Hazard Perception in Young Drivers: The Role of Hazard Types*

Sun Long, Chang Ruosong**
(School of Psychology, Liaoning Normal University, Dalian, 116029)

Abstract Although experienced drivers outperformed novice drivers in several hazard perception studies, little was known about the influencing mechanism of hazard types on young drivers' hazard perception performance. In this study, 27 young novice drivers and 22 young experienced drivers were asked to complete a hazard perception task, where they were asked to respond quickly when a potential hazard was detected. The hazard in the clips was either an overt hazard with continuous visibility or a covert hazard with interrupted visibility during their materialization. The results revealed that young experienced drivers reacted to covert hazards and overt hazards faster than young novice drivers. The experience-related differences in response latency to overt hazards was due to faster processing after the initial fixation, while experienced-related differences in response latency to covert hazards was due to faster detection rather than differences in processing time. Additionally, hazard types influenced young drivers' eye movements with overt hazards were significantly fixated more time than covert hazards. These findings provided some implications for the hazard perception test and training for young drivers.

Keywords hazard perception, young driver, driving experience, hazard type, eye movements

1 Introduction

Young novice drivers are found to have the highest crash risk among all drivers. One of the underlying reasons associated with young novice drivers' accident involvement is their poor hazard perception (HP) ability. For example, 44% of young novice drivers' crashes can be attributed to the fact that they failed to detect hazards in time (McKnight & McKnight, 2003). Boufous, Ivers, Senserrick, and Stevenson (2011) found that young drivers who failed the HP test at least twice had an increased risk of being involved in a traffic crash compared to those who passed the test on their first attempt. More recently, a prospective study found that young novice drivers' scores on a video-based HP test could predict their crash involvement in the year following the test (Horswill, Hill, & Wetton, 2015).

Hazard perception is the process of detecting, evaluating and responding to dangerous events on the road that have a high likelihood of leading to a collision (Crundall et al., 2012). Based on the reaction time paradigm, many studies found that compared to experienced drivers, young novice drivers have not driven long enough to improve their situation awareness or form a flexible visual scanning pattern, thus leading to slower detection and reaction to potential hazards (Borowsky, Shinar, & Oron-Gilad, 2010; Sun & Chang, 2016; Underwood, Ngai, & Underwood, 2013; Wetton, Hill, & Horswill, 2011).

Although young novice drivers can benefit from HP trainings, some studies failed to find differences in HP performance between young novice drivers and young experienced drivers (Sagberg & Bjørnskau, 2006; Yeung & Wong, 2015). One explanation for this was that hazard type may play an important role in young drivers' hazard perception (Crundall et al., 2012; Sagberg & Bjørnskau, 2006). In other words, the lack of awareness of the influence of hazard types may provide some explanation for inconsistencies in previous hazard perception studies.

Using a video-based hazard perception task, Sagberg and Bjørnskau (2006) did not find differences in HP reaction time among three groups of novice drivers

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** Corresponding author: Chang Ruosong. E-mail: changruosong@126.com
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(driving experience was 1, 5 and 9 months) and one group of experienced drivers (driving experience was more than 10 years). However, a post-hoc analysis revealed that experience-related differences in reaction time were only found in 6 out of 31 video clips used in the task. The results suggested that there may be particular hazards for which the gap between novice and experienced drivers is larger than others. To date, only a few studies have provided evidence regarding the effect of hazard type on drivers' HP performance (Crundall et al., 2012; Sun & Chang, 2016; Underwood et al., 2013). In these studies, some hazards differentiated drivers with varying driving experience more effectively than others, and drivers' visual strategies during these hazards were also associated with their HP reaction time (Crundall et al., 2012; Sun & Chang, 2016).

According to our knowledge, little is known about the influencing mechanism of hazard types on young drivers' HP performance. Thus, this study examined the effects of hazard types and driving experience on young drivers' HP performance using a video-based HP task and aimed to provide a theoretical framework for why young novice drivers have poorer ability to address particular hazards. It was predicted that young novice drivers would detect and react to hazards slower due to interrupted visibility or/and longer processing time after the initial fixation.

2 Methods

2.1 Participants

Forty-nine young drivers (12 males) agreed to participate in this study. Participants' ages ranged from18 to 26 years (*Mean* = 22.99 years, *SD* = 2.10 years), and their driving experience was less than two years (*M* = 1.07 years, *SD*= .63 years). Participants were divided into two groups according to their driving experience and total driving mileage since they obtained a valid driver's license. Our study included 27 young novice (YN) drivers and 22 young experienced (YE) drivers. Table 1 shows the detailed information of the two driver groups.

