


## Article

# Correlation Analysis between Young Driver Characteristics and Visual/Physiological Attributes at Expressway Exit Ramp

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**Abstract:** More collisions occur at the exit ramps of expressways due to frequent lane-changing behavior and interweaving between vehicles. Young drivers with shorter driving mileage and driving experience, radical driving styles, and worse behavior prediction are likelier to be involved in collisions at the exit ramps. This paper focuses on the correlation analysis between young drivers' characteristics and their visual and physiological attributes at expressway exit ramps. First, the driver's gender, driving experience, and mileage are classified. Then, seven expressway exit models are established using the UC/Win road modeling software. The driver's driving plane vision is divided into four areas using the K-means clustering algorithm. In addition, the driver's visual and heart rate attributes were analyzed at 500 m, 300 m, 200 m, and 100 m away from an expressway exit. The results show that the visual attributes, gender, and driving mileage of young drivers strongly correlate with the fixation times and average saccade amplitude. In contrast, the driving experience has almost no correlation with the fixation behavior of young drivers. Young drivers' driving experience and mileage strongly correlate with cardiac physiological attributes, but there is virtually no correlation with gender. The practical implications of these results should be helpful to highway planners and designers.

**Keywords:** highway exit; driver; visual characteristics; heart rate; fixation; saccade



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## 1. Introduction

Expressway exit and entrance ramps are complex areas where vehicles merge into or diverge from the stream. At the entrance ramp, vehicles entering the mainline from the ramp compete for suitable headways with the vehicles driving in the merging lane. At the exit ramp, the vehicles slow down for the exit ramp speed. An expressway exit is a highly space-competitive position for vehicles, where traffic accidents are likely to occur at expressway exits. Therefore, studying drivers' driving behavior at expressway exits is warranted. As the most unstable main factor in the human–vehicle–road closed-loop system, drivers often show various characteristics during the driving process. For example, in lane changing, drivers will adopt other processing methods in the selection of the lane-changing timing and the search for surrounding environmental information. The human–machine interaction can be realized only when the vehicle system's performance meets the current driver's characteristics. Research shows that the driving behavior characteristics will show specific rules according to various types. Analyzing and comparing the driver's control of the vehicle and the driver's visual characteristics can provide an essential data basis for predicting expressway lane-changing behavior. Young drivers' characteristics include short mileage, short driving experience, radical driving style, and a challenging behavior.

To the authors' best knowledge, limited studies have addressed young drivers' workload in the areas with different distances to an expressway exit. Thus, the current study tended to explore the effects of the visual and physiological attributes of young drivers at the expressway exit segments.

## 2. Literature Review

As indicated in Table 1, the recent literature review shows that most previous research has focused on characterizing drivers' visual and psychophysiological parameters. Still, a limited body of research efforts exists on the correlation between driver characteristics and visual and psychophysiological attributes. There is also little research on young drivers. Therefore, this paper mainly focuses on the correlation between young drivers' characteristics and visual and physiological characteristics at an expressway exit. Therefore, this study aimed to evaluate the correlations between young driver characteristics (gender, driving experience, and driving mileage) and their visual/physiological attributes at expressway exit ramps.

**Table 1.** A summary of previous research regarding characterizing drivers' visual and psychophysiological parameters.

Previous Research Efforts	Findings	Research Gap
Ji [1] and Sun et al. [2]	The authors classified lane-changing behavior into two categories according to the purpose of lane changing: subjective lane-changing behavior (driven by the driver's subjective desire for better lane-changing benefits)	However, drivers' forced lane-changing behavior at an expressway exit was not analyzed.
Ji [1] and Xiong et al. [3]	They analyzed the conditions of these behaviors and the main influencing factors of drivers' lane-changing behavior, such as drivers' characteristics, vehicle type, traffic flow environmental impact, and road conditions. Finally, they established an urban road vehicle lane-changing model based on driving behavior (subjective lane-changing model, forced lane-changing model)	However, there was no specific correlation analysis between drivers' characteristics and the characterization parameters of lane-changing behavior.
Portera and Bassani [4]	They studied the influencing factors on driving behavior at expressway off-ramps and on-ramps. It was proposed that the radius of the lane circle curve, the position of the entrance and exit ramps, and the length of the ramps significantly influence drivers' driving behavior.	However, the parameters, such as the radius of the lane circle curve, were not mapped to the characterization parameters, such as drivers' visual characteristics.
Yuan [5] and Yu et al. [6]	They fitted the distribution functions of three parameters, i.e., fixation duration, saccade amplitude, and saccade speed. They found that they had approximately logarithmic, exponential, and logarithmic normal distributions, respectively. The proficiency level significantly influences four parameters, by comparing and counting the parameters of proficient and unskilled drivers. The dynamic clustering theory was used to determine the fixation area and to divide the various fixation areas.	However, the differences in proficiency among various types of drivers and their correlation with visual characteristics were not specifically analyzed.
Ji [7]	Three evaluation indexes of visual characteristics were determined: fixing characteristics' evaluation indexes (fixation times, fixation duration, line of vision transfer probability); evaluation indexes of saccade characteristics (saccade duration, saccade range, and saccade speed); head motion evaluation indexes (rotation angle of vertical motion, rotation angle of horizontal motion). The drivers were classified into various styles, and their correlations to fixation, saccade, and head movement behaviors were analyzed.	The influence of drivers' characteristics on visual characteristics was neglected.
Hou [8] and Feng [9]	They determined the driving intent time windows according to the driving style of various drivers. They built GM-HMM and SVM models based on the difference significance analysis [10]. Finally, they concluded that the parameters of drivers' perceptual characteristics of lane-changing intention were the number of rearview mirror views, the average saccade amplitude, and the standard deviation of the head horizontal angle [11].	

