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Investigating Truck Drivers' Behavior Towards Potential and Developing Hazards

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ABSTRACT – *Having attentive drivers is essential to maintaining road safety, especially when it comes to road freight transportation. The hazard perception experiment assesses a person's ability to see the whole road scene, recognize potentially dangerous situations, and respond to them in a way that is appropriate and safe. There is a correlation between a higher collision risk and poor hazard perception, or the inability to recognize potentially hazardous traffic and road conditions. In the effort to improve the current understanding of driver attentiveness will perhaps increase the safety of road freight transportation, this article suggests performing trials. The study intends to ascertain if danger-anticipating skills may be enhanced without explicit teaching by utilizing the repetition effect, which is frequently shown in procedural learning tasks. This research will identify the merits or demerits of an emergency response team's repetitive procedural driving culture, inspired by principles of skill acquisition. In this study, the analysis of driving hazard detection and reaction times reveals significant insights into driver behavior and safety. The study identifies scenarios such as broken-down vehicles and cattle on the roadside as frequently detected hazards, indicating high driver awareness in these situations. Conversely, dynamic scenarios like motorcycles ahead and pedestrians at roundabouts are less often detected, suggesting a need for enhanced driver training and awareness in these contexts. Finally, the significance of this research lies in its exploration of an alternative driving training methodology that is in line with implicit learning principles. This technique may provide truck drivers with a more effective and efficient way to improve their ability to anticipate hazards.*

KEYWORDS: Truck driver, hazard perception, driving simulator

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1. INTRODUCTION

Traffic safety is a major issue in the transportation industry. The driving environment, vehicles, and drivers all affect traffic safety. Despite age and driving experience, limited research has been conducted on additional factors that may affect drivers' hazard detection and response skills (Ibrahim et al., 2018). These factors include visual attention (Huestegge & Böckler, 2016; Barragan & Lee, 2021), the behavior of offender drivers (Ventsislavova et al., 2016), emotional valence and arousal (Trick et al., 2012), familiarity with routes (Martens & Fox, 2007), understanding of traffic laws, and the impact of a repetitive procedural driving culture.

Driving risk analysis heavily relies on driving behavior and response to hazards. However, assessing risk in real-world scenarios is challenging (Eboli et al., 2017). According to Pankok and Kaber (2018), driving simulators are frequently used to study driving behaviors in a variety of experimental settings. These methods also facilitate identifying drivers who are more likely to be aware of and respond to hazards on the road. According to Crundall et al. (2020), danger perception is the process by which drivers take in and analyze information from the traffic environment.

Hazard perception, or the ability to anticipate dangerous road situations, is a key skill linked to crash risk (Horswill & McKenna, 2009). Studies indicate that hazard perception skills can be enhanced through experience and training. This skill improves with age and experience, and while brain development can't be sped up, training can enhance hazard perception (Horswill, 2016). Driver training programs often include hazard perception tests that simulate real driving situations to evaluate how well drivers respond to hazards. These tests can utilize computer simulations where drivers must identify and react to hazards as they arise.

Research shows that drivers who fail the hazard perception test twice are more likely to have traffic accidents, while those who pass on their first attempt experience a 17% reduction in at-fault injury crashes during their provisional licensing period (Boufous & Finch, 2011; Senserrick, & Williams, 2015; Horswill, 2016; Thomas et al., 2016). This indicates that the hazard perception test can predict driving safety, and each driver differs in their ability to identify possible risks in traffic, and the intricate traffic environment might make it more difficult for them to accurately identify potential hazards (Boufous et al., 2008). It is commonly known that a driver's likelihood of having a collision is closely correlated with their ability to recognize and react to hazardous driving situations (McGwin & Brown, 2004; Lee & McGehee, 2006).

This research will examine truck drivers' abilities to perceive hazards and their corresponding behavioral traits. Using a specially designed driving simulator, 58 drivers took part in this session to see how they responded and behaved in various hazardous situations. The study's findings can be applied to driver hazard assessments and training to gauge and enhance participants' defensive driving abilities and hazard perception awareness.

