Evaluating Hazard Perception and Prediction Across Different Countries: Implications for Road Safety

Petya Ventsislavova, PhD

Senior Lecturer in Psychology

Email: Petya.petrova@ntu.ac.uk

NTU Webpage: https://www.ntu.ac.uk/staff-profiles/social-sciences/petya-ventsislavova-petrova

X: https://x.com/vppetya

Nottingham Trent University

Abstract

Hazard perception involves complex cognitive processes, including identifying and prioritising potential hazards and making timely decisions while driving. While widely used in Western countries, traditional hazard perception tests may not be as effective in regions with higher accident rates due to cultural and criterion biases. Recent research has shown that a variant of the hazard perception test, called the hazard prediction test, which assesses drivers' ability to anticipate hazards, is less influenced by cultural biases and correlates with crash involvement. This suggests that the hazard prediction test could complement traditional methods, offering a more universally applicable tool for evaluating driver safety.

Key words: hazard perception, hazard prediction, criterion bias, situation awareness

Hazard perception in driving is defined as "the ability to predict dangerous situations on the road" (Horswill & McKenna, 2004). The process of perceiving hazards while driving is inherently complex, involving various sub-processes such as prioritising relevant information, identifying potential sources of hazards, assessing the associated risks, and responding to these hazards in a timely manner. Hazard perception, therefore, extends beyond merely perceiving a hazard. It encompasses an extensive process of becoming aware of and interpreting sensory information, integrating it with prior knowledge and contextual factors to form a mental model of the driving environment, ultimately enabling the recognition of imminent dangers. Due to its complexity, some researchers have argued that the term "hazard perception" does not reflect the full scope of the process, and have suggested alternative terms, such as "hazard avoidance" (Pradhan & Crundall, 2017).

The process of hazard perception has been associated with the theoretical framework of Situation Awareness (SA) as proposed by Endsley (1995), which aligns well with the concept of developing and continuously updating a mental model of the current environment (e.g., Jeannot et al., 2003; Walker et al., 2009). The theory divides SA into three levels that explain how this mental model is formed: Level 1 SA (perception) involves the recognition of the environment and the information it contains, Level 2 SA (comprehension) pertains to the interpretation of the information gathered at Level 1, and Level 3 SA (projection) involves predicting future events based on this information (Endsley, 1995). It has been argued that SA is essential for safe driving, as strong SA is closely related to the ability to prioritise relevant stimuli on the road and identify hazardous scenarios (Endsley, 2021a). While SA has undoubtedly contributed to hazard perception research, it remains limited in its ability to explain how drivers perceive elements of a scene and select the appropriate response based on SA (Durso & Gronlund, 1999). Despite these limitations, there is a general consensus that high levels of SA are associated with strong hazard perception performance, though this association has primarily been supported by practical observations (for a review see Horswill & McKenna, 2004).

While the process of hazard perception is complex, and the underlying mechanisms remain not fully understood, it is nonetheless possible to measure this ability. The ability to perceive hazards is typically assessed via the hazard perception test and its variants. The test includes short video clips filmed from the driver’s perspective, depicting hazardous road scenarios. Participants are required to press a button as fast as possible when they see a hazard, with quicker responses indicating better hazard perception skills (Horwill et al., 2015). The most popular version of this test, which measures reaction time to hazards, has been a part of the official UK driving test since 2002. Since its introduction, significant reductions in non-low speed collisions were observed in the UK, demonstrating its effectiveness in differentiating between safe and less safe drivers (Wells et al., 2008).

Given the demonstrated effectiveness of the hazard perception test in the UK, the European Transport Safety Council (ETSC, 2016) proposed that other countries facing more severe road safety challenges might benefit from incorporating this test into their official driving assessments. However, the evidence regarding the effectiveness of the test in differentiating between safe and less safe drivers in countries with more demanding driving environments has been inconsistent. While some studies have found that safe drivers generally perform

better than less safe drivers (e.g., Horswill & McKenna; Wallis & Horswill, 2007), others have failed to observe this effect (e.g., Lim et al., 2013; Sagberg & Bjørnskau, 2006; Yeung & Wong, 2015). A notable distinction between these studies is the country in which they were conducted.