Table 1 Demographic characteristic and test scores

Demographic factors	Driver group		*p*-value
	YN (*n*=27) *Mean (SD)*	YE (*n*=22) *Mean(SD)*	
Gender ratio (M/F)	5/22	7/15	>.05
Age (yr)	22.89 (2.08)	23.59 (2.28)	>.05
Years of licensure (yr)	.62 (.43)	1.63 (.31)	<.01
Total driving mileage (km)	451 (458)	2223 (2373)	<.01
Years of education (yr)	14.41 (2.19)	14.18 (2.04)	>.05

Participants were recruited from Liaoning Normal University and the nearby community. All participants had normal or corrected-to-normal vision.

2.2 Materials

A hazard perception task, with 24 filmed video clips shooting from drivers' perspective, was used in the current study. The clips were filmed around the city of Dalian and surrounding areas along different roads in fine weather. The clips showed traffic situations where a potential hazard was developing slowly as the camera car was approaching. The hood of the camera car can be seen at the bottom of the screen. The task was developed by the first author and it showed good validity in a previous study (Sun & Chang, 2016).

Hazards were split into overt hazards and covert hazards according to the visibility of their materialization in the clips (Sun & Chang, 2016; Vlakveld, 2014). Overt hazards in the clips had continuous visibility. These hazards were totally visible in the process of materialization in front of the camera car (e.g., a child walked into the driving lane from the other side of the road in front the camera car). Covert hazards in the clips had interrupted visibility. These hazards were partially or totally blocked in the process of materialization, and they became visible at the very moment when a manoeuvre was needed to avoid a collision (e.g., the camera car overtakes a bus when a pedestrian was crossing the road in front of the bus from the same side). In this study, twelve video clips contained overt hazards, and 12 video

Table 2 Descriptions of the hazards in the clips

Hazard description		Overt hazard	Covert hazard
Car in the same direction	Signalling to turn right/left	1	1
	Merging	0	1
	Parking/slowing down	1	1
Car in the opposite direction	Crossing the path from the left	2	2
	Crossing the path from the right	1	1
	Head-on	1	0
Others	Pedestrians	4	4
	Cyclists	2	2

clips contained covert hazards. Table 2 shows the detailed information for hazards in the clips.

The road types were counter-balanced under each hazard type to minimize the effect of local familiarity. Although the lengths of the video clips ranged from 10 to 20 seconds, the mean length of each hazard type were not significant, $t = .96$, $p > .05$. The onset time and location of the hazards also differed from one clip to another. The complexity of the driving context in each clip was also well controlled. Clips with complex driving contexts were eliminated during the development of the HP task.

All the hazards contained a response window, which was defined by 3 experienced drivers (2 male and 1 female, mean age = 36.1, mean driving experience = 15.9 years) with a high degree of agreement (inter-rater reliability for the hazards ranged from .73 to .92). The window began at the earliest point in time when the hazard was detectable and ended at the point when a braking or avoidance response by the driver would no longer prevent a collision (Lim, Sheppard, & Crundall, 2013; Sagberg & Bjørnskau, 2006). Thus, mouse clicks that occurred outside the window were treated as invalid data.

2.3 Design

A 2 × 2 mixed design was employed in the current study. The between-groups factor was driving experience (young novice drivers vs. young experienced drivers). The within-groups factor was hazard type (overt hazards vs. covert hazards).

The dependent variables were response rate, response latency (RL) and mean fixation duration (MFD). To reveal the experience-related differences in response latency, RL was further divided into time to first fixation (TFF) and reaction time (RT) according to the first fixation on hazards (Mackenzie & Harris, 2015; Sun & Chang, 2016; Yeung & Wong, 2015). Response rate was calculated by using the number of participants' correct responses divided by the total number of hazards contained in the HP task. RL was defined as the time from the onset of the hazard to the moment when a manoeuvre was needed to avoid a collision. TFF was time from the onset of the hazard to the moment when participants first fixated on the hazard, while RT was the time from when participants first fixated on the hazard to the moment when they reacted to it. MFD was the mean amount of time in which participants fixated on the hazard.

2.4 Procedure

At first, participants sat in front of a 17-inch monitor, with a viewing distance of 65 cm from the screen. Their eye movements were recorded by a Tobbi T120 eye tracker (120 Hz). After calibrating participants' gaze points, they then viewed 3 practice clips. During the experiment, participants were asked to click the left mouse button quickly when a potential hazard was detected and they needed to slow down or change their driving course to react to it. Finally, after another calibration, 24 video clips were randomly assigned to each participant on the monitor at a resolution of 1280 × 720. The experiment lasted approximately 15 minutes.