**Table 1.** *Cont.*

Previous Research Efforts	Findings	Research Gap
Wei [12]	They studied the predictions of drivers' lane-changing behavior based on in-depth learning and correlated the visual characteristics with drivers' behavior characteristics.	However, the driver's features were not related to visual attributes.
Wang and Yin [13]	They concluded that driving behavior is influenced by drivers' driving intentions and the driving environment outside the vehicle.	
Cheng [14], and Cheng and Zhang [15]	They preprocessed and extracted physiological signal data and designed neural network architecture. The changing regularity of drivers' psychological and physiological characteristics during driving was analyzed.	However, the driver's features and psychological characteristics were not analyzed.
Mahmud et al. [16]	The effectiveness of dynamic speed feedback signs (DSFSs) as a speed reduction countermeasure was evaluated.	
Tian [17]	The heart rate variability parameter was mainly used to obtain the time-frequency domain index of the ECG signal. The authors studied this aspect and proposed that in the element of ECG detection, the ECG data should generally be paid attention to, mainly analyzing the time-frequency domain index of the ECG signal.	The change in the driver's heart rate during a lane change at an expressway exit was not analyzed.
Sun et al. [2]	They analyzed the correlation between drivers' characteristics and psychophysiological characteristics under natural driving conditions on the expressway.	

### 3. Experimental Design

#### 3.1. Participants

Various types of young drivers have other physiological characteristics at 500 m, 300 m, 200 m, and 100 m from an expressway exit. The drivers' gender, driving experience, driving mileage, and visual and heart rate attributes were classified. The experiments and questionnaire were completed by 30 people, including 17 males and 13 females. The drivers were all between 18 and 25 years old.

#### 3.2. Material

The experimental platform comprised UC-Win/Road scene modeling software version 1.1, a driving simulator, a driver, an eye tracker, a biofeedback instrument, and an Ergolab (Stockholm, Sweden) human-machine environment synchronization platform. Among them, UC-Win/Road is mainly used to construct road scenes and road alignments conducive to driving fatigue. The driving simulator used in this experiment is shown in Figure 1. The instrument comprises three display panels, real car body instruments, and other parts. At the same time, the actual scene simulation system, the operation system, the sound simulation system, the vehicle dynamics simulation system, and the data recording system constitute the experimental platform. Ergolab human-machine environment synchronization (HMI) is a platform for simultaneous data collection and analysis of human-machine environmental data. It is essential in experimental design, data collection, statistical analysis, and human behavior research.

The biofeedback instrument can collect the driver's physiological and psychological signals in the driving experiment. In this study, an eight-channel multi-parameter biofeedback instrument was used to collect the heart rate data of the experimenter. The biofeedback instrument is small and light, so it will not cause much interference to the driver. The eye tracker model adopted is Tobii Pro Glasses2, which can obtain eye movement signals for subsequent research and analysis.



**Figure 1.** Driving Simulator.

### 3.3. Driver Attributes

The main experiment consisted of two parts: the visual characteristics of lane-changing behavior, the acquisition of heart rate data, and the determination of the basic information about the driver. First, the participants were given questionnaires for basic driver information before the experiment, and then the driving simulation was carried out in the UC-Win/Road driving simulation software. The Tobii Pro Glasses2 eye tracker was used to collect the visual characteristics of the drivers, and the biofeedback device was used to collect the participants' heart rates. After the test, the vehicle operation data parameters in the simulator were extracted. After the preliminary processing and analysis of the obtained data, abnormal data were eliminated, and the influencing factors and correlation between the visual characteristics and heart rate of the drivers of various types were finally obtained. The main variables of this experiment were divided as shown in Table 2.

**Table 2.** Main variables of this experiment.

Variable	Variable Name	Instruction
Independent Variable	Driver Characteristics	Gender, Driving Experience, Driving Mileage
Dependent Variable	Visual attribute (Fixation)	Fixation Times, Percentage of Cumulative Fixation Duration
	Visual attribute (Saccade)	Average Saccade Amplitude, Average Saccade Speed

### 3.4. Experimental Process

The UC-Win/Road software built a two-way, eight-lane expressway with seven exit ramps. The mainline was a straight line, and the radius of the circular curve was 1500 m; the width of each lane was 3.75 m; the longitudinal slope was 0.305% and -0.286%. For the deceleration lane, the length of the gradient segment was 100 m, the length of the deceleration segment was 150 m, and the total length was 250 m. The ramp had a 350 m circular curve radius, a single lane form, and a lane width of 4.5 m. The ramp signs included exit warning signs, exit signs, straight signs, and the following exit warning signs. The questionnaire was concisely developed, generally with multiple-choice questions to help the respondents complete the questionnaire quickly. The experimental process included the following steps:

#### Step 1: Questionnaire filling stage

After entering the laboratory, the participants had to first register their primary information (name, gender, serial number, etc.), sign the experimental record form, and then scan the code to fill in the questionnaire. The person in charge of the experiment guided the participants to complete the questionnaire (the specific information is shown in Table 3).

**Table 3.** Basic driver information questionnaire.

Question	Answer Form
Name	Fill in the Blanks
Gender	Multiple-choice
Driving Experience	Multiple-choice
Whether or Not Owns a Car	Multiple-choice
Driving Hours Per Day	Multiple-choice
Mileage Per Week	Multiple-choice
Mileage Per Year	Multiple-choice
Number of Violations in One Year	Multiple-choice
Number of Accidents in a Year	Multiple-choice
Points Deducted from Driving License within a Year	Fill in the Blanks

### Step 2: Instrument Configuration

The person in charge of the experiment introduced the primary experiment situation to the experimenter (the expected experiment time, the method of using the experimental equipment, the experiment process, the steps, etc.). After the introduction of the experiment, the eye tracker and heart rate monitor were worn to detect the visual characteristics and heart rate characteristics of the experimenter during the experiment. The model was initialized and prepared to start the experiment.

