applied sciences

MDPI

Article

Analyzing Pedestrian Behavior at Unsignalized Crosswalks from the Drivers' Perspective: A Qualitative Study

Yanqun Yang [1], Yu Wang [1], Said M. Easa [2] and Xinyi Zheng [3,*]

[1] College of Civil Engineering, Fuzhou University, Fuzhou 350116, China; yangyanqun@fzu.edu.cn (Y.Y.); 200527226@fzu.edu.cn (Y.W.)
[2] Department of Civil Engineering, Ryerson University, Toronto, ON M5B 2K3, Canada; seasa@ryerson.ca
[3] College of Humanities and Social Sciences, Fuzhou University, Fuzhou 350116, China
* Correspondence: zhengxinyi@fzu.edu.cn

Abstract: This study investigated drivers' perceptions of pedestrian crossing behavior at unsignalized crosswalks, which was less fruitful in quantitative and qualitative traffic research. Subjective and snow-ball sampling were used to conduct semi-structured in-depth interviews based on drivers' daily driving experience from qualitative research. A theoretical model of pedestrian behavior at unsignalized crosswalks was constructed using the grounded theory and the theoretical saturation test. The model involved 4 three-level codes and 13 two-level codes (main category) used to obtain seven subcategories. The results show that drivers believe that pedestrian characteristics, driver characteristics, and age factors are the three factors that affect pedestrian crossing safety. Targeted improvement measures are put forward to guide the design of pedestrian crossing facilities, pedestrian management and guidance, and future research on conflicts between autonomous vehicles and pedestrians.

Keywords: pedestrian crossing behavior; drivers' perspective; interviews; unsignalized mid-blocks; the grounded theory; improvement methods

Citation: Yang, Y.; Wang, Y.; Easa, S.M.; Zheng, X. Analyzing Pedestrian Behavior at Unsignalized Crosswalks from the Drivers' Perspective: A Qualitative Study. *Appl. Sci.* **2022**, *12*, 4017. https://doi.org/10.3390/app12084017

Academic Editors: Roland Jachimowski and Michał Kłodawski

Received: 16 March 2022
Accepted: 14 April 2022
Published: 15 April 2022

1. Introduction

Worldwide, vulnerable road users such as pedestrians account for a disproportionate share of road traffic crash statistics [1]. According to the World Health Organization (WHO), more than 270,000 people die on roads worldwide each year, and more than 50% are located at pedestrian crossings [2]. Urbanization is one of the most significant global trends [3]. In the rapidly developing China, with the increase in urban population density, residents' travel activities are increasing day by day. As a result, the contradiction between pedestrians and motor traffic is becoming increasingly prominent, which is difficult to change in the short term. More attention has been paid to the construction of environment-friendly and humanized transportation systems. However, the actions in many regions remain at the stage of chanting slogans, and no traffic improvement measures have been proposed for pedestrian traffic.

Unsignalized crossings are common traffic crossing facilities on city roads. Compared with signalized crossings, pedestrians and vehicles are difficult to separate in time and space due to the lack of traffic signal control. When pedestrians cross the street, the walking and vehicle trajectories may be intertwined on the road. This competition for road rights is very dangerous for pedestrians [4]. On the other hand, pedestrians are numerous, and their violations of the crossings also cause a great disturbance to drivers, while the relevant Chinese laws are mainly restrictions on them. For example, the "Road Traffic Management Regulations" for motor vehicles through the unsignalized crosswalks are as follows: when passing through the unsignalized crosswalks, shall yield to oncoming pedestrians. The authors of [5] argued that pedestrian crossing markings would only provide pedestrians with a false sense of safety. In this case, it is necessary to investigate

drivers' views on pedestrian crossing behavior in unsignalized crossings to alleviate the conflict between drivers and pedestrians and improve the efficiency of traffic operation. An in-depth discussion of drivers' opinions is one of the critical components of understanding the conflict between pedestrians and drivers, which has not been extensively investigated in previous studies. Therefore, it is essential to study pedestrian crossing behavior in unsignalized crossings from the driver's perspective.

