Exploring the Hazard Perception Ability of Cyclists on Natural Roads

Yanru Zhao[1, *]

[1]School of Automobile and Traffic Engineering, Hefei University of Technology, Hefei, 230009, Anhui, PR China

*Email: 2020171034@mail.hfut.edu.cn

Abstract

As a vulnerable group involved in road traffic, cyclists are more likely to be involved in traffic accidents and have a greater probability of injury and death than motor vehicles. Therefore, the purpose of this study was to explore the risk perception ability of cyclists when riding on natural roads. By recruiting subjects and setting up a natural road riding experiment, the visual characteristics of the subjects were obtained based on an eye tracker. Evaluate visual indicators to reflect the hazard perception ability of subjects in different hazard scenarios. The results showed that the visual characteristics of subjects in different scenarios were different. Displaying better visual search patterns for common road hazards can lead to faster detection of hazards and longer fixation duration for hazards, resulting in higher risk perception abilities.

Keywords

Cyclists; Hazard perception; Adults; On-road test.

1. INTRODUCTION

In recent years, due to the advocacy of green travel, people have gradually adopted bicycles as a means of transportation [1]. Cycling can not only exercise but also help reduce traffic pollution. However, relevant data show that the increase in bicycle use has led to an increasing number of bicycle related traffic accidents [2]. In Europe, bicycle related traffic accidents account for 7.8% of all road accidents [3]. According to a survey conducted by the National Bureau of Statistics of China, the number of injuries and deaths caused by bicycle traffic accidents has shown an overall upward trend in the past 10 years [4]. According to research reports from the UK, the risk of bicycle accidents was twice that of motor vehicle drivers, and the probability of death and injury was 4.5 times that of motor vehicle drivers [5]. This may be due to the unstable structure of the bicycle itself. In the event of a traffic accident, cyclists who are completely exposed without protective measures can easily be injured or even killed. On the other hand, cyclists lack the ability to perceive hazards on the road. Hazard perception is the ability to perceive, predict, and respond to upcoming hazardous events on the road environment [6]. Better hazard perception helps cyclists detect and predict hazards earlier, allowing cyclists more time to avoid collisions [7].

Previous tests of hazard perception have mostly been applied to driver research [8-10] to explore whether drivers' predictions of hazards on the road are related to crashes. In the field of bicycle research, relevant scholars have also explored. Most hazard perception tests for bicycles are conducted through the visual characteristics of cyclists, as vision is the first source of perception of surrounding traffic information for road participants [11]. Visual search while riding on the road often reflects the inherent mechanism by which cyclists process traffic

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information, reflecting their visual characteristics of actively selecting and focusing on the content they care about. This feature can effectively improve the ability to identify hazards in traffic scenarios such as hazard screening and target retrieval [12]. In the study by E. Lehtonen [13], after randomly playing a previously recorded riding video, the screen was shielded and a rectangle appeared, requiring children to select all rectangles containing dangerous targets. In another study, they used slide potentiometers to demonstrate how carefully they believed the situation needed to avoid a collision in a riding scene to assess children's overall situational awareness [14]. Some scholars have also used eye trackers to study the visual characteristics of cyclists on the road. W.B. Hu and others measured the eye movement data of cyclists and found that the main way to obtain traffic information is to scan when cycling on urban roads [15]. The scanning range and scanning speed of cyclists are much higher than those of motor vehicle drivers. L. Gao [16] selected typical urban roads including T-intersections and intersections as experimental roads, and selected indicators such as gaze frequency, scanning frequency, scanning angle, and horizontal visual angle distribution as the basic characterization parameters of the visual search mode of cyclists to further explore the eye movement characteristics and laws of cyclists at urban level crossings. P. Vansteinkiste and others [17] studied the visual attention regions of interest of children when riding on real roads, and found that children tend to pay more attention to unrelated regions when riding bicycles, and exhibit different visual motor strategies than adults when riding on low-quality roads. L. Zeuwts [18] explored the visual characteristics of children and adults towards danger by allowing children to watch typical street crossing related scenes taken from the perspective of cyclists and participate in hazard detection tasks. Studies have shown that children have significantly longer reaction times to recognize hazards, lower reaction rates to certain traffic hazards, and that adults are more sensitive to potential hazards than adults.