This research aims to analyze drivers' ability to detect potential or developing hazards on the road using a driving simulator approach. In addition, this experiment will determine whether a repetition effect based on job condition, commonly observed in procedural learning tasks, can be leveraged to improve hazard anticipation abilities without explicit instruction.

2. METHODOLOGY

2.1 Driving Simulator

A potential road hazard is defined as a circumstance that could lead to a dangerous situation while driving. The 30-minute simulated drive encompassed a variety of settings, including rural roads, urban traffic, and expressways, designed to assess driving behavior, attention levels, and risk perception through a series of scenarios. Roads can be categorized into rural, urban, and expressway types based on several factors, such as speed limits, infrastructure, surrounding environments, and usage patterns. Tables 1-3 outlined the scenarios that were established during the driving simulation.

2.2 Data Acquisition

The experiment was conducted using a driving simulator (Borhan et al., 2019), as shown in Figure 1. The data acquired while driving on the simulator will form the basis of the first portion of the findings. Throughout the journey, data were captured and saved by utilizing the simulator's software and video camera. The simulator keeps track of the vehicle's condition and the driver's actions.

TABLE 1: Scenarios in expressway **(H)**

Code	Description	Class
H1	A broken-down truck parked on the roadside	P
H2	A bus moves swiftly from behind	D
H3	The lorry moves rapidly from behind	D
H4	Motorcycle	D

TABLE 2: Scenarios in rural road **(V)**

Code	Description	Class
V1	Cattle on the roadside	P
V2	Motorcycle speeding from behind	D
V3	Motorcycle ahead	D
V4	Bicycles ahead	D
V5	Pedestrian crossing	D
V6	Bicycle ahead	P
V7	Car approaching at the junction	D

TABLE 3: Scenarios in urban road **(T)**

Code	Description	Class
T1	Parked trucks at shoulder L/R	P
T2	Parked cars L/R	P
T3	Stalls L/R	P
T4	Bus stops at the bus shelter	P
T5	Pedestrians L/R	P
T6	Pedestrians crossing	D
T7	Pedestrians crossing at the roundabout	D
T8	Broken-down van	P

FIGURE 1: The setup of the Hazard Perception Test via a driving simulator

2.3 Assessment of Risk

The assessment process involved analyzing driving simulator data consisting of video footage, verbal responses describing a detected hazard, and response time to assess driver behavior and concentration levels throughout the driving sessions. During the simulator evaluation, hazards were categorized as illustrated in Figure 2. Besides, the risks faced by drivers were evaluated by examining the nature of emerging hazards, considering factors such as the severity of the risk, its location, and the likelihood of escalation over time.

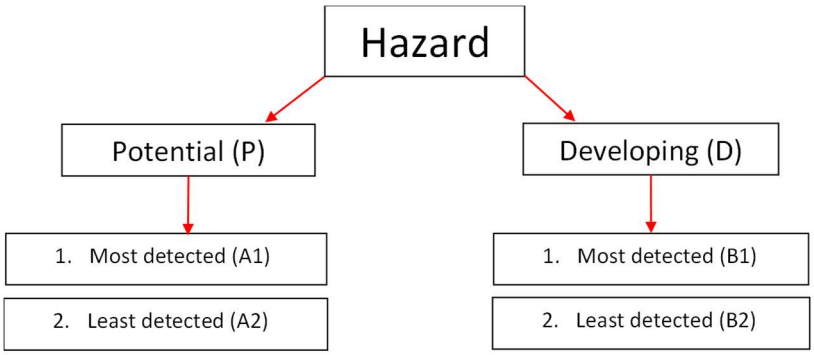


FIGURE 2: Road hazard classification

3. RESULTS AND DISCUSSION

Hazard detection refers to the cognitive process by which individuals perceive potential environmental risks. Nonetheless, decision-making and detection are separate processes. Enhancing road hazard perception involves scanning the roadway and concentrating on relevant stimuli (Cao et al., 2022). It is essential for drivers to consistently improve their hazard perception skills through practice, experience, and continuous training. As illustrated in Figure 3; by recognizing potential road hazards and responding appropriately, drivers can greatly lower the risk of accidents and promote safer driving experiences for themselves and others. For that reason, scientific measures of hazard perception have been developed to evaluate driver capabilities more objectively (Omran et al., 2023). The reaction time to detect hazards was recorded and analyzed during the simulation process.

