperienced and experienced drivers. The use of dynamic hazard perception tests was more common than static tests, and in some cases, simulators were used. Moreover, the results indicated a weak correlation between the results of dynamic and static tests. Therefore, it could be claimed that both dynamic and static methods measured certain dimensions of hazard perception.
Conclusion: Regarding the importance of hazard perception, the findings of this study can provide further progress in designing hazard perception tests. The hazard perception tests can be sensitive to cultural or legal differences. It should also be noted that in developing tools for measuring drivers' hazard perception, different dimensions of hazard perception must be considered, so that the level of drivers' hazard perception can be reported accurately.

Keywords: Hazard, Perception, Traffic accident, Automobile drivers.

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Introduction

Traffic accidents and their consequences are a global issue. This is specifically important in developing countries such as Iran, where traffic accidents account for about 90% of fatalities [1]. According to statistics, the number of traffic-related fatalities in Iran is 20 times higher than the global average [2]. According to statistics from the Iranian Ministry of Health and Medical Education, car accidents are the second leading cause of fatality and the first cause of death in Iran. Car accidents cause 60% of accidents that result in injuries and death, whereas it is less in global statistics [3-6].

Most traffic accidents are caused by three primary causes: the environment, the car, and the human. Several studies in different countries indicated that the highest rate was related to human factors [7, 8]. Recent studies in the U.K. and the United States reported that 95% of traffic accidents were the result of various human errors. Driving mistakes, distractions, or abnormal behaviors [9] are examples of human errors, which are primarily influenced by the driver's perception of hazards related to the road, cars, and the environment. One of the most fundamental and essential skills for a driver to possess is the ability to perceive driving hazards [10]. Having hazard perception ability demonstrates great skill in driving. It contains examples in which knowledge about different hazards, the anticipation of hazards, and their visual perception are enhanced [11]. The rate of drivers' hazard perception has a direct effect on traffic safety [10, 12]. Accordingly, studies have shown that increasing the rate of hazard perception reduces the number of traffic incidents [12, 13].

Drivers' perceptions of hazards can be improved by expanding their knowledge. To accomplish this purpose, first, it is necessary to first conduct a test to establish a standard for hazard perception [14]. Hazard perception tests are used in many countries to train and assess drivers [11, 15], and in some countries such as the U.K., Netherlands, and Australia, they are used as one of the legal tests for driving licenses [11, 15-17]. According to research findings, those who passed the hazard perception tests on the first attempt had fewer accidents than others [12, 13, 18].

Hazard perception tests come in a variety of forms and can be static, dynamic, or a combination of both [19, 20]. Static tests contain questionnaires and fixed images, whereas dynamic tests include footage, a simulator, and a driving test [21]. Research showed that each country's traffic culture and infrastructures had an impact on drivers' behavior, hence, this was both a cultural and infrastructural issue [22] When comparing the driving behavior of 41 countries throughout the world, it was found that committing driving violations were related to the developing condition of each country [23]. For instance, a significant difference was observed in road traffic hazard perception rates among drivers in Norway, Russia, and India [24]. Experimental data even indicated a difference in drivers' behavior among countries in the same geographical area [25], which showed that culture had a direct effect on drivers' understanding of a hazard condition [26]. Therefore, to measure drivers' hazard perception rate in one country, it is needed to construct and design a test that is standard and appropriate to the culture and infrastructures of that country [27, 28].

Regarding the importance of hazard perception (HP) and its crucial role in reducing accident occurrence, having a clear definition of the term and identifying HP tests can be beneficial for both researchers in this field as well as for authorities in developing transparent policies to prevent accidents. Moreover, a review of studies conducted in Iran indicated that a small number of studies were conducted to assess the Iranian drivers' hazard perception rate, and the results were limited and sometimes contradictory. Therefore, through a systematic review, the available studies can be retrieved and integrated to offer a far more comprehensive image of the issue dimensions. Thus, the current systematic review was conducted to assess drivers' hazard perception test.

Materials and Methods

This systematic review was designed and conducted to assess hazard perception tests among drivers in 2021. Its approach was adapted from the book "systematic reviews to support evidence-based Medicine" [29].

Searching Strategy

An experienced and knowledgeable librarian developed and implemented a search strategy in current research with the assistance of an expert and pundit in the field (Table 1). The required data was synthesized by searching the related Persian and English keywords such as, "test", "hazard perception" and "drivers, as well as the medical subject heading terms collected as the main keywords available on the Iranian database of Iranmedex, SID, Irandoc, and International database of Science Direct, PudMed, Scopus, Embase and Web of Science published

Table 1. Complete search strategy for PubMed databases

Set	Strategy	Results
#1	(((((((((driver[Title]) OR (driving[Title])) OR (road[Title])) OR (hazard[Title])) OR (risk[Title])) OR (perception[Title])) OR (prediction[Title])))	670,458
#2	(test[Title]) OR (questionnaire[Title])	174,302
#3	#1 AND #2	234*

* Filters activated: Journal Article, Full text, Humans, English, Persian, 2000-2021

between January 2000 and September 2021. To find and cover additional published articles, a number of top popular journals in the field as well as the Google Scholar search engine were manually searched. After removing articles with poor relationships with study objectives and selecting the main articles, the reference list of the selected articles as well as the gray literature was searched once more to ensure that all the existing publications were identified and had their content thoroughly examined.

Inclusion and Exclusion Criteria

This review study included all English-language studies on hazard perception tests of drivers that were published between 2000 and 2021. The exclusion criteria were abstracts of articles that were published in congresses and conferences, studies with a quality evaluation checklist average of less than 36, and referenced cases rather than drivers' hazard perception.

Quality Assessment

This systematic review comprised 61 papers that were critically appraised. Two researchers (Y.H. & H.S.) independently evaluated the reporting quality of the studies using the 22-item STROBE checklist for cross-sectional studies. There were 22 items on the checklist. According to matching the checklist question criteria with the contents of the articles, the items scored 0, 1, and 2. The minimum score for checklists was 0, and the maximum score was 44. The studies were rated as good (a score of 30-44), medium (15-29), and poor (0-14) quality [30, 31].