In general, previous studies have mostly conducted hazard perception tests in virtual environments. There is little research on the hazard perception ability of cyclists on actual roads, and there is no good consideration of how to better integrate cyclists into the traffic environment. Therefore, this study aims to test the risk perception ability of cyclists in actual road environments, record and analyze the visual characteristics of cyclists during riding by setting different hazard scenarios.

2. METHOD

2.1. Planning

In this study, 12 adult cyclists aged 18-30 years were recruited and required to have normal vision or correction without eye disease.

2.2. Test scenarios

The road suitable for conducting the test was selected in Hefei, Anhui Province, China. During the riding process, you will successively passed through the six hazard scenarios set in Figure 1. The total length of the test section was about 1.9 km, with good pavement conditions and low traffic flow.

Figure 1 showed the six scenarios and their hazard settings that the subjects rode through, with relevant researchers assigned to each scenario. The area where the researcher was located was marked A1. Scenario 1 was set as shown in (a), with the subject riding on the road and preparing to turn left. When the subject arrived at the designated location, the researcher rode and turned left. After completing, continue cycling back to the starting point and wait for the next subject to arrive. Scenario 2 was set as shown in (b). Before the test, a car parked at a roadside location from north to south. When the subject arrived at the designated location (after the front wheel started turning left), the researcher prepared to open the driver's door in

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the car (to avoid accidents, the right hand was required to gently open the door). After finishing, closed the door and waited in the car for the next subject to arrive. Scenario 3 was set as shown in Figure (c), with the researcher waiting at the roadside. When the subject arrived at the designated location, rode in front of the subject. After arriving at the intersection, turned right and entered the waiting area (to ensure the safety of the subjects, the researcher was required to pay attention to the position of the subjects before turning right to prevent accidents). After the subject continued to ride forward, the researcher returned to the starting point and waited for the next subject to arrive. Scenario 4 was set as shown in Figure (d), with the researcher waiting at A1. When the subject arrived at the designated location of the zebra crossing, turned right, and the subject turned left into the non-motorized lane. Then pushed back to the starting point and waited for the next subject to arrive. Scenario 5 was set as shown in Figure (e), where the researcher stood and waited at the protruding bus stop (A1) on the roadside. When the subjects arrived at the designated location, they walked through the non-motorized lane from the platform. After the subject has driven away, returned to the starting point and waited for the next subject to arrive. Scenario 6 was set as shown in Figure (f), with the researcher waiting in pre-positioned position. When the subjects arrived at the designated location, they rode opposite the researchers. When the longitudinal distance was the smallest, the ride ended and returned to the starting point to wait for the next subject to arrive.