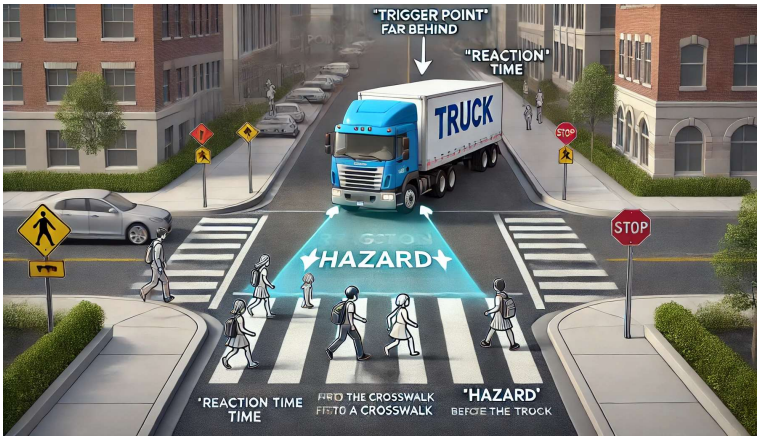


FIGURE 3: Theoretical of driver reaction time during simulator experiment

3.1 Most and Least Detected Scenario

Detection and response systems aim to mitigate risks and enhance overall driver safety on the road. The most detected scenario involves sudden and unexpected obstacles or changes in traffic conditions that can pose a threat to drivers' safety. The most detected scenario encompasses a range of potential and developing hazards as described in Table 4.

TABLE 4: Most detected scenarios during the simulation experiment

Code	Description	%	Class
T8	Broken-down van	82.76	P
V1	Cattle on the roadside	77.59	P
H1	A broken-down truck parked on the roadside	72.41	P
V5	Pedestrian crossing	60.34	D

In common road hazard experiments, most of the least detected scenarios usually are challenging to detect due to their infrequency, unpredictability, or unique nature. Surprisingly, for this investigation, the least detected scenario involves highly common events that were sometimes overlooked by participants. Our hypothesis is that participants may perceive these events as common traffic situations, yet they still pose significant risks to drivers' safety. The least detected scenarios in this road hazard testing are shown in Table 5.

TABLE 5: Least detected scenarios during the simulation experiment

Code	Description	%	Class
T3	Stalls	5.17	P
V3	Motorcycle ahead	8.62	D
V6	Bicycle ahead	10.34	P
T7	Pedestrians crossing at the roundabout	10.34	D

3.2 Analysis of Driver Reaction Time

The reaction time analysis provides a crucial understanding of how drivers perceive and respond to road hazards. The study, as in Figure 4, categorizes reaction times into three segments: Not Applicable (NA), Quick, and Late. Scenarios like encountering a broken-down van (T8) and cattle on the roadside (V1) showed that a significant portion of drivers reacted late (72.41% and 44.82% respectively), indicating that these hazards are not always immediately recognized as threats. Conversely, scenarios like a truck breaking down on the roadside (H1) and pedestrian crossings (V5) also showed high late reaction times (72.41% and 53.44%, respectively), underscoring a widespread issue in timely hazard perception. These findings highlight the importance of improving drivers' hazard recognition skills and reaction times through better training and advanced driver assistance technologies, aiming to reduce the latency in recognizing and responding to potential dangers on the road.