Two authors evaluated the articles and based on their overall score, they classified them into three categories, high, moderate, and low quality. Then, any unresolved challenges were discussed with other researchers.

Data Extraction Procedure

Initially, the data extraction form was designed manually in the Microsoft Office Word software (version 2016, Microsoft Corporation Co., USA) to extract the required data. The extracted data included the first author's name, place of study, year of publication, the objective of the study, sample size, sampling method, measurement tools, scale, and the findings of the study.

Initially, data from five publications were experimentally retrieved for these forms and the initial shortcomings and difficulties were resolved. Two researchers independently extracted information from selected articles. To organize the included resources, Endnote software version X9 (Clarivate, Philadelphia, PA, USA) was used. First of all, after removing the duplicates, the included articles were screened by investigating the titles and abstracts of all available articles. In the next step and following the identification of the included articles, the full text of the articles was evaluated and the related articles were included.

Data Analysis Methods

Using the content analysis method, information extracted from a data extraction form was manually evaluated, summarized, and reported.

Two researchers independently coded the data. The procedure of data analysis and coding was as follows: Initially, the articles were read several times by the researcher to become familiar with the text (steeped in article results). The initial scopes and bases were then identified and extracted. The following phase involved extracting screening program challenges and obstacles from each study and organizing them in a determined area. The results of each area were reviewed and finalized in the last stage. Besides, the reliability of areas and extracted results in each domain was confirmed by reaching an agreement between two coders through discussion and resolving the conflicts.

Results

At the initial stage of searching in different databases, 234 articles were found. Subsequently, 27 articles were removed due to duplication. After reviewing the remained titles and abstract (according to inclusion and exclusion criteria), 132 unrelated articles were also removed. In accordance with the quality evaluation checklist and inclusion and exclusion criteria, 61 related articles were included in the study (Figure 1).

According to the findings of the included articles, the studies were conducted in 21 countries, the majority of which were in Australia (9 articles). The majority of studies were in Europe, while there were none in Africa. In addition, the fewest studies were conducted in Asian countries including Hong Kong, Malaysia, China, Singapore, and Thailand, each had only one study (Figure 2).

Quality Assessment Results

The average overall quality of reporting cross-sectional studies was 38.2 (range=0-44). In general, the reporting quality of articles was estimated as good (Table 2).

Characteristics of Conducted Studies

Table 2 indicates the characteristics of selected studies for review, with a numbering system ranging from 1-61 used in the interpretation of the results. Three articles were in the Persian Language, while the rest were in English (or non-Iranian). The majority of the studies, 11.5% (n=7), were published in 2013. The first article was published in 2003. Dynamic test, which was based on video scenarios, had the highest frequency and was employed in 42 (69%) articles [11, 17, 19, 28, 29, 32-63]. Static tests were used in 9 (15%) studies [11, 12, 22, 40, 41, 64-68]. Simulators for hazard perception tests (HPT) were