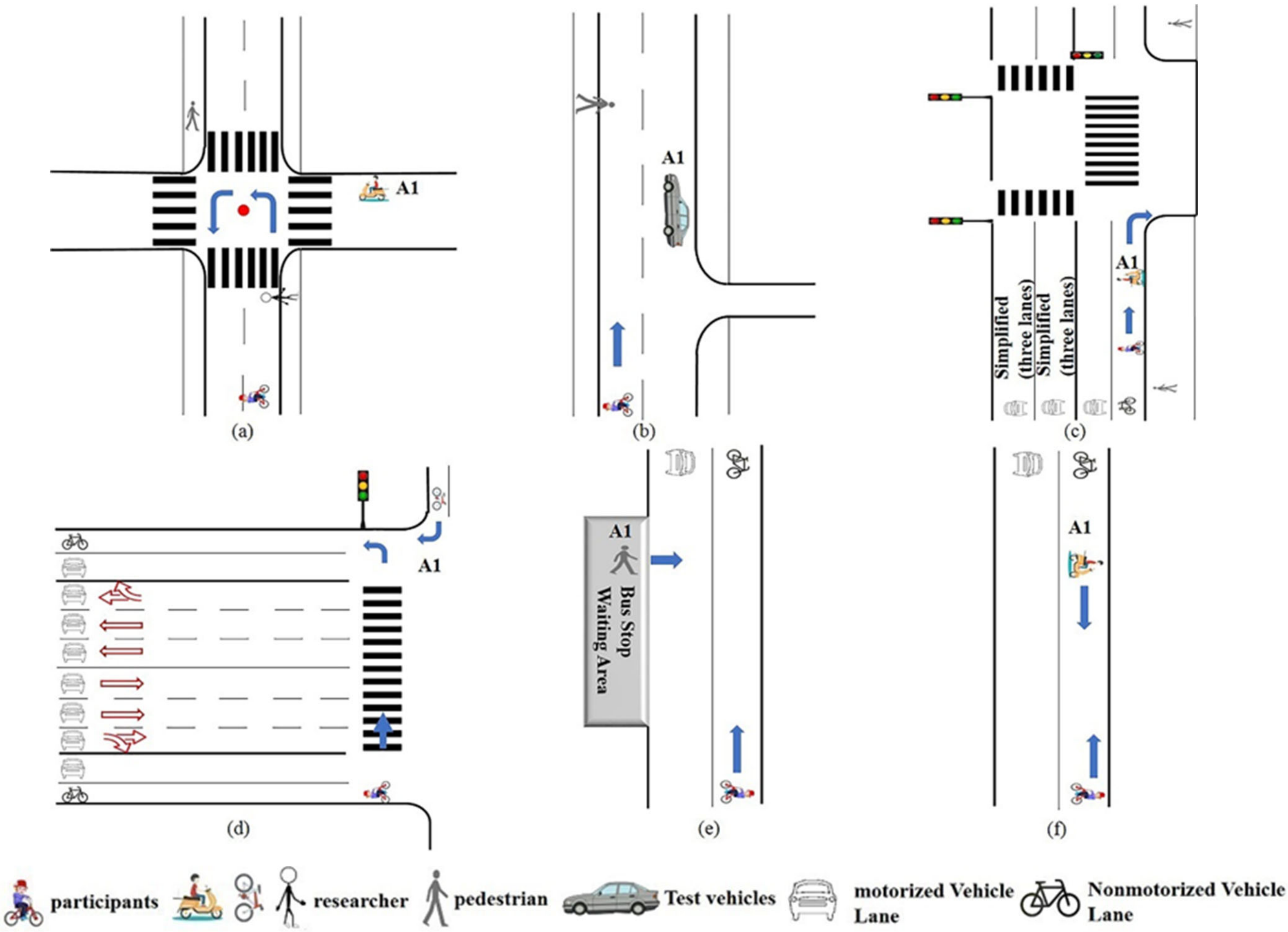

Figure 1. Schematic diagram of hazardous scenarios

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2.3. Equipment

In this test, a Tobii Pro Glasses2 eye movement meter was used. which could record the eye movements of subjects during riding, including the position and time of eye observation points, the order of eye observation, and the number of eye movements. This device has the following advantages: it can collect eye movement data within the true visual field of the subject, and due to its lightweight nature, it can collect experimental data without interfering with the natural behavior of the subject. Mobile phones were used to maintain communication between the researchers and to record the riding behavior of the subjects during the test. A cross country bicycle was used for the subjects to cycle.

2.4. Process

The test was arranged on sunny days on Saturdays and Sundays every week. Considering that the large traffic flow during the morning and evening peak hours has an impact on the test and was prone to riding safety issues, we have set the specific experimental time points at 9:00-11:00 a.m. and 2:00-4:00 p.m.