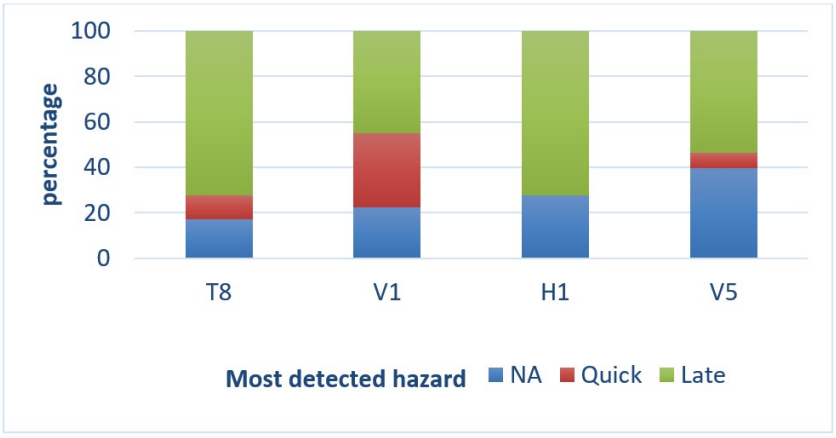


FIGURE 4: Truck driver reaction time concerning the most detected hazard

The study conducted to evaluate truck drivers' behavior towards potential and developing road hazards yielded several critical insights into the relationship between driving behavior, hazard perception, and road safety. The findings can be categorized into key areas: the impact of driving behavior on hazard perception, the role of repetition and procedural learning, and the implications of reaction times in hazard detection.

3.3 Impact of Driving Behaviour on Hazard Perception

One of the study's significant revelations is the clear distinction between aggressive and defensive driving behaviors and their influence on hazard perception. Drivers classified as aggressive (e.g., Emergency Response Team - ERT) demonstrated different hazard detection patterns compared to those with defensive driving habits (e.g., Chemical Tanker Drivers - CTD). This dichotomy suggests

that driving style significantly affects a driver's ability to perceive and respond to potential hazards, as illustrated in Figure 5. In both driving groups, the ability to perceive and react to potential road hazards is critical:

a. ***Aggressive Driving Group****:* Members may exhibit shorter reaction times due to their focus on immediate response rather than anticipation of potential hazards. This can lead to an inadequate perception of developing dangers on the road.

b. ***Defensive Driving Group****:* Drivers in this group typically maintain longer reaction times as they are trained to anticipate and mitigate potential hazards early. This proactive approach enhances their ability to navigate safely through various road conditions.