The data collection method of pedestrian crossing behavior is mainly photography, but the data processing methods are different. Pedestrian behavior data can be collected through video capture of pedestrian crossing preferences, roadside and traffic characteristics, and pedestrian characteristics [6,7]. These data can be used to establish binary logistic regression models for pedestrian crossing strategies. They also enable pedestrian behavior studies such as the effect of waiting time on dangerous pedestrian behavior and driver-pedestrian interactions during pedestrian crossings [8,9]. Pedestrian safety is a multi-factor, multi-stakeholder issue [10]. The research of these scholars has important implications for improving pedestrian crossing safety.

There are several research directions on pedestrian crossing behavior. According to the literature, nearly one-third of pedestrians use cell phones when crossing the street, including listening to music, texting, and talking on the cell phone, with texting being the riskiest [11]. Pedestrians using cell phones wait longer before crossing the street. Meanwhile, they cross the street more slowly [12,13]. In terms of age, adult pedestrians have the fastest crossing speed than children and older pedestrians. The average speed of older pedestrians crossing the street is lower than that of child pedestrians, and a group of people crossing the street is slower than a single person crossing the street [14,15]. Older people behave more unsafely when crossing the street than younger people. The reason is that older pedestrians have reduced cognitive and visual abilities that make the decision-making process difficult [16,17]. Children are exposed to many dangers when crossing the street, whether from the crossing environment, psychology, or crossing behavior perspective. The crossing gap suitable for adults may be too small for children to pass safely in the general crossing environment [18]. Studies have shown that some children are so afraid of drivers that they dare not cross the street [19], whereas daring children will take more risky behaviors when crossing the street in pairs [20].

At present, the research scenarios of pedestrian crossing mainly include signalized crossings, unsignalized crossings, and pedestrian crossing in autonomous driving scenarios. At the signalized crossings facility scenarios, [21] investigated pedestrian crossing speed, delay, and gap perception at signal-controlled intersections, revealing their significant impact on safety margins. Ref. [22] investigated the relationship between environmental information and pedestrian behavior at intersections. Ref. [23] developed a binomial logistic model to evaluate the factors influencing pedestrian red-light running behavior by using a questionnaire. In the unsignalized crossings facility scenarios, ref. [24] investigated the patterns of pedestrian gender and age, the presence of pedestrian groups, vehicle interference, and intersection orientation on intersection travel times at unsignalized mid-block street intersections in Changsha City. The curvature of pedestrian crossing trajectories was explored by [25]. Furthermore, [26] argued that crosswalks on the road sections are the most influential pedestrian facilities. In autonomous driving scenarios, scholars discussed the interaction between pedestrians and vehicles. Ref. [27] studied the traffic signal control problem at an isolated intersection in a CAV environment, considering mixed traffic including various types of vehicles and pedestrians. Ref. [28] discussed how to ensure safe interaction between pedestrians and vehicles in an auto age. Based on the pedestrian death analysis report, [29] set up the functional scope of the most advanced AVs pedestrian sensor technology. Ref. [30] believed that the external human–machine interface (ehmi) can improve the efficiency of pedestrian–avi interaction and enhance the safety of pedestrians. Therefore, the research on pedestrian crossing behavior in unsignalized crossings is not only helpful for improving pedestrian safety and traffic order, but also has

a positive effect on the development of pedestrian behavior recognition technology for autonomous vehicles.

In summary, various research methods are available to study pedestrian crossing behavior, and research results are abundant. The existing research methods include virtual experiments, field investigation, and photography. The experimental data are obtained by various methods to establish mathematical models and conduct quantitative research on evaluation. Although quantitative research methods are commonly used and effective in traffic and pedestrian studies, the results are strongly influenced by the sample size, and human empirical characteristics may be ignored. Furthermore, the pedestrian crossing is a complex behavior that is influenced by people's living environment, habits, safety awareness, and cultural quality, which is difficult to develop by quantitative research methods [31]. Therefore, to understand the characteristics of pedestrian crossing, we adopt qualitative research to interpret people's experiences in different environments and complex factors. In the people-oriented principle, this study explores how these experiences affect pedestrian crossing behavior to promote the optimization of the pedestrian crossing environment and has specific reference significance for pedestrian crossing behavior recognition and classification technology.