Before the test, the researcher led the subjects to familiarize themselves with the route to be tested, but did not explain any riding skills to them. Each subject wore and calibrated an eye tracker with the help of researcher. After completing the calibration, each subject began 10-minute familiarization process with the eye movement meter to eliminate possible discomfort after wearing it. Then the subjects walked through each scenario in the order shown in Figure 1. After the test, they were asked to independently complete a short demographic questionnaire that included their basic information (age, gender, riding experience, etc.). Finally, all the subjects successfully completed the test and received a reward of 80 RMB.

2.5. Measurement

This study first conducted descriptive statistical analysis of the eye movement characteristics of subjects passing through six different scenarios. Then used one-way ANOVA test to compare the differences in eye movement indicators of cyclists passing through different scenarios. The significance level was set to $P<0.05$. All statistical tests were conducted in SPSS.

3. RESULT AND DISCUSSION

The eye tracking data and videos of participants were recorded using an eye tracker, and then exported, processed, and analyzed using the software tool Tobii Pro Glasses Analyzer. Recorded A1 in Figure 1 as hazard area in each scenario, and defined the following dependent variables to measure the subjects' eye movement characteristics during test: (1) Average fixation duration - the ratio of the total fixation time to the total fixation times for the hazard area, which measures the degree of attention participants pay to the hazard area; (2) Saccade frequency - the number of times participants scan per unit time in each scenario; (3) Pupil Diameter - Select the average value of participants' left eye data under various scenarios to measure their cognitive level of the traffic environment; (4) The entry time of the first gaze hazard - measures the sensitivity of participants to the hazard area.

From Table 1, we could find that the average fixation duration of the subjects on the hazard area in scenario 2 was the shortest, and the average fixation duration on scenario 6 was the longest. The hazard set in scenario 1 was hidden. For the saccade frequency, the difference between the various scenarios was not significant, with the maximum saccade frequency in scenario 1 and the minimum saccade frequency in scenario 2. Compared to Scenario 1, the entry time of the first gaze hazard in the remaining scenarios took longer. This indicated that the subjects were more familiar with the hazard type of scenario 1 and had stronger sense of vigilance, so they could notice the hazard area more quickly. Similarly, the pupil diameter was

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the largest in scenario 1, corresponding to the entry time indicator. Subjects were more sensitive to the hazard types of scenario 1, so they payed more attention to scenario 1. The higher the cognitive load, the larger the pupil diameter.

Table 1. Descriptive analysis of eye movement indicators under different scenarios

	Indicators	1	2	3	4	5	6
Mean	Average fixation duration(s)	0.157	0.045	0.214	0.054	0.178	0.181
	Saccade frequency (times/s)	13.655	11.337	12.692	13.076	12.299	11.882
	Pupil diameter(mm)	3.180	2.869	2.563	2.949	2.750	2.591
	The entry time of the first gaze hazard(s)	0.261	1.426	2.274	2.516	2.055	1.747
standard deviation	Average fixation duration(s)	0.095	0.041	0.058	0.046	0.086	0.059
	Saccade frequency (times/s)	3.014	3.773	3.392	4.753	4.662	4.236
	Pupil diameter(mm)	0.190	0.206	0.135	0.202	0.183	0.211
	The entry time of the first gaze hazard(s)	1.246	1.001	1.074	1.162	1.039	0.678

In order to explore whether there were differences in the visual characteristics of dangerous areas in different scenarios among cyclists, this study used one-way ANOVA to conduct an overall test. As shown in Table 2. The results showed that there were significant differences in the average fixation duration among the six scenarios (F (5,66)=4.093, p=0.003). Similarly, there were significant differences in pupil diameter and the entry time of the first gaze hazard among subjects in six scenarios (pupil diameter: (F (5,66)=14.679, p=0.000); The entry time of the first gaze hazard: (F (5,54)=4.927, p=0.001)). For the index of saccade frequency, there was no significant difference (F (5,66)=5.825, p=0.753).