One specific study that did not replicate the basic experiential effect was conducted by Lim et al. (2013). This study evaluated the hazard perception ability of Malaysian and UK drivers using video clips from both countries. The findings indicated that experienced drivers were not more accurate in detecting hazards than novice drivers. However, differences were observed between the two nationalities, with UK drivers being faster in spotting hazards than Malaysian drivers. The study also found that familiarity with both the driving environment and type of hazard significantly improved drivers' ability to identify hazards. Lim et al. concluded that the lack of differences in performance between experienced and novice drivers might suggest that Malaysian drivers require a higher threshold of danger to identify a situation as hazardous, potentially reflecting the more demanding road environment in Malaysia. A year later, Lim et al. (2014) conducted a follow-up study with UK and Malaysian drivers, this time using a slightly modified version of the hazard perception test known as the *hazard prediction test*. In this study, they did observe differences between experienced and novice drivers in their ability to *predict* hazards.

Hazard prediction in driving

Hazard prediction, which corresponds to the third level of the Situation Awareness model—projection into the future—refers to the driver's ability to anticipate upcoming events in the driving scene before they occur (Endsley, 1995). The evidence suggests that drivers with a well-developed situation awareness of the driving scene are better equipped to prioritise relevant stimuli and anticipate future hazardous events (Crundall, 2016; Endsley, 2021a). This mental model of the driving situation, developed through previous experience (top-down processes), assists experienced drivers in focusing on critical areas of the visual scene and identifying precursors to hazards, thereby enabling them to detect potential hazards before they fully materialise. The process involves drivers continuously monitoring the most likely sources of danger and predicting the likelihood of a hazard based on the evidence provided by its precursors. Consequently, if a precursor evolves into a hazard, the experienced driver is likely to detect it first. In contrast, novice drivers may not have fully developed their mental model of the driving scenario for identifying potential hazards and may struggle to understand the significance of certain precursors (e.g. Pradhan & Crundall, 2017).

The ability to predict hazards is assessed in a manner similar to the ability to perceive hazards, with the key difference being that the hazardous video scenarios stop immediately before the hazard unfolds (e.g. Ventsislavova & Crundall, 2018). Participants are then asked to predict what will happen next on the driving scene. Each clip, prior to the occlusion, contains a precursor to the hazard that aids drivers in predicting how the driving situation will develop. This approach is based on the Situation Awareness Global Assessment Technique (SAGAT), the most successful measure of Situation Awareness (Endsley, 1995).

Lim et al. (2014) were not the first to employ this variant of the test. The hazard prediction test was initially developed by Jackson et al. (2009), although the underlying methodology can be traced back further to McKenna and Crick (1997). In their study employing the

prediction paradigm, Lim et al. (2014) were more successful in differentiating between experienced and novice drivers. However, this distinction was only evident with the UK video clips. In addition, the disparity between nationality persisted with Malaysian drivers predicting fewer hazards compared to their UK counterparts. As a result, it was questioned whether Malaysian drivers are indeed less accurate than UK drivers in perceiving and predicting hazards.

Cross-cultural comparisons have shown that UK drivers exhibit a narrower search pattern when navigating UK roads, while Malaysian drivers maintain a wider search pattern (Miller et al., 2021). This suggests that exposure to the Malaysian driving environment may have led to Malaysian drivers naturally adopting a broader search strategy, even when such a broad search is not necessary on less complex roads. Consequently, their attention, judgments about potential dangers, and decision-making processes are likely influenced by top-down processes stemming from their prior experiences in their driving environment. Therefore, it is highly plausible that the driving environment can have an impact on perceptual processes involved in driving, such as hazard perception. In addition, research has shown that the driving environment could also influence post-perceptual processes, with drivers from Western countries showing a higher optimistic bias in their risk appraisal compared to those in low-income countries (Bränström et al., 2006), where exposure to greater collision risk is more common (Lund & Rundmo, 2009). For example, Wang et al. (2019) assessed cultural differences in criterion bias by comparing the hazard perception performance of German and Chinese drivers. Their results revealed that Chinese drivers reacted more slowly to hazards and time-to-collision scenarios than their German counterparts.