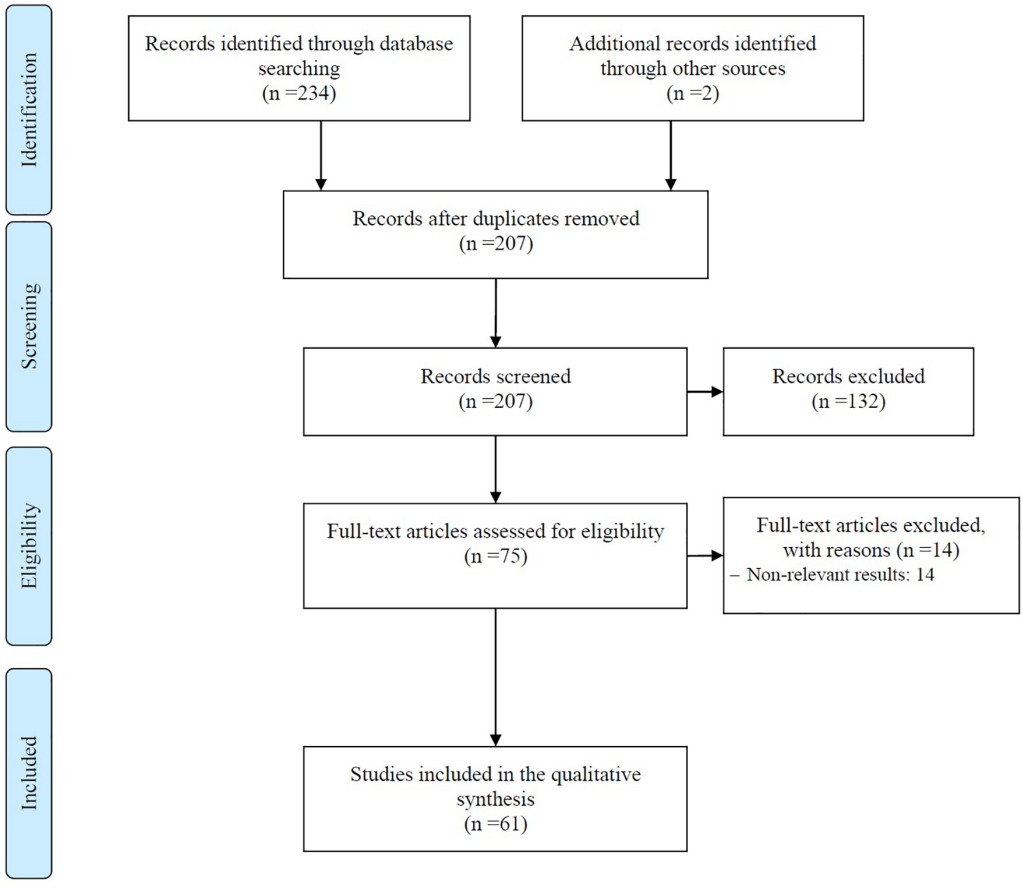

Fig. 1. Flow chart of reviewing and searching the articles

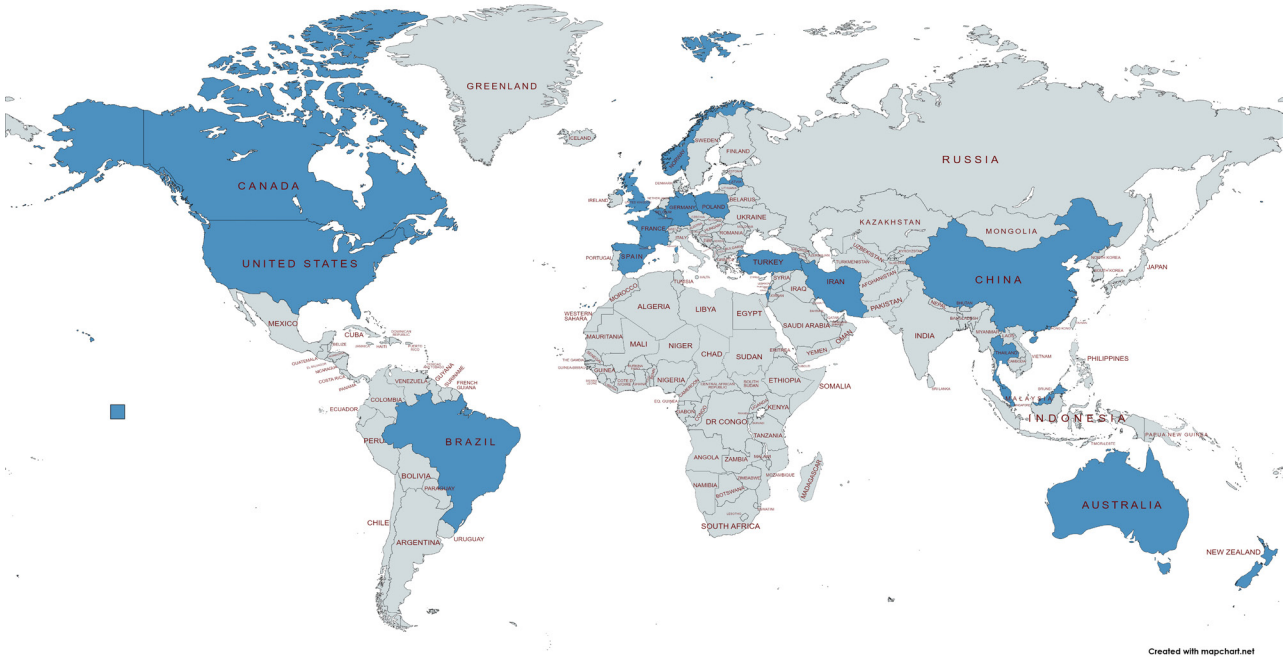

Fig. 2. Frequency of studies conducted in different countries

employed in 10 (16%) studies [69-78]. Alberg and Randmo's hazard perception questionnaire was used in one study [79]. One study [80] applied driving tests. In 14 studies (23%), eye tracking was employed as an add-on to video, static image, and simulator methodologies [13, 28, 39, 44, 51, 59, 64, 70, 72, 74, 76, 77, 81, 82].

The total number of participants was 26645. In 54 articles (89%), the participants were studied as drivers [10-12, 17, 19, 22, 28, 29, 32-38, 40-47, 50-56, 58, 60, 61, 63, 64, 66, 68-71, 73, 74, 76, 77, 79, 80, 82-86], in 4 articles (7%) as motorcyclists [42, 69, 71, 72], in one article as a police officer [46], in 3 articles as pedestrian [48, 49, 76], in 3 articles as a cyclist [56, 59, 61], and in one article as a student [62]. All studies were original and cross-sectional in nature.

Table 2. Characteristics of initial studies included in the systematic review

	Author/ Year of publication	The purpose of the study	Country	Type of study	Test method	Sample size	The overall result	Quality appraisal
1	Feizabadi *et al.* 1394 (27)	The relationship between risk perception and driving experiences	Iran	Cross-sectional study	Video	126 drivers	There was a positive and significant correlation between driving experience and traffic risk perception score and driving experience could predict risk perception.	40
2	Mahmoodi *et al.* 1394 (28)	The effect of driving experience on the perception of traffic hazards	Iran	Cross-sectional study	Video	53 novice drivers, 30 experienced drivers	There was a significant difference between the two groups in terms of risk perception. Novice drivers did not recognize hazardous situations as potentially hazardous situations or reacted to those situations later than the group of experienced drivers.	38
3	Kamran Madadian, Salah Soufi 1397 (29)	Predicting high-risk driving behaviors based on hazard perception	Iran	Cross-sectional study	Driving risk perception questionnaire Ulleberg, & Rundmo	303 drivers of public transport	driving hazard perception could predict high-risk driving behavior.	36
4	Horswill, M., Helman, S. 2003 (30)	Factors affecting the risk of an accident	United Kingdom	Cross-sectional study	Simulator	48 car drivers and 47 motorcycle drivers	The results showed that car drivers who also ride motorcycles have a faster hazard perception than other people who were just car drivers or only motorcyclists.	38
5	Pradhan *et al.* 2005 (31)	hazard perception assessment	US	Cross-sectional study	Simulator with eye tracking	24 novice drivers, 24 experienced young drivers, 24 experienced older drivers	Novice drivers had weaker hazard detection and perception than other drivers.	38
6	Underwood *et al.*2005 (32)	Scanning the fixed pathways of the eyes of young and old drivers in assessing hazard perception	United Kingdom	Cross-sectional study	Video	12 young drivers and 12 old drivers	There was no significant difference in perception of risk and ocular stability between young and old groups. Older drivers received videos of more dangerous scenes than the younger group.	38
7	Sagberg & Bjørnskau 2006 (33)	Assessment of the driving experience on the hazard perception	Norway	Cross-sectional study	Video	48 novice drivers and 28 experienced drivers	No significant difference was found in the perception of hazard or response time between the groups.	40
8	Wallis & Horswill, 2007 (34)	Investigation of why experienced drivers are faster at hazard perception than novice drivers	Australia	Cross-sectional study	Video	25 novice drivers trained, 27 novices untrained, 17 experienced	Trained novice drivers and experienced drivers had significantly better hazard perception than untrained novice drivers.	40
9	Horswill, *et al.* 2008 (35)	The ability of hazard perception in older drivers	Australia	Cross-sectional study	Video	16 novice drivers and 17 experienced drivers	Experienced drivers perceived hazards significantly faster than novice drivers.	40