2. Methodology

The study methodology is shown in Figure 1. First, the study's content and the interview's outline were determined based on the literature. Next, the respondents were purposefully selected for semi-structured interviews to collect primary data. Then, the interview data were processed and coded using the NVIVO 11 software. A three-level grounded theory model consisting of open coding, axial coding, and selective coding was developed. A saturation test of the model was then conducted. Finally, the pedestrian crossing behavior was analyzed and discussed using the model's results. Details about various aspects of the study methodology are presented next.

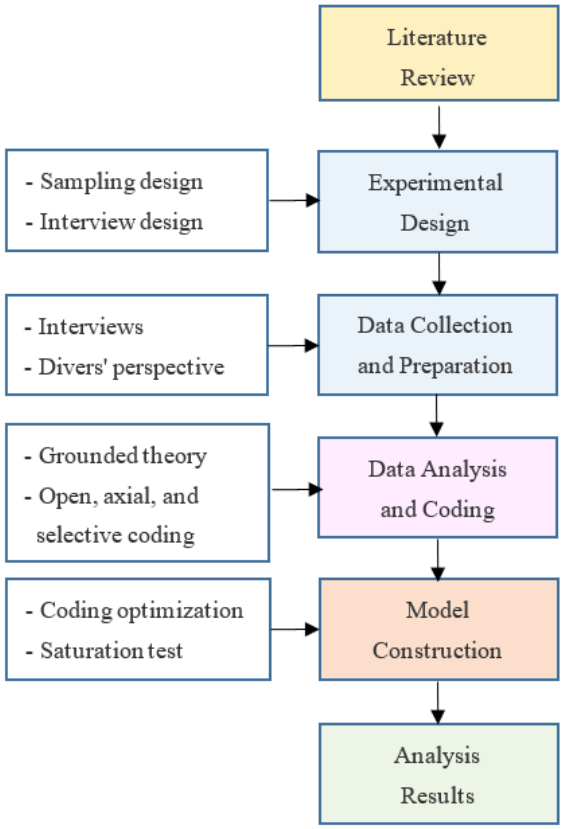

Figure 1. Study methodology.

2.1. Sampling Design

Qualitative research usually adopts subjective sampling, which is also one of the essential characteristics of the grounded theory research model. Moreover, there is no strict requirement on the number of samples [32]. However, according to [33], a sample size between 20 and 30 is appropriate. We used three sampling methods; first, purposive sampling was used to select experienced drivers among people we knew. Secondly, we also selected some traffic industry practitioners, such as cab drivers and traffic police officers. Third, we used a snow-ball sampling approach in which we asked respondents of the purposive sampling to recommend drivers with similar characteristics to be interviewed.

Based on this research, the subjective and snow-ball sampling approaches were adopted to select drivers from Fuzhou city, China. As the capital of Fujian Province, Fuzhou is the political, cultural, and transportation center of Fujian Province, attracting a large number of external people with diverse population distribution. In this study, 22 drivers were invited to conduct interviews, with an average age of 36.4 years old. They were healthy and had good eyesight without glasses. Among them, 81.8% of the respondents believed they were very concerned about other road participants and the surrounding environment, while 18.2% of the respondents were more concerned. Detailed information on the respondents' characteristics is shown in Table 1. Twenty samples were randomly selected for coding. The remaining two samples were tested for the theoretical saturation test. The study was approved by the University Human Research Ethics Committee. Every respondent signed the informed consent form.

Table 1. Summary statistics of demographic variables.

Variables	N	%
Gender		
Male	15	68.2%
Female	7	31.8%
Age		
20–30	6	27.3%
31–40	9	40.9%
41–50	5	22.7%
51–60	2	9.1%
Driving experience		
3–6 years	10	45.5%
7–10 years	7	31.8%
11–14 years	5	22.7%
Occupation		
Full-time driver	5	22.7%
Office worker	6	27.3%
Traffic policeman	5	22.7%
Sole trader	6	27.3%
Number of accident experiences		
0	19	86.4%
1	2	9.09%
2	1	4.5%
Degree of concern		
4	4	18.2%
5	18	81.8%

2.2. Interview Design

A pre-interview is conducted with one interviewee before the formal interview to obtain valid information. The syllabus is modified based on the test results to allow drivers to give individualized responses without asking specific questions as much as possible, provided they could be guided to give helpful information. The semi-structured interview

process does not have to follow the outline strictly but can be adjusted appropriately and handled flexibly. The finalized interview outline is shown in Table 2.