Cross-cultural effects on drivers' hazard perception and prediction

To explore potential cultural differences in the ability to predict and perceive road hazards, Ventsislavova et al. (2019) conducted a cross-cultural comparison involving participants from the UK, Spain, and China. The aim was to determine whether there were differences among the three nationalities in their ability to predict and perceive hazards, and to identify which version of the tests was more sensitive to cultural versus experiential differences. To this end, bespoke hazard perception and prediction tests were developed featuring footage filmed in China, Spain, and the UK (see, Figure1). Both tests contained identical clips, with the key difference being that the prediction clips were occluded immediately before the hazardous scenarios unfolded, requiring participants to predict what would happen next on the driving scene. In contrast, the hazard perception test displayed the complete hazardous scenario, and participants were instructed to click the mouse as soon as they detected a hazard. Using identical clips for both tests was crucial to eliminate potential biases related to differences in the clips themselves. All clips were specifically filmed and edited for this study, rather than using previously captured footage. Each participant viewed three sets of clips: one set filmed in the UK, one in Spain, and one in China.

Figure 1. *Three screen shots taken from hazard perception/prediction clips filmed in China (top panel), Spain (middle panel) and the UK (bottom panel)*

The first experiment compared participants' performance using the hazard *perception* methodology, with 50 Chinese participants, 51 Spanish participants, and 52 UK participants (46% experienced drivers and 54% inexperienced drivers). The second experiment involved a new cohort of participants from the same three countries (50 Chinese, 52 Spanish, and 51 UK drivers; 50% experienced drivers and 50% inexperienced drivers) and employed the hazard *prediction* paradigm using identical clips. All hazards represented the driving environments of each country and were identified prior to the study. The between-group factors were participants' driving experience (experienced vs. inexperienced) and their nationality (Chinese vs. Spanish vs. UK). The within-group factor was the origin of the clips (China vs. Spain vs. UK). The dependent variables included the accuracy of hazard identification, response times, and correct hazard predictions. Participants were also asked to rate the level of hazardousness for each clip using a Likert scale ranging from 1 to 7, with 1 indicating "not hazardous at all" and 7 representing "extremely hazardous."

The results of the first experiment revealed that the hazard perception test did not discriminate between experienced and novice drivers across any of the three nationalities, including the UK. However, the test did show sensitivity to participants' nationality, revealing that Chinese participants were the slowest to identify hazards, made fewer clicks overall, and rated all clips as less hazardous compared to their Spanish and UK counterparts. In

comparison, UK drivers were the fastest and most accurate, although no differences based on their driving experience were observed.

In contrast, the results of the second experiment demonstrated that the hazard prediction test effectively distinguished between experienced and novice drivers, with experienced drivers outperforming their novice counterparts across all three nationalities. However, no differences were observed between the three nationalities, indicating that all groups performed equally well. The only similarity with the results from the first experiment was that Chinese drivers consistently provided the lowest hazard ratings across all clips.

Please, refer to Figure 2 for a visual representation of the results.