### Step 3: Driving Simulation

The experiment was divided into seven groups. Each group had a different starting point. When the participants started driving, they were given a driving destination.

## 4. Methodology

The division method of the driver's field of vision (FOV) plane used in this paper is the dynamic clustering method, with the screenshot shown in Figure 2.

**Figure 2.** FOV of one sample of participants.

### 4.1. Design of the k-Means Clustering Algorithm

Let  $X = \{x_1, x_2, \dots, x_i, \dots, x_n\}$  be  $n$  data in  $R^d$  space. Before clustering,  $k$  should be specified as the number of initial clusters. There are many methods to determine  $k$ . Generally, it is determined according to the sample situation and the number of samples. The following are the basic steps of the  $k$ -means clustering algorithm:

Step1: Select  $k$  objects from  $n$  data objects as the initial clustering center, and the similarity  $s(x_i - c_j)$  of the remaining points can be derived from the following formula:

$$s(x_i - c_j) = \frac{1}{d(x_i, c_j)} \quad (1)$$

where  $c_j$  = the cluster center of class  $j$ , and  $d(x_i, c_j)$  = the distance between sample  $x_i$  and cluster center  $c_j$  [18].

The three types of distances are given by:

$$d(x_i, c_j) = \sqrt[p]{|x_i^1 - c_j^1|^p + |x_i^k - c_j^k|^p + |x_i^d - c_j^d|^p} \text{ (Makowski distance)} \tag{2}$$

$$d(x_i, c_j) = |x_i^1 - c_j^1| + \dots + |x_i^k - c_j^k| + \dots + |x_i^d - c_j^d| \text{ (Manhattan distance)} \tag{3}$$

$$d(x_i, C_j) = \sqrt{(x_i^1 - c_j^1)^2 + \dots + (x_i^k - c_j^k)^2 + \dots + (x_i^d - c_j^d)^2} \text{ (Euclidean distance)} \tag{4}$$

Step2: Calculate the cluster center of each updated class, and assume that the sample in the  $j$  class is  $\{x_{j1}, x_{j2}, \dots, x_{jn_j}\}$ ; that is, it contains samples, and then the cluster center of this class is  $c_j = \{c_j^1, c_j^2, \dots, c_j^k, \dots, c_j^d\}$ , where  $c_j^k$  is the  $k$  attribute of the center  $c_j$  of the class, which can be obtained according to the formula:

$$c_j^k = \frac{x_{j1}^k + x_{j2}^k + \dots + x_{jn_j}^k}{n_j} \tag{5}$$

Step3: Repeat the steps until the standard detection function converges, as shown in the following formula:

$$J = \sqrt{\frac{\sum_{i=1}^k \sum_{j=1}^{n_i} (x_{ij} - c_i)^2}{n - 1}} \tag{6}$$

Note that  $k$  means clustering of the fixation points in the driver’s FOV.

#### 4.2. Clustering Algorithm Results

The  $k$  means clustering algorithm was used to explore the division law of the driver’s FOV plane at the expressway exit. The results showed that the number of drivers’ FOV plane divisions at the expressway exit was mainly based on the number of classes selected. A large selection of  $k$  value will lead to the angle of the divided field of the vision plane and weak goal. Determining the relationship between the divided FOV plane and its internal targets is challenging. In contrast, the selection of  $k$  value is small and the divided areas are less, so it is difficult to determine the characteristics of targets and lines of vision. In this study, according to the driver’s main fixation points at the expressway exit, the value of  $k$  was preliminarily set as 4, 5, and 6. That is, the FOV plane was divided into 4, 5, and 6 areas for clustering calculation, respectively. The clustering results of  $k = 4, 5,$  and 6 are shown in Table 4, while the optimal number of  $k$  is 4.

**Table 4.** Clustering results for various  $k$ .

Category	Initial Cluster Center	Final Cluster Center	Number of Cases
( $k = 4$ )			
1	(−55.96, −16.88)	(−46.54, 13)	13
2	(35.36, 3.28)	(22.18, 2.76)	17
3	(50.99, −20.40)	(44.77, −19.65)	121
4	(18.44, 21.05)	(18.83, 22.04)	12
( $k = 5$ )			
1	(−54.77, −16.45)	(−46.54, 13)	14
2	(17.45, 22.17)	(23.64, 5.63)	23
3	(−8.55, −6.04)	(2.845, −6.44)	137
4	(−47.11, 22.16)	(−20.44, −3.39)	7
5	(−14.48, −42.37)	(−10.81, −27.67)	14

Table 4. Cont.

Category	Initial Cluster Center	Final Cluster Center	Number of Cases
	( $k = 6$ )		
1	(17.65, -14.34)	(23.00, 7.45)	21
2	(-11.33, 1.48)	(0.75, -3.91)	21
3	(-13.88, -43.58)	(-19.92, -9.66)	145
4	(-47.45, 21.68)	(-20.68, 4.22)	6
5	(47.65, -22.34)	(47.66, -12.53)	14
6	(16.63, -27.77)	(5.33, -7.44)	3

Thus, the driver's line of vision plane was divided into four areas: front, interior rear-view (RV) mirror, left RV mirror, and right RV mirror. According to the driver's visual characteristics at the expressway exit, this paper dynamically clusters the driver's line of vision points. It puts forward the selective division of the following visual field planes (four types in total): A-front, B-interior RV mirror, C-left RV mirror, and D-right RV mirror. After clustering, each cluster point was reflected in the coordinate system in the driver's FOV. The division of the driver's FOV plane is shown in Figure 3.



Figure 3. Division of driver's FOV plane.