Table 2. Semi-structured interview outline.

Number	Question	Purpose
1	What are you most concerned about during the driving process?	Guiding the respondent into a driving thinking situation.
2	Please rate how concerned you are about other traffic participants and your surroundings while driving, from 1 (very unconcerned) to 5 (very concerned).	Learn about the degree of the interviewed drivers concerned about other traffic participants and the surrounding environment.
3	Have you ever done anything unsafe as a pedestrian when crossing a pedestrian crossing without a traffic light? What do you think about it?	Obtaining data on respondents' perceptions of pedestrian crossing behavior.
4	How do you observe the older people, young people, and children crossing the street at pedestrian crossings without traffic lights?	Obtain data on respondents' perceptions of pedestrians in different age groups.
5	Are there pedestrians who cross the street while looking at their cell phones at pedestrian crossings without traffic lights? Do such people look at oncoming traffic when crossing the street? Please evaluate their behavior.	Obtaining data on respondents' perceptions of pedestrian use of cell phones.
6	Do you think there should be more legal constraints on pedestrians to punish those who cross the road?	Obtaining data on respondents' perceptions of the use of legal constraints.
7	From which sources have you received information about traffic safety?	Obtaining data on respondents' sources of traffic safety awareness education.
8	Do you have any comments or suggestions on how to make improvements to the pedestrian crossing environment?	Obtain data on respondents' perceptions of the street crossing environment.

2.3. Data Collection and Preparation

The semi-structured interview is the primary method of our original data collection. We carry out free conversation according to some themes and scope determined in advance during the interview. The interviews are conducted in a one-on-one format to create a comfortable and relaxed interview atmosphere. Such a format helps us obtain detailed data and gain insight into the true feelings of the interviewees. Taking the driver's standpoint to understand these drivers' perceptions of pedestrian crossing behaviors and the impact pedestrian crossing behaviors have on them. At the same time, the changes in their mental and physical actions in the face of different pedestrian crossing behaviors can also be learned.

Compared with quantitative research, qualitative research can experience the relevant experience from the perspective of the studied target, comprehensively demonstrate the driver's understanding of pedestrian crossing behavior, and find effective methods to solve the pedestrian crossing problem. We hypothesized that an analysis of open-ended questions based on their knowledge and driving experience with pedestrians would reveal a comprehensive understanding of the driver's perceptions and usual rules. Based on the results of this study, detailed policies and measures can be developed by the relevant authorities to mitigate pedestrian and driver conflicts, improve the pedestrian crossing en-

vironment, and enhance traffic safety. The measures include speed limit setting, pedestrian crossing facility installation, crosswalk location design, and potential crossing locations.

2.4. Model Development

The grounded theory method was used to analyze the data. This method is a qualitative tool that uses a systematic procedure that inductively leads to a rooted theory for a phenomenon. The core idea of this theory is to collect a wide range of original materials, dig out the core concepts of the problem under study from the original materials, find the connections between the concepts, summarize them, and finally construct a three-level theoretical model [34].

The primary data were analyzed, and the initial theoretical model was constructed according to the steps of the three-level coding of the grounded theory (see Figure 2) [35]. The coding process is a cascade of open, axial, and selective codings, respectively. The first step is open coding. Original data were examined line by line in order to identify the interviewees' descriptions of thought patterns, feelings, and actions related to the themes mentioned in the interviews. Through open coding, we conceptualize the original data as initial categories. The second step is axial coding. This step requires clustering the related initial concepts into main categories by constantly comparing the logical relationships between the initial concepts. When the relationship cannot be well expressed at one level, the axial coding is divided into two categories: the primary category and the secondary category. The third step is selective coding, which is used to select the core categories. Finally, the logical relationship between the main categories in the primary categories was established, followed by a summary of the core categories and the formation of the three-level theoretical model.