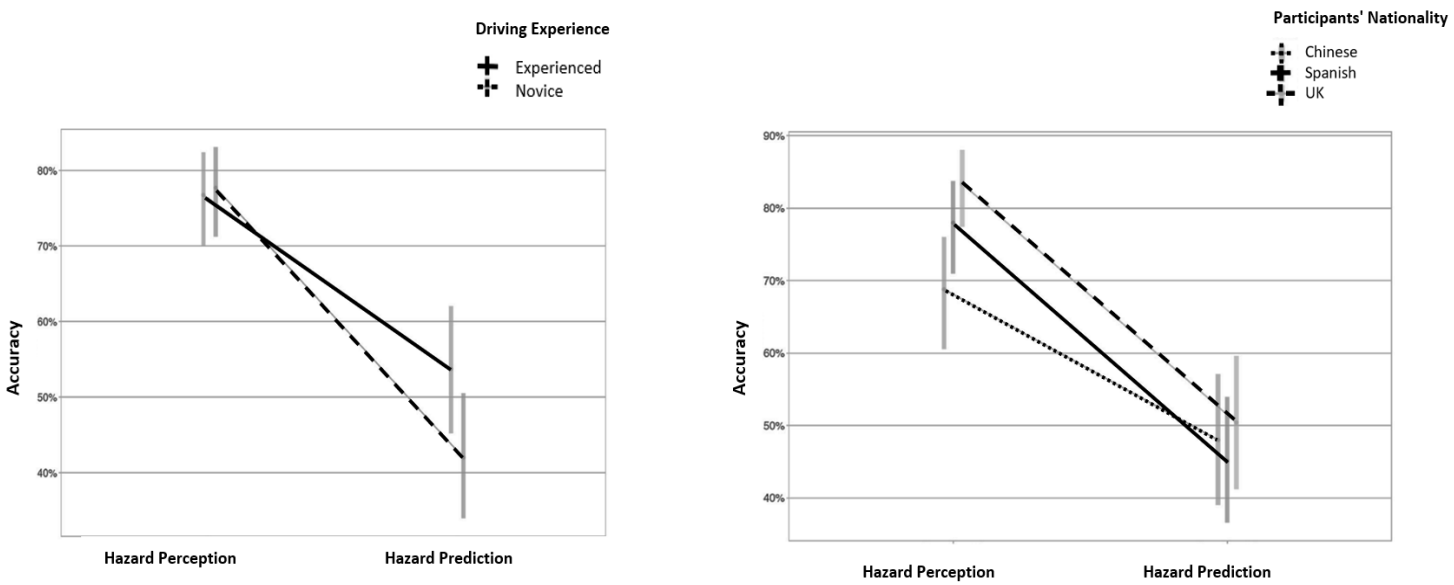

Figure 2. *Percentage of hazard perception and hazard prediction accuracy across nationality and driving experience (with standard error bars)*

The study conducted by Ventsislavova et al. (2019) indicated that the observed differences in hazard perception abilities between the Chinese, Spanish, and UK participants are likely attributable to differences in criterion bias rather than inherent ability. This became evident when cultural differences vanished under the prediction paradigm, where participants were asked to anticipate hazards independently of the perceived danger they might pose. When participants were required to demonstrate their awareness of the driving situations without evaluating the potential danger, all three nationalities performed equally. This indicates that

differences between drivers from different countries are more pronounced in post-perceptual processes—how they assess the danger of a driving scenario—rather than in their ability to understand the situation and prioritise relevant stimuli.

Ventsislavova et al., (2019) concluded that the hazard perception methodology is more sensitive to cultural differences than the prediction methodology. The hazard perception process includes the sub-process of hazard appraisal, which appears to influence the response time measured in this test. Given that Chinese drivers are regularly exposed to a higher frequency of potential hazards, their criterion bias may have shaped their responses to the test. This frequent exposure to hazards likely desensitises Chinese drivers to the seriousness of certain hazardous events, thereby raising their thresholds for reporting them during post-perceptual processes. The fact that the prediction test, which is generally considered more challenging, did not reveal cultural differences in hazard prediction abilities supports the idea of a post-perceptual bias in evaluating hazardous scenarios. These biases may confound hazard reaction time, as participants' responses might not indicate the moment they first recognize an event as a potential hazard, but rather when it has escalated to a point where they are prepared to identify it as hazardous. This issue is particularly pertinent in developing countries with higher accident rates, where drivers are more likely to be desensitized to hazards (e.g. Lim et al., 2013).