Table 2. one-way ANOVA for eye movement indicators under different scenarios

Indicators		df	Sum of squares	Mean square	F	P
Average fixation duration	Between group	5	0.306	0.061	4.093	0.003*
	Within group	66	0.987	0.015		
	Total	71	1.292			
Saccade frequency	Between group	5	42.804	8.561	0.529	0.753
	Within group	66	1067.908	16.180		
	Total	71	11110.712			
Pupil diameter	Between group	5	3.254	0.651	14.679	0.000*
	Within group	66	2.927	0.044		
	Total	71	6.181			
The entry time of the first gaze hazard	Between group	5	54.447	10.889	4.927	0.001*
	Within group	54	119.340	2.210		
	Total	59	173.786			

Note: *p<0.05, **p<0.01, ***p<0.001

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Since Table 2 can only indicate the significance level of visual characteristics in the above different scenarios, it was not possible to determine which two scenarios have a single significant difference. Therefore, it was necessary to further use Bonferroni post hoc testing to determine which two scenarios may have significant single pair differences under different visual characteristics.

The analysis results in Table 3 showed that for the average fixation time index, there was a significant difference in the average fixation time of subjects in the dangerous area between scenario 2 and scenario 3 (p=0.018), and there was also a significant difference between scenario 3 and scenario 4 (p=0.031), while there were no significant difference between the other scenarios. For pupil diameter index, there were significant differences between scenario 1 and scenario 2, scenario 3, scenario 5, and scenario 6. Compared to scenario 2, the pupil diameter of the subjects in scenario 3 and scenario 6 was larger, and there were significant differences between scenario 2, scenario 3, and scenario 6. Similarly, there was a significant difference in pupil diameter between scenario 3 and scenario 4, and there was a significant difference between scenario 4 and scenario 6 (P=0.002). For the entry time of the first gaze hazard, we found significant differences between scenario 1 and scenario 2, scenario 3, scenario 4, and scenario 5. Moreover, the subjects' entry time to gaze at the hazard in scenario 1 was shorter than that in the other scenarios.

Table 3. Bonferroni post-test for one-way ANOVA

Indicators	Scenario I	Scenario J	I-J	P
Average fixation duration	2	3	-0.169	0.018
	3	4	0.160	0.031
Pupil diameter	1	2	0.312	0.008
		3	0.617	0.000
		5	0.430	0.000
		6	0.589	0.000
	2	3	0.305	0.011
		6	0.278	0.029
	3	4	-0.383	0.000
	4	6	-0.356	0.002
The entry time of the first gaze hazard	1	2	2.838	0.003
		3	1.989	0.043
		5	2.209	0.009
		6	2.516	0.002

Note: *p<0.05, **p<0.01, ***p<0.001

From the above analysis results, for some common hazards on the road, the subjects showed better visual search strategies, which reflected in the ability to detect dangerous targets faster and have more fixation duration for hazards. This was consistent with previous research results [14][19]. Scenario 2 was set as roadside parking, and the danger was set as door opening and killing operation. Although the danger target was visible, subjects often lack awareness of this

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danger situation, had longer entry times to gaze at the danger while riding, and had lower cognitive load in this scenario. For dangerous targets with vehicles or pedestrians on the road ahead, subjects often have better hazard perception abilities. According to the research results, it will be important to improve our cognitive ability of relevant information in the cycling traffic environment [20]. Improve cyclists' hazard perception ability while improving their traffic knowledge and attitude, so that they can better explain and predict dangerous situations.

4. CONCLUSION

This study evaluated the hazard perception ability of cyclists when riding on natural roads from the perspective of visual characteristics indicators. The results showed that for some common hazards, cyclists have higher hazard perception abilities. In the field of transportation, cyclists are high-risk groups, and safety education for cyclists is very important, which is also a key direction of future research. Based on the visual characteristics of cyclists, this study will help to develop intervention programs for researchers to improve their hazard perception ability, in order to improve their safe riding ability.

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