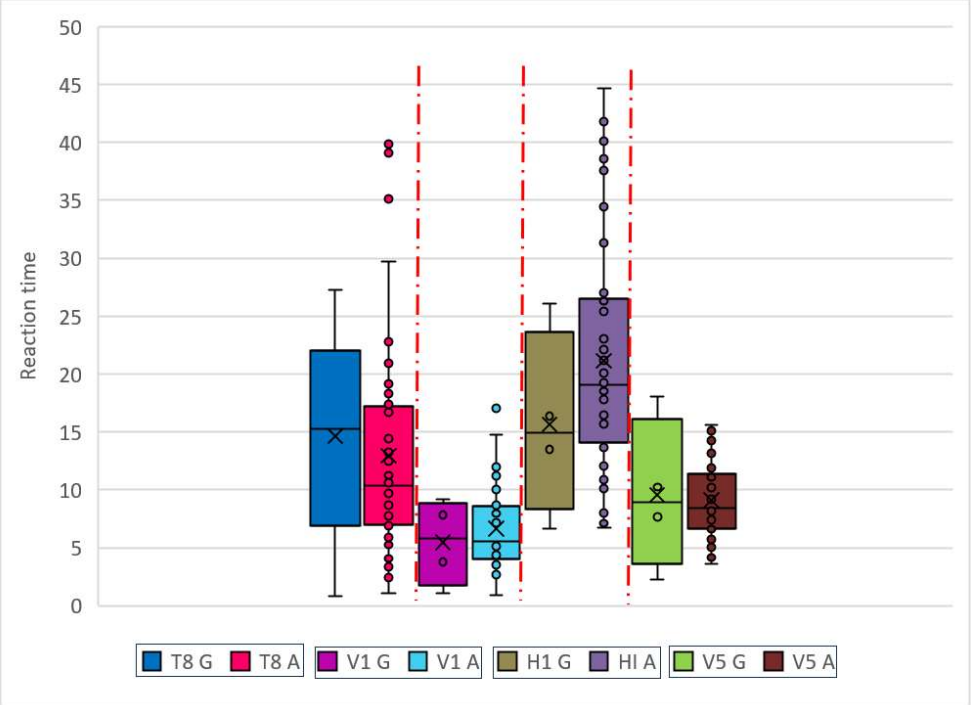


FIGURE 5: Reaction time: ERT (G) versus CTD (A)

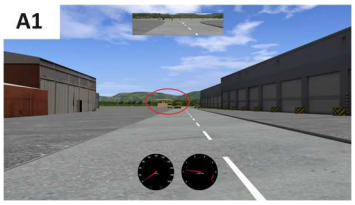
Aggressive drivers might be less attentive to hazards due to their tendency to engage in riskier behaviors, potentially leading to higher accident rates. In contrast, defensive drivers, who are more cautious and vigilant, tend to have better hazard perception skills, which can contribute to lower accident risks. Table 6 presents the image with descriptions for most and least detected test scenarios. After all, these findings underscore the importance of promoting defensive driving practices to enhance road safety.

3.4 Influence of Repetition and Procedural Learning

The study also highlighted the phenomenon of repetition in procedural learning, which can be a double-edged sword. On the one hand, repetition can enhance a driver's ability to anticipate hazards without direct instruction, improving their overall hazard perception. On the other hand, excessive reliance on repetitive patterns may reduce a driver's ability to make sound decisions in novel or unexpected situations.

The analysis of the repetition effect on driving behavior underscores the dual impact of procedural learning on hazard anticipation and decision-making. Procedural learning, where drivers repeatedly encounter similar tasks or scenarios, can significantly enhance their ability to anticipate hazards without needing direct instruction. This improved anticipation can lead to better preparedness and potentially safer driving practices.

TABLE 6: Image and criteria for most and least detected test scenarios

Scenario	Classification	Description
A1 	Most detected (Potential)	**Broken-down Van (T8)** On an urban road, encounter a vehicle that has broken down on the side of the road. The driver should be alert and cautious of their speed.
A2 	Less detected (Potential)	**Stalls (T3)** Stalls attract pedestrians, so be on the lookout for people crossing the road. Drivers also should be aware of vehicles that may stop suddenly to park.
B1 	Most detected (Developing)	**Pedestrian Crossing (V5)** Pedestrians are crossing from the left/right as the driver approaches; be prepared to yield to pedestrians at crosswalks, especially in areas with high foot traffic.
B2 	Less detected (Developing)	**Motorcycle Ahead (V3)** Driver approaching motorcycle on the rural road. The driver should be alert and remain in the same lane.

However, the study also indicates that this repetition can sometimes impair decision-making, as drivers might become over-reliant on familiar patterns and less adaptable to unexpected changes. In the context of aggressive versus defensive driving, the findings show that aggressive driving scenarios, such as a bus or lorry moving swiftly from behind or a speeding motorcycle, are among the least detected by monitoring systems as shown in Table 7. This suggests a gap in both driver awareness and system sensitivity to dynamic, aggressive driving behaviors.

TABLE 7: Least detected scenarios among all emergency response team participant

Code	Description	Class
H2	The bus moves swiftly from behind	D
H3	The lorry moves rapidly from behind	D
V2	Motorcycle speeding from behind	D
V7	Car approaching at the junction	D

The under-detection of these aggressive driving behaviors suggests a significant gap in both driver awareness and the sensitivity of monitoring systems. This issue may stem from the nature of emergency response teams, which typically operate vehicles equipped with sirens and flashing lights to navigate through emergencies. As other drivers tend to yield space for these emergency vehicles, this habitual behavior may cause them to overlook approaching vehicles, particularly those coming from behind.