## 5. Correlation Analysis

The correlation between young drivers' characteristics (gender, driving duration, driving mileage, and driving style), visual attributes (fixation and saccade behavior), and physiological attributes (heart rate difference) was analyzed at 500 m, 300 m, 200 m, and 100 m away from the expressway exit. In the normal driving process, drivers obtain external information in three ways: fixation, saccade, and blinking. Blinking behavior does not represent the driver's visual characteristics, so the saccade and fixation behavior characteristics were selected for analysis. In addition, the heart rate was also selected as the physiological characterization parameter of the driver.

### 5.1. Fixation Times

The number of fixation times is the total number (frequency) of the driver's fixation on a point or an area in the FOV during driving, and the frequency also shows the driver's attention to the FOV from the side, reflecting the driver's interest in this area. In this paper, the number of drivers' fixation times at a location can represent the change in the driver's focus. The correlation of fixation times of various types of drivers was analyzed regarding gender, driving experience, and driving mileage at various distances from the expressway exit.

#### 5.1.1. Fixation Times by Gender

A comparison of the fixation times of the drivers of both genders at various distances is shown in Figure 4. First, at the expressway exit, the attention to the left RV mirror and the inside RV mirror is low because the driver is about to change lanes to the right, so his attention will mainly focus on the front and right RV mirrors. However, there is a small difference between the number of female drivers' fixation times on the right RV mirror and

the number of fixation times at the front. In contrast, male drivers pay more attention to the right RV mirror and the front, but their attention still mainly stays in the front. Therefore, gender has a strong correlation as a factor affecting the fixation behavior characteristics of young drivers at the expressway exit. This is consistent with recent studies [19].

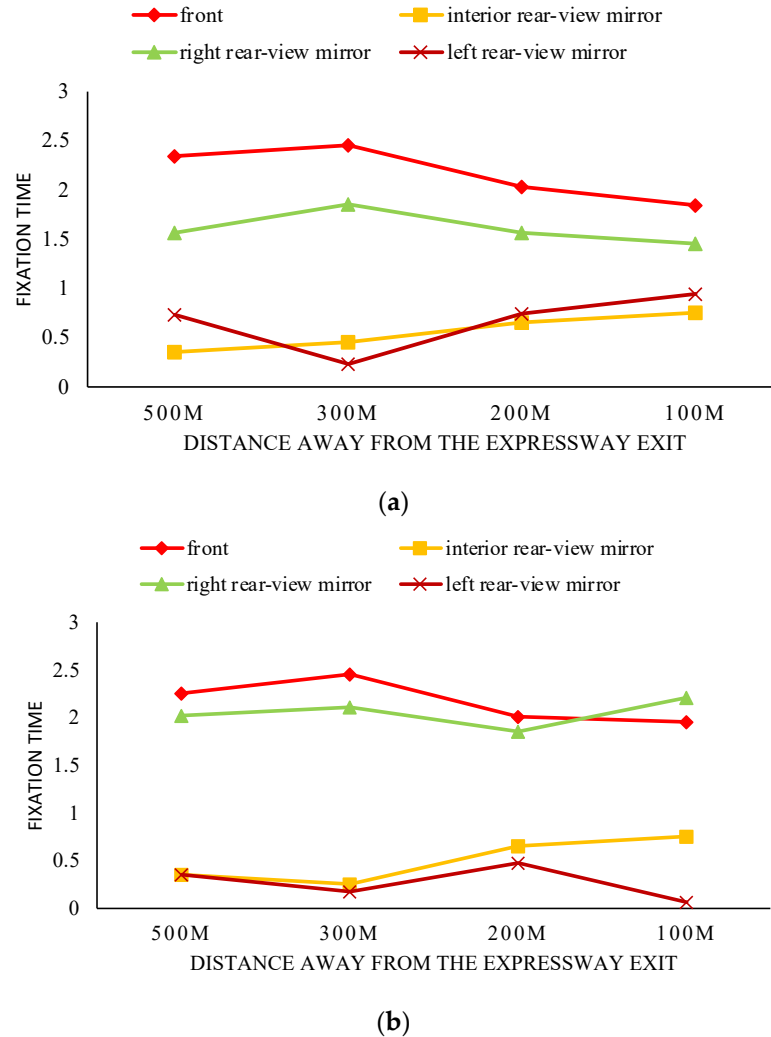


Figure 4. Driver fixation times by gender. (a) Male drivers. (b) Female drivers.

### 5.1.2. Fixation Times by Driving Experience

A comparison of the fixation times of drivers with various lengths of driving experience at various distances is shown in Figure 5. Similarly, the driver’s attention is mainly focused on the front and right RV mirrors, but when comparing the number of fixation times of drivers of various ages, it is found that the age of driving has little effect on the number of fixation times at the expressway exit. As a result, the driving experience has little correlation with the fixation behavior characteristics of young drivers at the expressway exit.

### 5.1.3. Fixation Times by Driving Mileage

A comparison of the fixation times of drivers with varying driving mileages at different distances is shown in Figure 6. Similarly, the drivers’ attention is mainly focused on the front and the right RV mirrors, but it is noteworthy that the number of eyes on the right RV mirror by drivers with under 10,000 km of driving mileage differs slightly from the number of eyes on the front. On the contrary, drivers with driving mileage of more than 10,000 km mainly focus on the front. Although the right RV mirror is fixed on more frequently than



the left and the interior RV mirror, there is still a large gap compared with the front. Unlike drivers with under 10,000 km of driving mileage, the gap is smaller. Therefore, driving mileage has a strong correlation as a factor affecting the fixation behavior of young drivers at the exit of the highway, especially between drivers with driving mileage above 1000 km and those with driving mileage below 1000 km.