10	Lee, *et al.*2008 (36)	Investigating road hazards from the perspective of novice and experienced drivers	US	Cross-sectional study	Driving test	42 novice teen drivers and 42 experienced drivers	Experienced drivers understood the hazard much more often than novice drivers.	40
11	Horswill, *et al.* 2009 (37)	Comparison of drivers' ability to perceive hazards	Australia	Cross-sectional study	Video	22 young drivers, 34 older drivers, and 23 older drivers	Older drivers perceived hazards less significantly than older and younger drivers.	36
12	Isler, *et al.* 2009 (38)	Improvement of driver hazard perception through video tutorials	New Zealand	Cross-sectional study	Video	24 inexperienced young drivers, 8 experienced drivers	Experienced young drivers were significantly less aware of the hazards encountered than experienced drivers and required a longer response time.	38
13	Jackson, *et al.* 2009 (39)	Predicting the behavior of other drivers	United Kingdom	Cross-sectional study	Video	41 novice drivers, 39 experienced drivers	Novice drivers were less careful than experienced drivers in the field of hazard perception.	38
14	Liu, *et al.*2009 (40)	Assessing the ability of hazard perception in experienced and novice drivers	Australia	Cross-sectional study	Simulator	12 inexperienced motorcyclists, 12 experienced motorcyclists, 12 novice car drivers, and 12 novice drivers with test certificates	The results showed that experienced drivers had a higher hazard perception than other drivers. They were also less likely to have a car accident than other drivers.	38
15	Smith, *et al.* 2009 (41)	Assessing hazard perception in novice and experienced drivers	Australia	Cross-sectional study	Video	32 novice drivers and 30 experienced drivers	Experienced drivers were significantly more aware of the hazards than other drivers and were more careful in answering questions.	40
16	Borowsky, *et al.* 2010 (42)	Assessment of drivers hazard perception	Israel	Cross-sectional study	Video with eye tracking	21 young drivers, 19 experienced drivers, and 16 older drivers	Differences in risk perception depended on the risk situation. Older drivers were the calmest people in response to traffic accidents. Experienced and older drivers had a wider visual scan than younger drivers.	38
17	Huestegge, *et al.* 2010 (43)	Investigating the effect of hazard perception training on driving	Germany	Cross-sectional study	A static scene with eye tracking	20 inexperienced drivers, 20 experienced drivers	Experienced drivers were significantly able to perceive more hazards than inexperienced drivers.	38
18	Shahar, *et al.* , 2010 (44)	Assessment of hazard perception	United Kingdom	Cross-sectional study	Video	20 drivers with one screen and 19 drivers with three screens	The number of hazards perceived by drivers who tested with three screens was significantly better than by drivers who tested with one screen.	36

19	Wetton, *et al.* 2010 (45)	Development and validation of two complementary criteria for the driver's hazard perception ability	Australia	Cross-sectional study	Video and image	24 novice drivers and 24 experienced drivers	Experienced drivers have hazard perception significantly faster than novice drivers. The two dynamic and static methods were not related to each other. The reliability (Cronbach's alpha coefficient) of the risk perception test was 0.93.	36
20	Cheng, *et al.* 2011 (46)	Comparing the hazard perception ability of motorcycle drivers with accident and without an accident	Hong Kong	Cross-sectional study	Simulator with eye tracking	63 motorcyclists without accidents and 46 motorcyclists with accidents	Non-crash motorcyclist's hazard perception was significantly faster than non-crash motorcyclists	36
21	Rosenbloom, *et al.* 2011 (47)	Assessing the hazard perception in motorcyclists and car drivers	Israel	Cross-sectional study	Video	35 motorcyclists and 25 car drivers	Motorcyclists performed significantly better in hazard perception than car drivers.	40
22	Scialfa, *et al.* 2011 (48)	Conducting a hazard perception test for novice drivers	Canada	Cross-sectional study	Video	29 young novice drivers and 146 experienced young drivers	Young novice drivers' hazard perceptions were significantly slower than experienced drivers.	38
23	Wetton, *et al.* 2011 (49)	Hazard perception test for novice drivers	Australia	Cross-sectional study	Video	175 car drivers	The results of this study showed that the employed test used could distinguish different groups of drivers who had different driving experiences. The ability to detect road hazards and predict accident risk was poor in novice drivers. Novice drivers were slower to respond to hazards than experienced young drivers. A subset of well-reliable scenes successfully distinguished the two groups.	38
24	Lyon, *et al.* 2011 (50)	Development of static hazard perception test in North America	US	Cross-sectional study	Static images	27 experienced young people, 29 novice young people	Novice drivers reacted less quickly to road hazards while their hazard perception was lower than that of young and experienced drivers. It was found that a short hazard perception test using static images could classify individuals with high accuracy.	40
25	Boufous, *et al.* 2011 (51)	Hazard perception test for novice drivers	New Zealand	Cohort study	Static images	20 822 young drivers	Drivers who failed at least twice in the hazard perception test were those who feared being involved in a traffic accident. The risk of accidents was high for those who failed the hazard perception test at least twice, especially among men and among villagers and remote areas.	40