Consequently, the data reveals that vehicles approaching from the rear are often undetected. This gap can lead to increased risks on the road, as drivers may not be adequately prepared to respond to sudden aggressive maneuvers from other vehicles.

These insights highlight the need for a balanced approach in driver training and system design, emphasizing both the benefits of repetition in building hazard anticipation and the necessity of maintaining decision-making flexibility in varied driving conditions.

This finding suggests that while training programs that incorporate repetitive hazard scenarios can be beneficial, they should also include varied and unexpected scenarios to ensure drivers develop comprehensive hazard perception skills. Balancing repetition with diversity in training scenarios can help drivers better prepare for real-world driving conditions

3.5 Implications of Reaction Times in Hazard Detection

The analysis of reaction times provided an intuitive measure of drivers' hazard perception capabilities. Longer reaction times were indicative of inadequate hazard perception, suggesting that these drivers are less prepared to respond promptly to developing hazards. The study identified specific scenarios where reaction times were notably longer, such as when encountering broken-down vehicles or pedestrians crossing. In Figure 6, emergency response teams demonstrated an average reaction time of 8.5412 seconds, which was notably quicker than the 9.3645 seconds recorded for chemical tank drivers shown in Figure 7, a difference of 0.8233 seconds. To put the 0.8233-second gap into perspective, at a highway speed of 110 km/h, emergency response teams would cover approximately 25.17 meters less distance before reacting to a hazard compared to chemical tank drivers. This distance could be critical in an emergency.

These insights can inform the development of targeted training interventions aimed at improving drivers' reaction times to specific hazards. For instance, incorporating more simulations or practical training exercises involving these less-detected scenarios can help drivers recognize and respond to them more effectively in real-world settings.

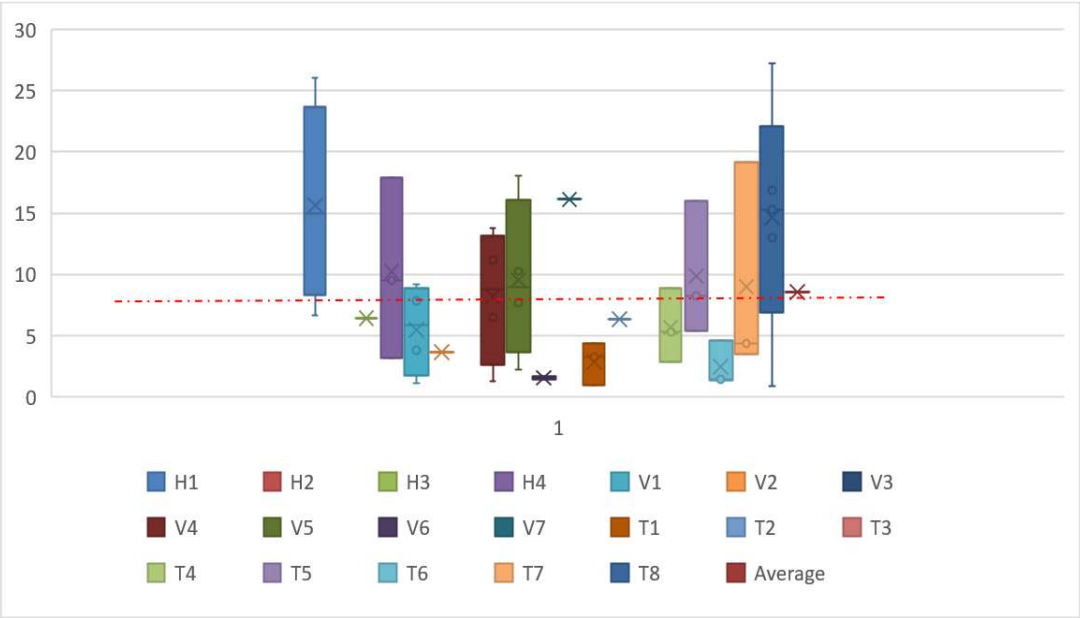


FIGURE 6: Reaction time in hazard detection among emergency response team drivers (ERT)