3 Results

3.1 Response Rate

A 2 × 2 analysis of variance (ANOVA) compared the mean response rate of the two groups. The main effect of driving experience was significant (F (1, 47) = 5.05, $p < .05$, $\eta^2 = .097$). Young experienced drivers' response rates (M = 76.9%, SD = 18%) were higher than those of young novice drivers (M = 63.9%, SD = 21.7%). The main effect of hazard type was significant (F (1, 47) = 4.29, p < .05, η^2 = .084); drivers' response rates for overt hazards (M = 71.9%, SD = 22.7%) were higher than those for covert hazards (M = 67.5%, SD = 21.8%). The interaction between driving experience and hazard type was not significant (F (1, 47) = .01, p = .96, η^2 = .00).

3.2 Response Latency

A 2 × 2 analysis of variance (ANOVA) compared the mean RL of the two groups. The main effect of driving experience was significant (F(1, 47) = 7.92, p < .01, η^2= .144). Young experienced drivers' RL (M = 2.90, SD = .49) was faster than that of young novice drivers (M = 3.22, SD = .31). The main effect of hazard type was significant (F(1, 47) = 186.20, p < .01, η^2= .798); drivers' RL for overt hazards (M = 2.75, SD = .46) was faster than that for covert hazards (M = 3.40, SD = .45). The interaction between the two factors was not significant (F(1, 47) = 1.07, p = .30, η^2 = .022).

3.3 Time to First Fixation

A 2 × 2 analysis of variance (ANOVA) compared the mean TFF of the two groups. The main effect of hazard type was significant (F(1, 47) = 48.89, p < .01, η^2 = .510); drivers detected overt hazards (M = .21, SD = .17) faster than covert hazards (M = .44, SD = .29). The main effect of driving experience was not significant (F(1, 47) = 2.19, p = .15, η^2 = .045).

The interaction between the two factors was marginally significant (F(1, 47) = 3.88, p = .055, η^2= .076). A simple effect test showed that young novice drivers' TFF for covert hazards was marginally slower than that of young experienced drivers (F(1, 47) = 3.47, p = .069, η^2 = .069). The two groups' TFF for overt hazards was not significant (F(1, 47) = .23, p = .63, η^2= .005).

3.4 Reaction Time

A 2 × 2 analysis of variance (ANOVA) compared the mean RT of the two groups. The main effect of driving experience was marginally significant (F(1, 47) = 3.65, p = .062, η^2= .072). Young experienced drivers' RT (M = 2.62, SD = .52) was faster than that of young novice drivers (M = 2.86, SD = .34). The main effect of hazard type was significant (F(1, 47) = 63.91, p < .01, η^2 = .576); drivers' RT for overt hazards (M = 2.54, SD = .48) was faster than that for covert hazards (M = 2.96, SD = .49).

The interaction between the two factors was significant (F(1, 47) = 4.45, p < .05, η^2 = .087). A simple effect test showed that young novice drivers' RT for overt hazards was slower than that for young experienced drivers (F(1, 47) = 7.24, p < .01, η^2 = .133). The two groups' RT for covert hazards was not significant (F(1, 47) = .78, p = .38, η^2 = .016).

3.5 Mean Fixation Duration

A 2 × 2 analysis of variance (ANOVA) compared the mean MFD of the two groups. The main effect of hazard type was significant (F(1, 47) = 8.45, p < .01, η^2= .152); drivers fixated on overt hazards (M= .41, SD = .19) longer than covert hazards (M = .38, SD = .18). The main effect of driving experience was not significant (F(1, 47) = 1.41, p = .24, η^2= .029).

The interaction between driving experience and hazard type was significant (F(1, 47) = 4.65, p < .05, η^2= .090). However, a simple effect test showed that the two groups' MFD for covert hazards (F(1, 47) = .88, p= .35, η^2 = .018) and overt hazards (F(1, 47) = 2.62, p = .11, η^2 = .049) were not significant.

4 Discussions

By manipulating the visibility of the hazards in the video clips, the present study examined the effects of hazard types on young drivers' hazard perception performance.

First, the two driver groups were not different in their male-to-female ratio, age and years of education. Therefore, the confounding effects of driving experience and age on hazard perception performance were not expected. Additionally, the role of driving experience in young drivers' hazard perception can be better examined.