As a result, Ventsislavova et al. (2019) suggested that the hazard prediction test may be better suited for international testing. To objectively measure the ability to perceive hazards and implement a hazard perception test across different countries, it is crucial to ensure that the test is not confounded by potential criterion biases. The hazard prediction test satisfies this criteria because it isolates the predictive element of the hazard perception process, providing a measure that records accuracy, unconfounded by bias. Participants are asked to predict how the driving scenario will develop independently of whether they find it hazardous or not. Hazard prediction as a sub-process lies at the heart of all hazard avoidance and is likely to be the key skill that traditional hazard perception tests are imperfectly measuring (e.g. Pradhan & Crundall, 2017).

To effectively perceive hazards in a timely manner, safe drivers must be capable of anticipating them, providing sufficient time to make informed and safe decisions rather than merely reacting to them. Hazard prediction takes precedence over hazard perception, as failing to focus attention on the right place at the right time can result in missing critical cues needed to prevent collisions. This process involves directing attention to relevant locations at the appropriate moments, guided by top-down processes that help predict hazards before they materialise (Gazzaley & Nobre, 2012). Since situation awareness is a precursor to decision-making in driving (Endsley, 2021a), the hazard prediction test does not capture post-perceptual processes involved in hazard avoidance, such as hazard appraisal and decision-making (and it is not designed to). Its purpose is to capture drivers' awareness of the driving environment and their ability to predict what would happen next on the driving scene, without confounding hazard prediction, hazard perception, and hazard appraisal processes.

Subsequent studies in different countries have further demonstrated the effectiveness of the hazard prediction test in distinguishing between safe and less safe drivers. Ventsislavova et al. (2022) assessed the hazard prediction skills of Israeli drivers who had never previously been exposed to any variants of the hazard perception test. Participants viewed both hazardous and

non-hazardous video clips filmed within the Israeli driving context and were asked to predict how the scenarios would develop. The test once again successfully distinguished between experienced and novice drivers. Additionally, a signal detection analysis revealed that while sensitivity to hazards was a significant predictor of hazard prediction, hazard criterion was not. This finding reinforced that the threshold bias did not significantly impact accuracy in the hazard prediction test, highlighting its robustness in assessing hazard prediction skills in different cultural contexts.

An identical hazard prediction methodology was also applied in Lithuania to ensure consistency across studies (Endriulaitienė et al., 2022). The hazard prediction test was adapted to the Lithuanian driving context and included hazardous scenarios filmed in Lithuania. Consistent with previous findings, the test effectively distinguished between experienced and novice drivers. Additionally, a negative correlation was observed between hazard prediction scores and crash involvement within the novice driver group. This study further confirmed that the prediction paradigm is not only resistant to cultural differences but also effectively correlates prediction accuracy with crash involvement.

Conclusion

The research conducted by Ventsislavova et al. (2016; 2018; 2019; 2022) has provided substantial evidence highlighting the importance of accounting for cultural differences in the assessment of hazard perception ability and the effectiveness of the hazard prediction methodology in distinguishing between safe and less-safe drivers across various cultural contexts. While the hazard perception test is widely recognised for improving road safety, most of the evidence supporting its effectiveness comes from the UK and Australia, both of which have notably lower crash rates compared to other countries. As many other countries are considering the possibility of integrating a hazard perception component into their driving assessments, Ventsislavova et al. has provided compelling evidence that incorporating a hazard prediction test alongside traditional hazard perception assessments could be very effective in differentiating between safe and less safe drivers. Countries such as Spain have already considered and assessed the possibility of incorporating a hazard prediction component into their driving licencing system, an initiative later followed by the Netherlands and the Czech Republic. Though still less common than hazard perception tests, early trials and research have shown promising outcomes regarding its potential to reduce collisions. While official collision statistics are not yet available due to the ongoing nature of the trials, recent studies have shown that drivers who had not been involved in a crash in the past two years demonstrated superior hazard prediction skills compared to those who had reported being involved in collisions (Horswill et al., 2020). This suggests that the ability of the prediction test to distinguish between safer and less safe drivers across different countries holds significant promise for reducing collisions on a global scale.

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