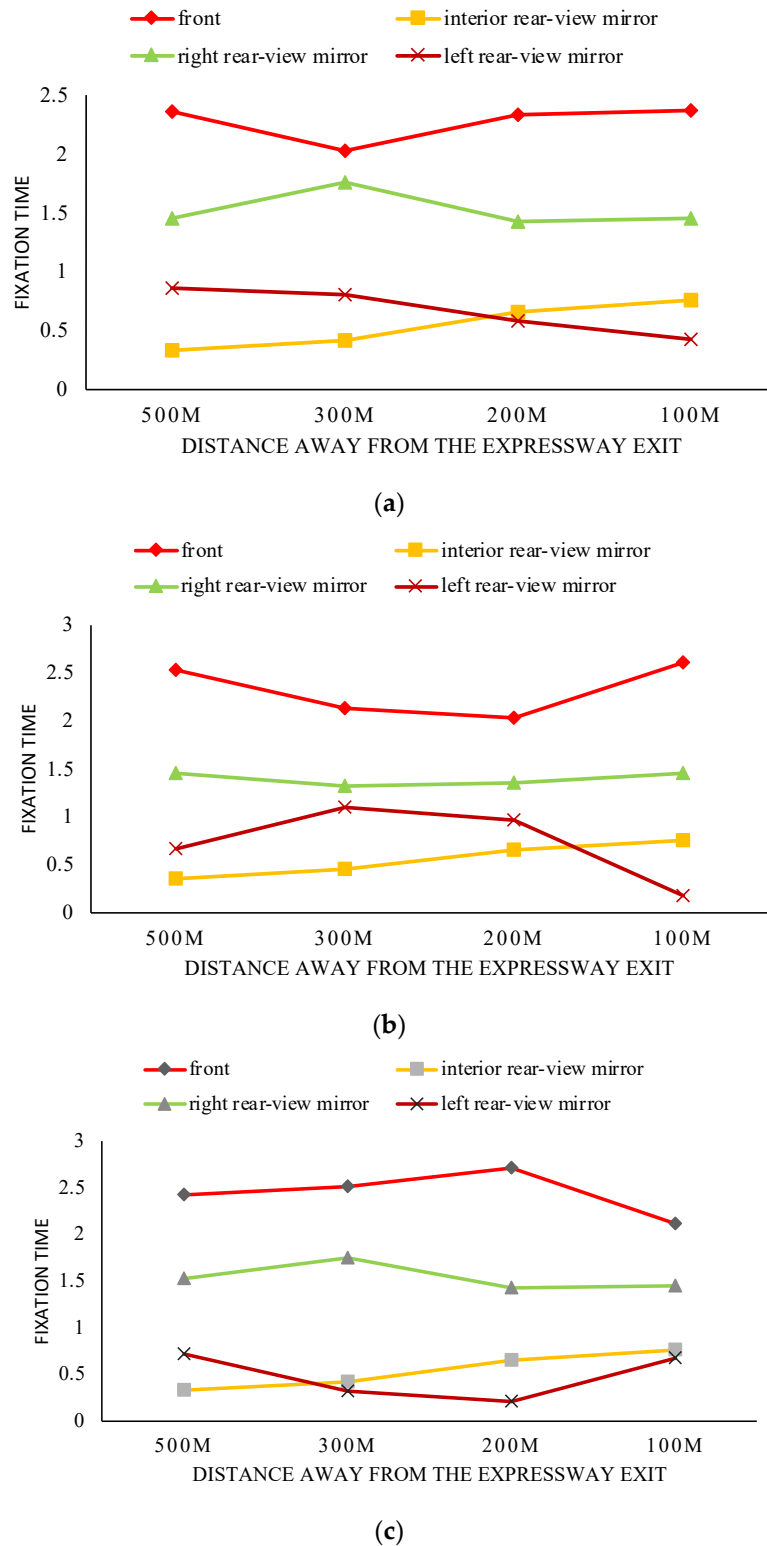
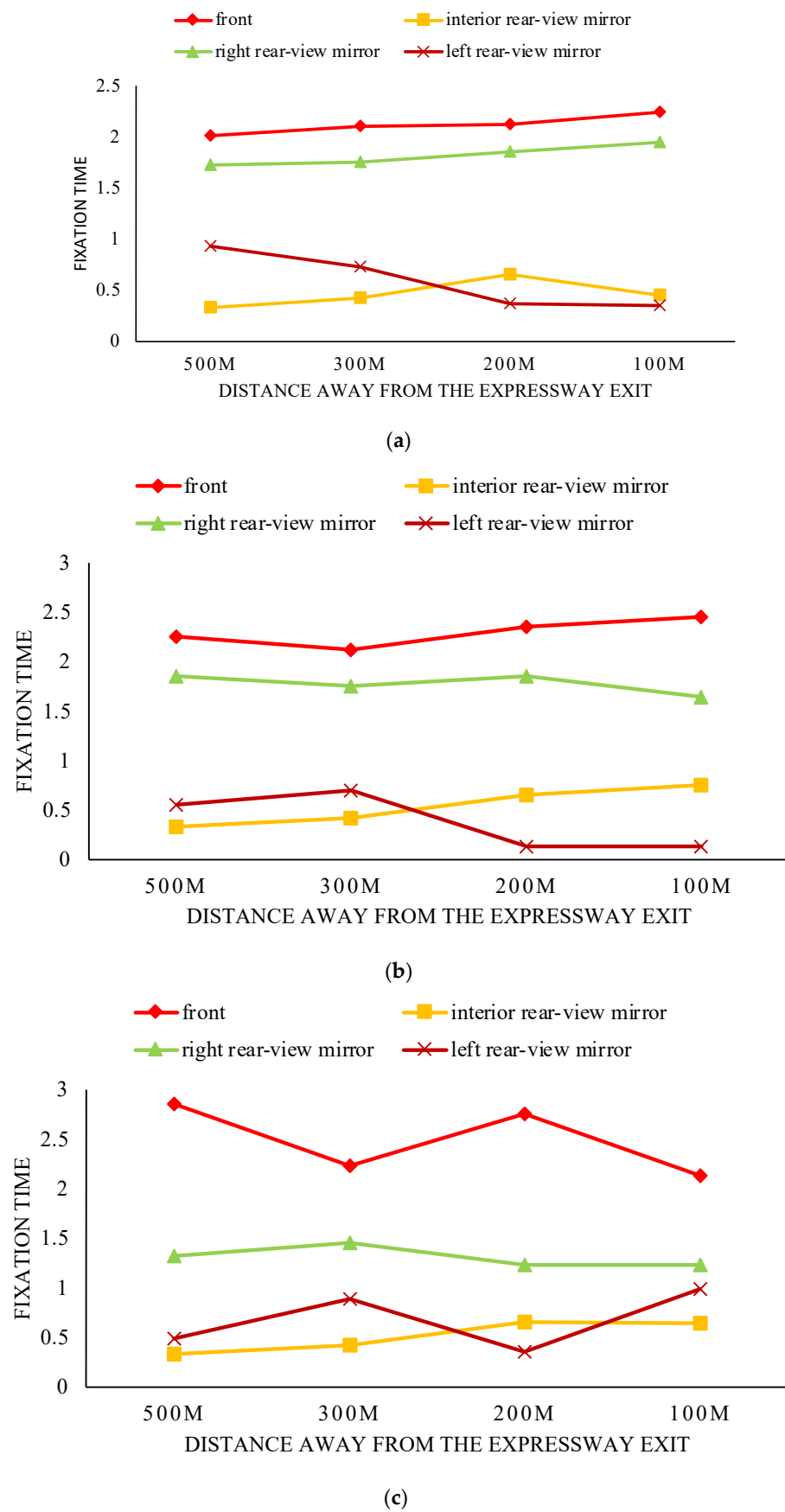