Second, both driving experience and hazard type influenced young drivers' response rates, with lower numbers of correct responses from young novice drivers than young experienced drivers and more responses to overt hazards than covert hazards. This result may be partially due to young experienced drivers' well-developed situation awareness. Situation awareness develops as drivers gain more driving experience, and it guides their visual attention to critical areas where potential hazards may occur, thus facilitating their hazard detection and reaction (Borowsky et al., 2010; Underwood et al., 2013). Due to the interrupted visibility of covert hazards, it was easy to understand why young novice drivers responded to fewer of them. Another explanation for this difference was that young novice drivers may overestimate their driving ability, which in turn leads to a high risk threshold for identifying a hazard on the road (Deery, 1999; Sun & Chang, 2016).

Furthermore, young novice drivers, overall, reacted to overt and covert hazards slower than young experienced drivers. Specifically, the time that it took for the two groups to first fixate on overt hazards was similar. However, the time that young experienced drivers spent on processing overt hazards was shorter than that of young novice drivers. This result indicated that young experienced drivers did not differ from young novice drivers in terms of where to look when confronted with a potential overt hazard, but they seemed to be faster at identifying a fixated object as hazardous (Huestegge, Skottke, Anders, Müsseler, & Debus, 2010; Mackenzie & Harris, 2015). Although differences in their processing time for covert hazards were not significant, the time that it took for young novice drivers to first fixate on covert hazards was longer than that of young experienced drivers. These findings suggested that experience-related advantage in hazard perception varied under different hazard types.

Finally, in line with previous studies (Huestegge et al., 2010; Lim et al., 2013; Yeung & Wong, 2015), we found driving experience was not a good predictor in terms of young drivers' mean fixation duration on hazards. However, the differences of the two groups' reaction time indicated that when a similar amount of attention was given to a specific hazard, young novice drivers were either unable to extract sufficient information from the stimuli, or they could not translate visual information into actions as faster as young experienced drivers did (Crundall et al., 2012).

With regard to hazard type, young drivers spent more time fixating overt hazards than covert hazards, suggesting it might serve as a fundamental factor when it comes to hazard perception training and assessment for young drivers. For example, given covert hazards were more dangerous than overt hazards in real driving, trainings that focused on guiding young drivers where to look and anticipating what might happen next may be more effective (Horswill, 2016). Additionally, using different types of hazards in an HP test may improve its discriminate validity, especially when the test is used as part of the licensing process for new drivers.

One limitation in the present study was that the number of male and female drivers was not equal. However, some studies have revealed that there were no differences in male and female drivers' hazard perception ability (Huestegge et al., 2010; Wetton et al., 2011). Although the effect of local familiarity was minimized by counter-balancing the road types for the two hazard types, some drivers may still have had an advantage/disadvantage in detecting and reacting to hazards due to their familiarity with some driving contexts. Thus, this should be properly addressed in future studies.

In summary, the present study revealed that hazard type played an important role in discriminating between young driver groups. We found that compared to their peers, young novice drivers' poor HP ability was due to their longer time spent processing overt hazards and their delayed detection of covert hazards.

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驾驶经验和危险类型对年轻驾驶员危险知觉的影响

孙 龙 常若松

(辽宁师范大学心理学院，大连，116029)

摘 要 结合反应时和眼动测量方法，采用驾驶经验分组 2（年轻新手驾驶员，年轻有经验驾驶员）× 危险类型 2（明显危险，隐藏危险）的混合实验设计，探索年轻驾驶员危险知觉的经验优势是否随着危险类型的不同而变化。使用一个基于真实交通情境视频的驾驶员危险知觉任务，对 27 名年轻新手驾驶员和 22 名年轻有经验驾驶员进行测试，并使用 Tobbi T120 记录眼动数据。结果发现，总体上，年轻新手驾驶员对潜在道路危险的反应次数比年轻有经验驾驶员更少，反应时间也更慢。两组驾驶员反应时间的差异，随着危险类型的不同而来源于不同的加工阶段。具体来说：一方面，年轻新手驾驶员对明显危险的反应时间慢，是因为他们对该类危险的评估时间长。另一方面，年轻新手驾驶员对隐藏危险的反应时间慢，是因为他们对该类危险的识别时间长。两组驾驶员对危险的平均注视时间受测试中危险类型的影响但不受驾驶经验的影响。这些研究结果表明，在对年轻新手驾驶员进行危险知觉训练或测试时，应重视危险类型对他们危险知觉的影响。.

关键词 危险知觉 年轻驾驶员 驾驶经验 危险类型 眼动