26	Bellet & Banet, 2012 (52)	Designing a conceptual model of risk awareness	France	Cross-sectional study	Video	12 people under training, 12 novice drivers, 12 experienced drivers, and 12 police	Experienced police and drivers understood the hazard significantly better than novices and trainees.	38
27	Borowsky, *et al.* 2012 (53)	Comparing the hazard perception ability of motorcycle drivers with accident and without an accident	Israel	Cross-sectional study	Video with eye tracking	10 young novice drivers, 10 active trained drivers, and 21 experienced drivers	There was no significant difference between the studied groups in terms of hazard perception. Experienced drivers had better image-scanning patterns than other people.	38
28	Bromberg, *et al.* 2012 (54)	Hazard perception of passers-by from the perspective of experienced people	Israel	Cross-sectional study	Simulator and video	22 experienced drivers, 20 experienced senior drivers	Older drivers had longer response times than younger drivers, but groups did not differ significantly in pedestrian hazard perception.	40
29	Crundall, *et al.* 2012 (55)	Assessing drivers' perceptions of various hazards	United Kingdom	Cross-sectional study	Simulator with eye tracking	14 people under training, 17 experienced drivers, and 18 training drivers	Experienced drivers and trainers understood the hazards significantly, more accurately, and quickly than those under training.	38
30	Scialfa, *et al.* 2012 (56)	Evaluation of the effect of driving experience on static hazard perception test	Canada	Cross-sectional study	Static images	25 young novice drivers, 26 experienced young drivers	Novice drivers perceived hazards significantly slower and less accurately than experienced drivers.	38
31	Crundall, *et al.* 2013 (57)	Investigating the experience of motorcycling in hazard perception	United Kingdom	Cross-sectional study	Video	20 novice drivers, 21 experienced drivers, and 20 advanced drivers	Advanced drivers perceived hazards much faster than novice drivers. Advanced drivers, because of their experience, better perceived the hazards.	38
32	Horswill, *et al.* 2013 (58)	Assessing the ability of hazard perception in drivers	Australia	Cross-sectional study	Video	42 experienced drivers, 26 police officers	Police officers perceived the hazards significantly faster and more accurately than experienced drivers.	36
33	Lim, *et al.* 2013 (59)	Investigating the effect of intercultural factors on drivers' hazard perception	Malaysia	Cross-sectional study	Video with eye tracking	20 novice English drivers, 25 experienced British drivers, 26 novice Malaysian drivers, 27 experienced Malaysian drivers	There was no significant difference between drivers' hazard perception with different cultures.	36

34	Scialfa, *et al.* 2013 (60)	Comparison of dynamic and static hazard perception tests	Canada	Cross-sectional study	Static video and image	56 experienced drivers	The relationship between dynamic and static tests was low to moderate and both tests had good validity. In the dynamic test, novice drivers perceived the hazard later than experienced drivers, but they responded faster to the static test than experienced drivers.	40
35	Oron-Gilad & Parmet, 2014 (61)	Evaluate the effectiveness of different educational scenarios in hazard perception	Israel	Cross-sectional study	Scenario	39 young novice drivers and 6 experienced drivers	The use of different educational scenarios is effective in hazard perception and makes a difference between the studied groups.	40
36	Castro, *et al.* 2014 (62)	Development and validation of the Spanish hazard Perception Test	Spain	Cross-sectional study	Video	14 trainees, 16 novice drivers, and 14 experienced drivers	Experienced drivers received higher scores than other groups in response to the hazard perception test. The reliability of the test (Cronbach's alpha coefficient) was 0.77.	40
37	Meyet, *et al.* 2014 (63)	Understanding the hazard of traffic on children	Norway	Cross-sectional study	Video	540 pedestrians	Children had the slowest time responding to the hazard perception test compared to young individuals and adolescents.	40
38	Vlakveld 2014 (64)	Comparison of the effect of two methods of video presentation on hazard perception	Nether-lands	Cross-sectional study	Video	First method: 30 people under training, 34 professional drivers Second method: 30 people under training, 30 professional drivers	Professional drivers scored higher on both methods than those trained. The first method was relatively better in distinguishing between the two groups.	38
39	Mackenzie & Harris, 2015 (65)	Evaluation of eye movement and hazard perception in active and inactive driving	United Kingdom	Cross-sectional study	Video, simulator, and eye tracking	17 drivers and 17 non-drivers	Those who drove identified and perceived the hazards faster than those who did not, but their accuracy did not differ significantly.	38
40	Malone & Brünken, 2015 (66)	Assess hazard perception	Germany	Cross-sectional study	Video	35 people under training and 31 experienced drivers	Skilled drivers performed better in hazard perception than those trained. Although they were more accurate, they were not statistically significant.	38
41	Meir, *et al.*2015 (67)	Measuring the ability of young pedestrian's hazard perception	Israel	Cross-sectional study	Simulator with eye tracking	27 minors and 20 adults	Younger children were less accurate in diagnosing and perceiving hazards than older children. The younger ones responded less slowly than the older ones.	40