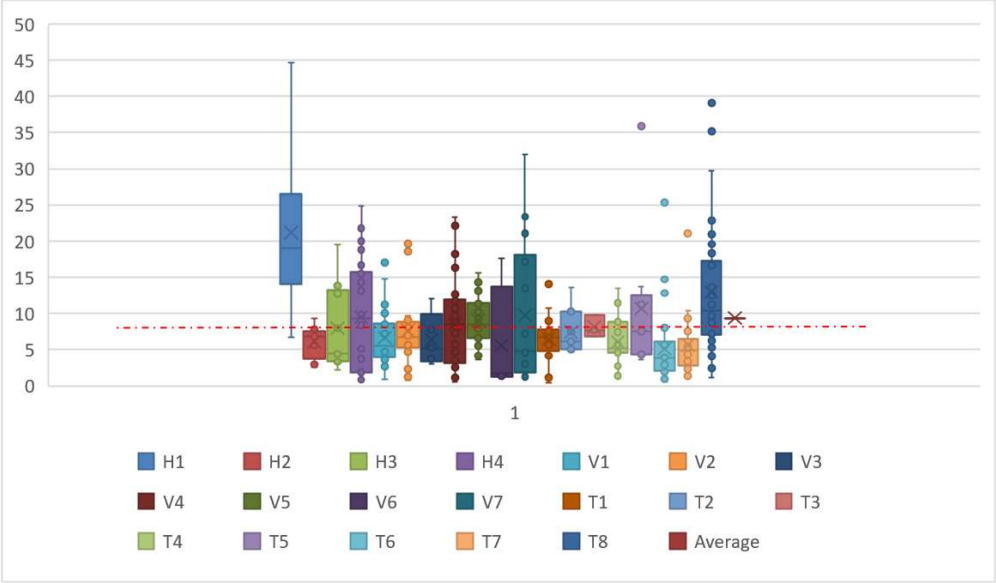


FIGURE 7: Reaction time in hazard detection among chemical tanker drivers (CTD)

4. CONCLUSION

In this study, the analysis of driving hazard detection and reaction times reveals significant insights into driver behavior and safety. The study identifies scenarios such as broken-down vehicles and cattle on the roadside as frequently detected hazards, indicating high driver awareness in these situations. Conversely, dynamic scenarios like motorcycles ahead and pedestrians at roundabouts are less often detected, suggesting a need for enhanced driver training and awareness in these contexts. The repetition effect in procedural learning enhances hazard anticipation but may impair decision-making, highlighting the complexity of driver response to repetitive tasks. Furthermore, the reaction-time analysis shows that long reaction times correlate with inadequate hazard perception, emphasizing the need for improved training and systems to foster quicker reactions.

The study provides valuable insights into the factors influencing hazard perception and reaction times among truck drivers. By understanding the impact of driving behavior, the role of repetition, and the implications of reaction times, stakeholders can develop more effective training programs and interventions to enhance road safety. Promoting defensive driving practices, incorporating diverse hazard scenarios, and focusing on improving reaction times are critical steps toward reducing accidents and ensuring safer roads for all users. These findings can inform the development of targeted road safety measures, advanced driver assistance systems, and educational programs to bolster driver readiness and response to diverse road hazards. The findings from this study have several practical implications for enhancing road safety:

a. ***Promote Defensive Driving Training***
Emphasizing defensive driving techniques in training programs can help instill safer driving habits and improve hazard perception skills.

b. ***Diverse Hazard Scenarios in Training***
Training programs should include a variety of hazard scenarios, both common and uncommon, to prepare drivers for a wide range of potential hazards.

c. ***Focus on Reaction Time Improvement***
Specific training modules aimed at reducing reaction times for hazards can help drivers respond more effectively and reduce accident risks.

d. ***Continuous Assessment and Feedback***
Implementing continuous assessment and feedback mechanisms can help drivers identify areas for improvement and reinforce safe driving practices.

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