Figure 5. Fixation times by drivers' experience. (a) Less than 1 year. (b) 1 to 3 years. (c) Over 3 years.



**Figure 6.** Fixation times for varying driving mileages. (a) Less than 5000 km. (b) 5000 km–10,000 km. (c) Over 10,000 km.

Thus, as far as the fixation behavior characteristics are concerned, gender and driving mileage (driving mileage of 10,000 km) have a greater correlation with the fixation behavior characteristics at the exit of the driver's highway, while driving time has a smaller correlation with the fixation behavior characteristics at the exit of the driver's highway.

### 5.2. Average Saccade Amplitude

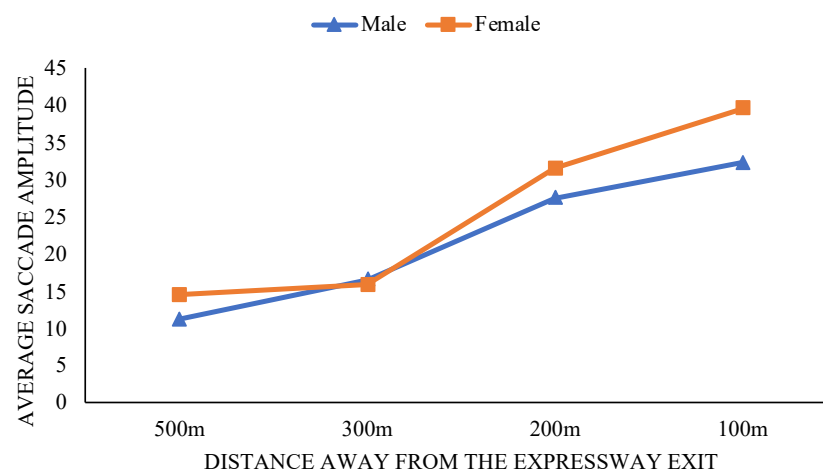
Saccade amplitude describes the extent to which the driver's eye covers when he completes a saccade (the extent to which the driver's eye saccades from the previous focus to the next). Saccade behavior can be represented by the angle between the last fixation behavior and the view of the following fixation behavior (the angle of view variation). In this paper, the average saccade amplitude uses the average vector angle between the two fixation behaviors over a certain period.

The correlation between the average saccade amplitude of various types of drivers is shown in Figure 7 at 500, 300, 200, and 100 m away from the expressway exit in three aspects: gender, driving time, and driving mileage.

Regarding gender, the average saccade amplitude of drivers approaching 200 m and 100 m from the expressway exit increases substantially, as drivers generally choose to change lanes here. It is not difficult to see from the diagram that the average saccade range of male drivers is usually smaller than that of female drivers, especially when the distance is 100 m from the expressway exit and the gap reaches 7.25 degrees. Therefore, gender strongly influences young drivers' saccade behavior characteristics (average saccade range).

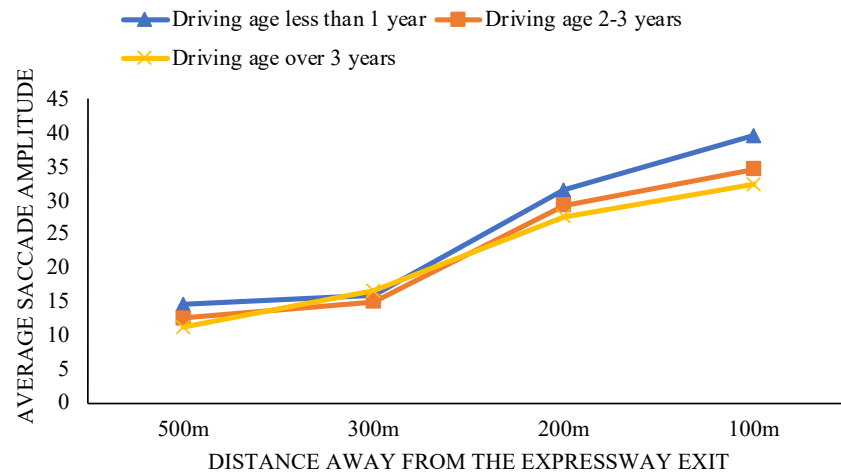
Regarding driving age, the driver changes lanes near the expressway exit, so the average saccade increases. It can be seen from the diagram that the average saccade decreases slowly with the increase in the driving experience, which is due to the increase in driver experience but does not change much. Therefore, there is no strong correlation with the age of driving as a factor affecting the saccade behavior characteristics (average saccade amplitude) of young drivers at the exit of a highway.