42	Rosenbloom, *et al.* 2015 (68)	Hazard perception test for pedestrians	Israel	Cross-sectional study	Video	158 children, 113 young and 88 elderly	Young people had the highest hazard perception. They were followed by children and then the elderly. Children were least likely to increase vision using the left and right arrow keys.	40
43	Yeung, & Wong 2015(69)	Investigating the effect of experience on hazard perception	Singa-pore	Cross-sectional study	Simulator with eye tracking	14 young novice drivers, 14 young experienced drivers, 12 old experienced drivers	No differences were observed between different groups in hazard perception. The first fixation was significantly slower in specific hazard scenarios for older drivers, with less scanning ability compared to younger drivers.	40
44	Horswill, *et al.* 2015 (70)	Video Scene hazard Perception Test	Australia	Cross-sectional study	Simulator with eye tracking	244 Australian drivers	Drivers who failed the risk perception test were 25% more likely to be involved in an active crash (such as an accident that occurred when the driver's vehicle was moving). Unsuccessful drivers were also 17% more likely to have been involved in pre-test active accidents while on a temporary license.	40
45	Castro, *et al.* 2016 (71)	Investigating the effect of education on hazard perception	Spain	Cross-sectional study	Video	20 trainees, 62 novice drivers, and 40 experienced drivers	Experienced drivers performed better than other groups. Compared to gradual start-up hazards, there were more differences between groups of drivers regarding sudden hazards.	36
46	Crundall 2016 (72)	Investigating the difference in hazard perception between experienced and novice drivers	United Kingdom	Cross-sectional study	Video	15 novice drivers and 15 experienced drivers	Experienced drivers were significantly more accurate in hazard identification and perception.	36
47	Johnston & Scialfa, 2016 (73)	Hazard perception assessment in emergency drivers	Canada	Cross-sectional study	Video	20 city drivers and 28 emergency drivers	Emergency drivers were significantly faster at hazard perception than urban drivers.	36
48	Malone & Brünken 2016 (74)	The role of ecological validity in hazard perception assessment	Germany	Cross-sectional study	Video	101 drivers under training, 49 experienced drivers	Experienced drivers performed better than learners in responding to the hazard scenario. There was no significant difference between the groups in terms of potential hazards. The high-validity test showed better performance for differentiating different drivers in terms of experience.	36

49	Vansteenkiste, *et al.* 2016 (75)	Hazard perception assessment in cyclists	Belgium	Cross-sectional study	Video with eye tracking	11 teenagers and 17 adults	There was no difference in accuracy or hazard stabilization between the two groups. Adults were quicker to answer video questions than teens.	36
50	Ventsislavova, *et al.* 2016 (76)	Drivers hazard perception	Spain	Cross-sectional study	Video	34 trainees, 36 crime-free novice drivers, 4 criminal novice drivers, 54 experienced non-criminal drivers, 21 experienced criminal drivers	Hazard detection, situational awareness, and caution were significantly higher for experienced drivers than for novice drivers and learners. Offenders were less cautious and identified fewer dangers than unauthorized individuals.	38
51	Meir, *et al.* 2016 (77)	Teaching the hazard perception to young driver	Israel	Cross-sectional study	Video	40 inexperienced young drivers, 21 inexperienced young drivers	Providing active, school, and combination training improved drivers' hazard perception.	38
52	Gugliotta, *et al.* 2017 (78)	Assessment of hazard perception experience	Spain	Cross-sectional study	Video	20 trainees, 62 novice drivers, and 40 experienced drivers	Trained drivers were significantly less accurate in identifying hazards than novice and experienced drivers, and answered decision-making questions more accurately than situational awareness questions.	36
53	Zeuwts, *et al.* 2017 (79)	Assessing the hazard perception in child and adult cyclists	Belgium	Cross-sectional study	Video with eye tracking	75 teenagers and 41 adults	Adolescents had a significant delay compared to adults in responding to hazard perception test questions.	36
54	Caparelli-Daque, *et al.*2017 (80)	Hazard perception test in Brazil	Brazil	Cross-sectional study	Static images	314 male and female drivers	Drivers' hazard perception clearly depended on variables such as expertise, age, and sex.	40
55	Feng, *et al.*2018 (81)	Hazard perception in old drivers	Canada	Cross-sectional study	Static images	16 young drivers and 21 old drivers	Older drivers were slower and less accurate in answering hazard perception test questions.	40
56	Tuske, *et al.* 2019 (82)	Development of Lithuanian Drivers hazard Perception Test	Lithuania	Cross-sectional study	Static images	34 experienced drivers and 125 drivers with diverse driving experience	The hazard perception test was able to differentiate between inexperienced and experienced drivers, and between experienced drivers who have had less than three or more accidents in their driving history. The reliability (Cronbach's alpha coefficient) of the test was 0.77.	38

57	Malone & Brunken 2019 (83)	Measuring hazard perception with traditional, verbal, and motor test methods	Germany	Cross-sectional study	Video with eye tracking	69 drivers	Drivers in the traditional test group (pushing a button) were slower to perceive hazards but were faster at responding to test questions than participants in verbal and motor skills. As a special improvement, the way of verbal testing was differentiated between different types of groups.	40
58	Manley, *et al.*2020 (84)	Development and validation of hazard perception test for Thai drivers	Thailand	Cross-sectional study	Video	87 Experienced drivers and 48 novice drivers	On average, experienced drivers perceived the hazard faster than novice drivers. Hazard perception test scores distinguish beginner and experienced Thai drivers. The reliability (Cronbach's alpha coefficient) of this test was 0.93.	38
59	Castro, *et al.* 2020 (85)	Hazard perception and prediction test for walking, cycling, and driving	Spain	Cross-sectional study	Video	30 pedestrians, 14 cyclists, 13 novice drivers, and 22 experienced drivers	This test was able to differentiate between different studied conditions: A) Between traffic hazards that have been recorded from different perspectives: walking, cycling, and driving; B) Between participants with different user profiles: pedestrian, cyclist, and driver.	36
60	Arslany-ilmaz2020 (86)	Improve hazard perception skills	Turkey	Cross-sectional study	Video	22 high school students	The results showed that computer-based education could increase the level of hazard perception in high school students and improve their skills in this field.	40
61	Wu *et al.* 2021 (87)	Development and validation of the Chinese version of the hazard Perception Test	China	Cross-sectional study	Video	54 novice drivers and 47 experienced drivers	The test had very good internal consistency. Drivers who had driving errors scored lower than drivers who did not. This test measured hazard perception well. The reliability (Cronbach's alpha coefficient) of this test was 0.86.	38

Hazard Perception Test of Car Drivers

According to a review of conducted studies, hazard perception was different among the studied groups, including novice, inexperienced, experienced, teenaged, young, and old drivers. Novice/young and inexperienced drivers had weaker perception skills than experienced/older ones. All studies that investigated hazard perception between novice and skilled drivers reported a significant difference in hazard perception test scores between groups, and also identified experience as an important factor for hazard perception [28-83]. The findings indicated that all different methodologies of testing, including dynamic, static, simulator, and real-world test-drive, revealed a difference between driver groups based on age and/or experience.

Twenty-six articles (43%) discussed the response time [17, 29, 34-37, 39, 41, 45, 46, 48, 51, 59, 60, 68, 69, 72-74, 76, 77, 81, 82, 84, 85, 87]. Fourteen articles stated that experienced drivers perceived hazards faster than less experienced ones [17, 29, 35, 37, 41, 45, 60, 66, 71, 72, 74, 84, 85]. Based on two factors of age and experience, five studies reported that experienced young drivers perceived the hazards faster than experienced older drivers [36, 39, 68, 73, 77]. Four articles reported that adults perceived hazards faster than children [48, 59,

76, 81]. Individuals who were both motorcyclists and drivers had faster hazard perception than those who were either car drivers or motorcyclists [69]. A study indicated that police officers perceived hazards faster than experienced drivers [46]. Furthermore, drivers were faster in hazard perception than individuals who had not driven at all [48]. Finally, ambulance drivers had a higher hazard perception rate than conventional urban drivers [34].

Participant accuracy was mentioned in 12 studies [19, 38, 46, 51, 52, 54, 56-58, 68, 74, 86]. Seven of these publications found that experienced drivers were more accurate than novice drivers [19, 38, 52, 54, 58, 74, 87]. In addition, a study found that police officers had more accuracy than experienced drivers [46]. According to a study, there was no significant difference in the accuracy rate between drivers and non-drivers [51]. In one study, the adults had higher accuracy than children [76], while in another one, there was no significant difference between the two groups [56]. However, a study indicated that young drivers had higher accuracy than older ones [68]. Four studies compared the methodology of hazard perception tests [11, 41, 51, 73], out of which two studies compared dynamic and static tests [11, 41], and the other two compared dynamic and simulator tests [51, 73]. The findings indicated that novice drivers had better response ability in static tests than dynamic ones, however, experienced drivers performed better in dynamic tests than novice drivers. Besides, older drivers responded faster in simulator tests than in dynamic tests. A study found no significant differences in hazard perception or time of response between studied groups [33]. Fourteen studies mentioned eye tracking during the test [13, 28, 39, 44, 51, 56, 59, 64, 70, 72, 74, 76, 77, 82]. In seven cases, eye tracking has used a supplement for the stimulator tests, which assessed cognitive processing during learning [13, 51, 70, 72, 74, 76, 77]. Eye tracking was used as an add-on for dynamic tests in six cases [28, 44, 59, 81-83], while in one case [64], it was used for static tests (Table 3).

The Hazard Perception Tests (HPT) were designed, developed, and validated in five studies [22, 41, 47, 60, 63]. These studies were conducted in Australia, Spain, Lithuania, Thailand, and China, respectively. In Australia, dynamic (including 15 videos) and static methods (on 24 novice drivers and 24 experienced drivers) were used to develop and validate two complementary criteria of drivers' hazard perception abilities. The results indicated that experienced drivers perceived the hazard significantly faster than novices. Test instructions, on the other hand, were appropriate for individuals with poor English skills. The findings (Cronbach's alpha coefficient of 0.93) supported the reliability of the test and demonstrated its eligibility for licensing [41]. In Spain, the hazard perception test was designed and validated using a dynamic method on 14 trainees, 16 novices, and 14 experienced drivers. A new video-based HPT with a total of 20 hazards and 8 quasi-hazardous clips was evaluated. This test had appropriate psychometric features and could discriminate between different types of drivers. The psychometric results validated the final version of HPT, which included 11 hazardous and 6 quasi-hazardous clips with Cronbach's alpha coefficient of 0.77. Additionally, trainees, novices, and delinquent drivers were shown to lack the ability to recognize the quasi-hazardous and differentiate them from dangerous situations. This test had adequate psychometric properties and was beneficial to discriminate between trainees, novices, and experienced drivers. Analysis of the safe and dangerous driving behavior of drivers, lawbreakers who had previously lost their driver's licenses, was also advantageous [47]. In Lithuania, HPT was developed and validated using a static method on 34 experienced and 125 experienced drivers with various vehicle driving experience. The final test consisted of 27 static traffic scenes. HPT could discriminate between inexperienced and experienced drivers, as well as between experienced drivers who had less than three accidents during their driving period and those with more than three accidents. The test's reliability (Cronbach's alpha coefficient) was 0.77 [22]. In Thailand, the test was constructed and validated using the dynamic method on 87 experienced and 48 novice drivers. It included 77 pieces of footage. The results indicated that on average, experienced drivers perceived the hazard faster than novice drivers. HPT discriminated between novice and experienced Thai drivers. The reliability of this test was 0.93 [60]. In China, the hazard perception test was expanded and validated using the dynamic method on 54 novices and 47 experienced drivers. This test began with 36 videos, which were reduced to 20 after redrafting and authenticating. It had a high internal consistency (Cronbach's alpha=0.86). Total test scores had a positive and significant correlation with the reaction time that was measured in video-based HPT. Drivers who made mistakes on the road received lower scores than drivers without mistakes. This test measured hazard perception accurately [63].