In terms of the amount of driving mileage, similarly, the driver changes lanes near the expressway exit so that the average saccade will increase. It can be seen from the diagram that as the driving mileage increases, there is a significant correlation between the average saccade amplitude and the driver's driving mileage. Especially when it is more than 10,000 km, the average saccade amplitude of the driver at the expressway exit decreases significantly. Therefore, driving mileage strongly correlates with young drivers' saccade behavior characteristics (average saccade amplitude).

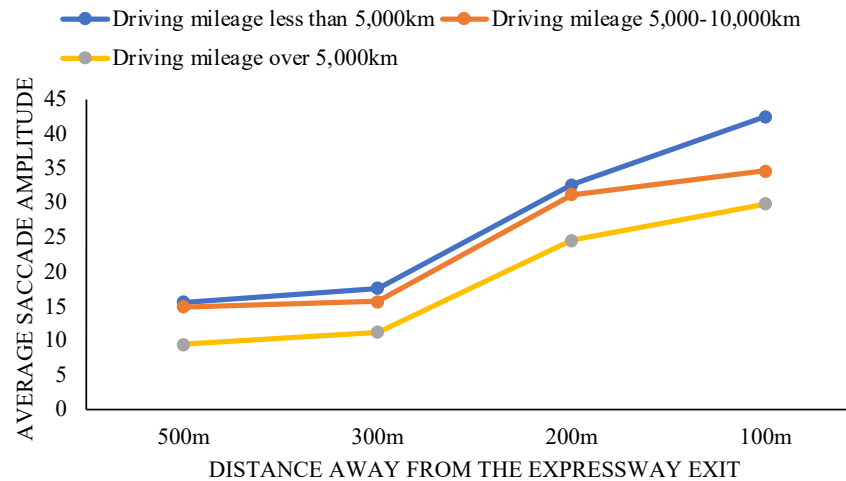


(a)

Figure 7. Cont.



(b)



(c)

**Figure 7.** Average saccade amplitude for various driver characteristics. (a) Gender. (b) Driving experience. (c) Driving mileage.