Table 3. Characteristics of dynamic and static tests for driver HP

Dynamic hazard perception tests	Static hazard perception tests
Contain live traffic footage	Contain static image
Utilization temporal responses	Utilization accuracy
Visual search measurement	Hazard detection measurement
More time-consuming test	Less time-consuming test
Designing and implementing the test with more cost	Design and implementation of the test with less cost

Discussion

In this review study, the findings of 61 original cross-sectional studies that investigated and examined the drivers' hazard perception were synthesized using a systematic review and specific research criteria. The findings indicated a significant heterogeneity. However, the measurement of drivers' hazard perception was the common point for all methodologies, and the dynamic test was applied in the majority of them. The results revealed that novice/young drivers were significantly weaker than experienced/older ones in terms of reaction times and response speeds. Box and Wengraf [88] argued that after 1000 miles of road driving, a novice driver's skill and safety could be equal to the skill of drivers with three or more years of experience, and the risk of an accident could be rapidly reduced. According to the findings, more training for driving learners or young novice drivers could enhance their skills in hazard perception and minimize their errors and accidents rate. As mentioned in previous research [13] it seemed that experienced drivers performed better than novice drivers. Therefore, they suffered less from distraction disorder [89]. The majority of the tests could discriminate between novice and experienced drivers' hazard perception abilities. Consequently, the results suggested that the hazard perception test is a useful tool to classify the drivers' groups [90]. Most notably, the findings revealed that drivers with driving errors might fail to appropriately identify and predict road hazards, which might have an adverse effect on driving safety. Drivers with traffic violations, on the other hand, had lower total scores in the HPT than drivers without them. Therefore, interventions or pieces of training focusing on hazard perception might lead to a positive impact on decreasing occurrences and accidents.

Both dynamic and static hazard perception tests can be used to assess a driver's ability to identify and respond to potential road hazards. Dynamic hazard perception tests involve simulating real-life driving scenarios on a computer, in which the driver must respond to hazards as they emerge in real-time [11]. Static hazard perception tests, on the other hand, provide motionless photos of road scenes and ask the driver to identify potential hazards. While both methods have their strengths and weaknesses, dynamic hazard perception tests are generally considered to be a more accurate and realistic representation of actual driving conditions. This is due to they simulate the demands of real-world driving and allow for a more comprehensive assessment of the driver's hazard perception skills [21]. However, static hazard perception tests might be more appropriate for drivers who struggled with computer-based simulations, or if resources or time constraints prevented the use of dynamic testing methods [91].

Numerous studies simply used one or two of the various components and subscales available for assessing hazard perception, such as response time, hazard detection, visual search, hazard prediction, hit rate, and hazard rating [92]. To improve driving hazard perception testing, more components should be introduced in the future.

According to the findings, using film or footage to test the drivers' hazard perception skills may offer advantages over using images. In dynamic tests, many real-world hazards that emerge abruptly and unexpectedly can be accurately shown to the drivers, where there is a limited range for drivers with high hazard perception. Therefore, drivers can use their own skills to improve perception and response time [93]. The tests that used static images have a lower frequency.

A comparison of dynamic and static testing revealed that both can discriminate between drivers based on age and experience. In static tests, novice/young drivers responded faster than experienced/older drivers, indicating that novice/young drivers unexpectedly responded faster than experienced/older drivers, although the response time in the dynamic tests was as expected [41]. Regarding the increased risk of accidents for novice/young drivers, static tests were unlikely to replicate the dynamic nature of real-world driving and might lack ecological validity in measuring hazard perception [11]. In addition, there was no correlation between dynamic and static tests, indicating that these methods could assess hazard perception from different aspects [41]. Static tests provide an explicit reaction time that can be calculated from the onset, while dynamic tests need more mental analysis and therefore may take longer time to complete. A short quick response to a still image (in a static test) can reduce the test time, allowing more different hazard scenarios to be tested. Using a combination of dynamic and static methodologies, licensing tests might be able to discriminate between road users group based on age and experience. This integrated method can provide a more comprehensive assessment of hazard perception skills.

Simulators were another HPT methodology employed in studies. Driving simulators, as opposed to dynamic and static tests, can be used to enhance the driving experience by introducing the physical and cognitive needs of drivers. However, using simulators is generally limited to research, which is likely due to the impracticality of mass testing as well as the costs associated with the arrangements. However, a comparison of the dynamic and simulator methods in young drivers showed that hazard perception was slower in the simulator method than the dynamic method, however, the simulator might reflect more cognitive load experience while driving [51]. Hazard perception of dynamic testing necessitates appropriately timed responses to hazard scenarios. The findings showed that dynamic tests might take longer time than expected to respond to

the hazards, but this doesn't necessarily invalidate this method; because it can discriminate between drivers of different ages and experiences. In addition, simulated and dynamic tests are less applicable in countries with inappropriate and inadequate infrastructures, due to their complexity and technologies that must be addressed throughout the development and implementation phase.

Findings showed that HPT could be sensitive to cultural and legal differences. Each country should design and validate the HPT tool in accordance with its own cultural and legal aspects [94]. Following scientific analyses and selections, the tests were finalized with video or image items and were reviewed according to participants' points of view. All the tests designed in different countries had sufficient reliability with a minimum Cronbach's alpha coefficient of 0.77 and a maximum of 0.93. Appropriate reliability indicated that this test can be used to assess and evaluate the driver's hazard perception [94].

One of the limitations of the current study was that the studies and papers were searched in two languages, English and Persian, while it was probable that studies and papers about drivers' HP tests were conducted in different countries and published in the language of those countries. Thus, they were not found and evaluated in the present study. One of the strengths of the present study was that it has tried to identify and focus on the factors influencing the occurrence of traffic accidents because identifying and defining these factors, as well as assessing drivers and providing training in these fields, can increase the drivers' accuracy and reduce road traffic accidents.

Conclusion

The findings of the study indicated that although the majority of tests in studies could discriminate between inexperienced and experienced drivers, there was a higher tendency to use dynamic hazard perception tests than static ones. Although each test evaluated different aspects of hazard perception and the superiority of one test over another could not be stated. In less developed countries, providing and using complex and dynamic hazard perception tests is somewhat challenging due to the low and limited infrastructure to implement them for the whole society. Therefore, due to the importance of the issue, it is recommended to use static hazard perception tests to evaluate a driver's ability to perceive hazards in drivers seeking a driver's license. These tests can also be used to assess the driver's ability, who wanted to extend the credit of their driving license to increase the assessment chain of drivers' hazard perception.

Declarations

Ethics approval and consent to participate: The Institutional Review Board and the Ethics Committee of Isfahan University of Medical Sciences, Isfahan, Iran, approved this study (IR.MUI.RESEARCH.REC.1399.719).

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