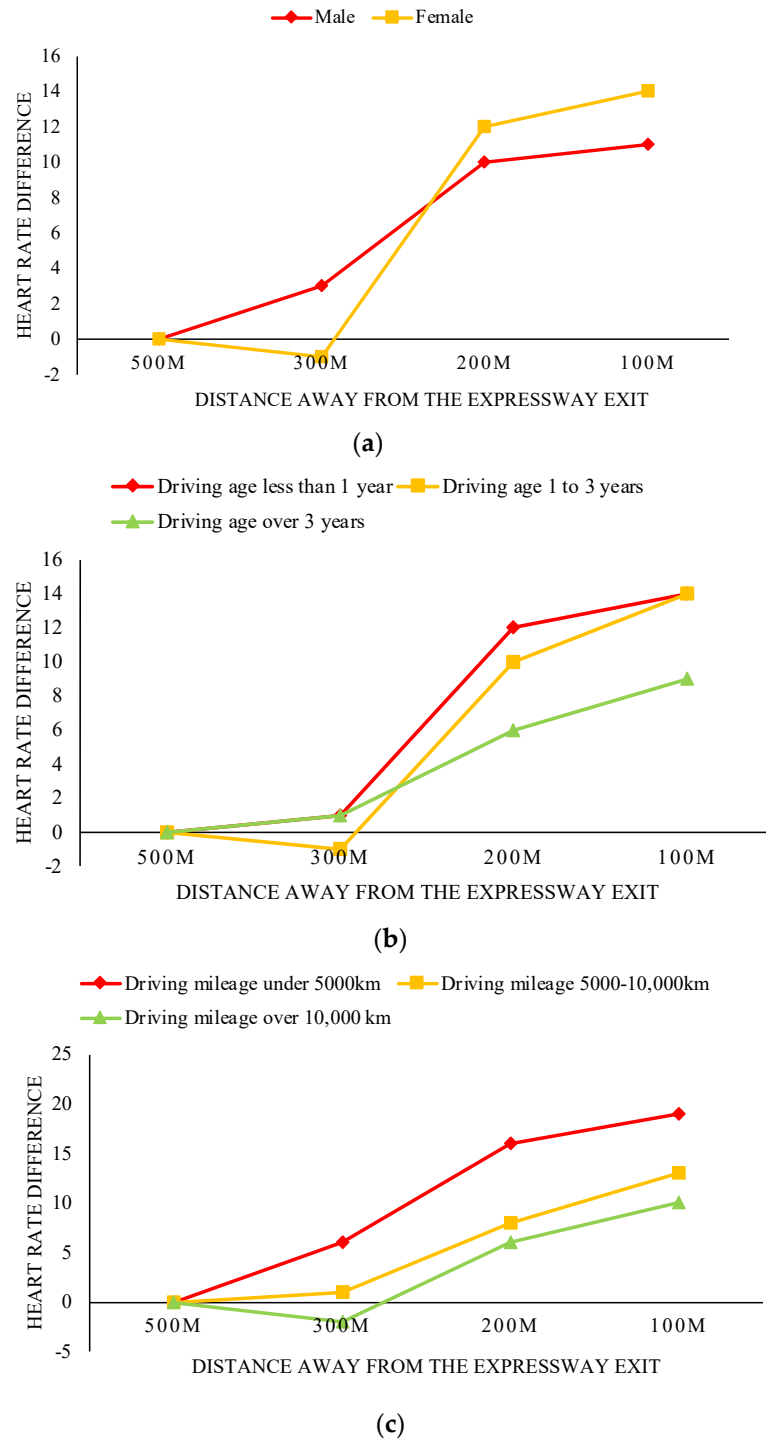
### 5.3. Heart Rate

Heart rate refers to the number of heartbeats per minute in a normal person’s quiet state, also known as the quiet heart rate, which is generally 60 to 100 beats/min. Individual differences can be caused by age, gender, or other physiological attributes. Generally speaking, the younger the age, the faster the heart rate. The slower heartbeat of the elderly than that of the young and the faster heart rate of females than that of males of the same age are both normal physiological phenomena.

The cardio-physiological index selected in this paper is the heart rate index, which was used mainly to obtain the heart rate data of the tested drivers during the experiment through the biofeedback instrument. The feedback from subsequent experimenters shows that the interference from the heart rate detection device with the driver was negligible. Therefore, the heart rate data obtained in this experiment have certain reliability.

The heart rate index in this experiment can roughly reflect the driver’s psychological changes while driving the vehicle. The characteristic parameters of the heart rate mainly include the mean value of the heart rate, the difference value of the heart rate, and the rate of change of the heart rate. Because the individual difference in the heart rate index is noticeable, the research on the mean heart rate value is insignificant. Therefore, the characteristic parameter of the heart rate difference is mainly used for statistical analysis

in the subsequent correlation analysis with the steering wheel index. Therefore, when the driver is 500 m away from the expressway exit, the driver’s heart rate is highly initial  $B_0$ , and then his heart rate at 300 m, 200 m, and 100 m is  $B_i$ , and the driver’s heart rate difference  $Z = B_i - B_0$ . The changes in the difference  $Z$  between various classifications of drivers’ heart rates at 500 m, 300 m, 200 m, and 100 m away from the expressway exit are shown in Figure 8.



**Figure 8.** Driver heart rate difference for various driver characteristics. (a) Gender. (b) Driving experience. (c) Driving mileage.

Regarding gender, the driver’s heart rate increased significantly at 200 m and 100 m away from the expressway exit because drivers generally choose to change lanes here. In

contrast, the female drivers had a gap in heart rate changes compared with the male drivers, but the gap was not particularly significant, and only about three times per minute. As a result, there is little correlation between gender as a factor influencing the change in heart rate at the expressway exit for young drivers.

Drivers with driving experience of less than 1 year and 2–3 years will have a significant increase in heart rate at 200 m and 100 m from an expressway exit of about 12–14 times/minute. For drivers with driving experience of more than 3 years, the heart rate at 200 m and 100 m from expressway exits will also change significantly, but the change is smaller than that of drivers with driving experience of less than 1 year and 2–3 years. There are only about nine times per minute, so the driving age strongly correlates with the heart rate change at the expressway exit for young drivers, especially drivers with over 3 years and under 3 years of driving experience.

In terms of driving mileage, varying driving mileages characterize the proficiency of the driver's driving behavior. The figure shows a significant difference in heart rate change between drivers with varying driving mileage at the expressway exit. The longer the driving mileage, the smaller the heart rate change at the expressway exit. Therefore, driving mileage has a strong correlation as a factor affecting young drivers' heart rate change at the expressway exit.

## 6. Concluding Remarks

This paper has focused on the correlation analysis between young drivers' characteristics and visual and physiological attributes at four typical distances of 500 m, 300 m, 200 m, and 100 m from the identification plate at an expressway exit. Based on this study, the following comments are offered:

1. The influence of the driver's characteristics on the number of fixation times is mainly studied for the fixation behavior. The results showed that gender, driving mileage, and fixation number strongly correlate. In contrast, the driving experience has almost no correlation with the fixation behavior characteristics of young drivers at an expressway exit.
2. The effect of driver characteristics on the average saccade magnitude showed that the average saccade magnitude could be affected by gender and driving mileage. At the same time, the driving experience has almost no correlation with the saccade behavior characteristics of young drivers at an expressway exit.
3. Concerning the heart rate, previous studies have shown a significant individual difference in the heart rate and considerable uncertainty in the case of small samples. Therefore, this study mainly analyzed the difference in the heart rate. The correlation between gender and the heart rate was weak, while the correlation between driving experience and driving mileage was strong for the change in the heart rate at an expressway exit.
4. Interestingly, the correlation between the driver's age, the number of fixation times, and the average saccade amplitude was low for young drivers. This is because the number of fixation times and the average saccade are related to the driver's driving experience. The longer the driving experience, the smaller the average saccade, and the less frequently an experienced driver looks at the right rearview mirror since the experienced driver quickly determines the road conditions and opts for the appropriate driving behavior.
5. Most young drivers in China do not necessarily have an immediate chance of obtaining a driver's license. After obtaining their license, they may still go to school or own a vehicle, so the age-responsive driving experience is unacceptable for young drivers. In contrast, driving mileage is a parameter that directly reflects the driver's driving experience. Therefore, the driving experience is directly related to the driver's driving mileage, so driving mileage is strongly related to the number of fixation times and the average saccade range.

6. Several practical implications could be developed based on such findings. For instance, the young drivers could practice their driving skills under the supervision of an experienced driver. An education program could be effective for the young drivers to improve their driving skills and form safe driving habits. The parents are also encouraged to be actively involved in the young drivers' driving education and monitor their progress, such as leaving an expressway at an exit. Moreover, more effective measurements should be set up to improve the driving safety on expressway exit ramps for the highway planners and designers.

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