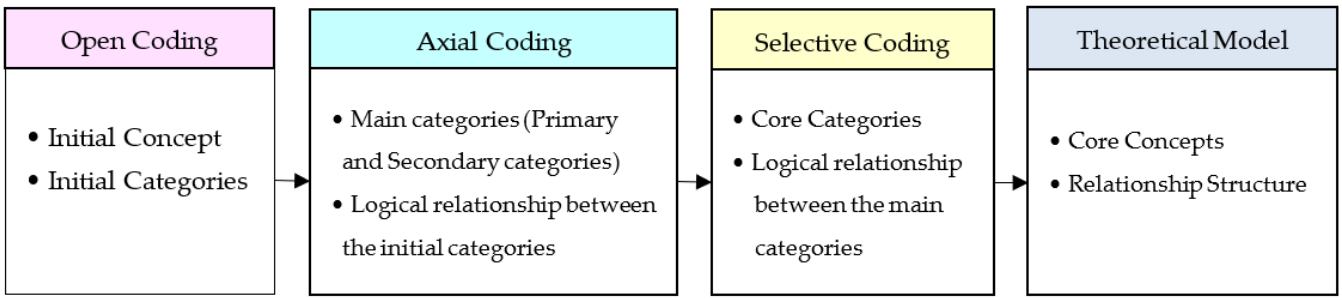

Figure 2. The logical relationship between the three codes and the research categories.

3. Analysis and Results

3.1. Analysis of Interview Data

The data analysis method followed [36]. After each interview, we compared the interview notes and transcribed the recorded content into text materials. Transcription relies on being faithful to the interview, and any missing information should be supplemented by contacting the interviewees as soon as possible. On the other hand, it is necessary to adjust the interview outline, summarize the interview skills, and ensure the accurate and complete data collected during the interview and the subsequent data compilation.

The respondents' answers were closely related to their own driving experience. They preferred to list the events they had encountered and express their views. The interview materials of drivers with 2 degrees of concern are rich and complementary to each other. Therefore, the different degrees of concern of the interviewees in this study had little impact on the research results. The 22 interview materials were used for the grounded theory analysis. The sample size met the requirements of research. After the text transcription was completed, the entire interview material was integrated, and the text material was more than 11,000 words. With the help of NVivo11 coding software, the textual material was open-ended and coded line by line [37], and the text material was cut into nodes and

sub-nodes [36]. The process is also called inductive coding [38], and 316 original codes were obtained.

The new concepts and categories are summarized and finally summarized in a first-level code, resulting in 79 concepts. An in-depth understanding of the concepts' similarities and differences reduces the overlap and redundancy between categories. The associated primary codes are formed into secondary codes (primary categories), 13 in total, and 7 secondary categories. Based on this, this study will use these 13 main categories to build a model of pedestrian crossing behavior and construct the internal relationship between the concepts. Four main categories: crossing state, crossing speed, attention shifting, and mental state, form the pedestrian characteristics. The three main categories of older people, young and children form the age elements. The three main categories of mandatory restraint, public education, and traffic facilities form suggestions for improvement. The three subcategories of unsafe behavior, external factors, and internal requirements form the driver behavior. Two subcategories, traffic environment, and traffic participants, form driver concerns. The two subcategories of information sufficiency and information form safety awareness. Due to the richness of the driver behavior section, the axial code level is further divided into primary and secondary categories. The three main categories of driver behavior, driver concerns, and safety awareness constitute the main categories of driver characteristics. Based on this, this paper will use these 13 main categories to build a model of pedestrian crossing behavior and construct the internal relationship between the concepts. In particular, in the axial coding of driver characteristics, the relationship between concepts could not be well expressed by only one level, so the axial coding was divided into two categories. The final conceptual model was divided into Tables 3 and 4. According to the interviewees' descriptions, some pedestrian violations are shown in Figure 3.

Table 3. The three-level coding process of interview data.

Selective Coding	Axial Coding (Categorization)	Open Coding (Conceptualization)
Pedestrian characteristics	Crossing status	Walking backward; stopping in the road; forcing through; sudden intrusion; eating while crossing; intoxication; starting to cross in front of a crosswalk, forming a curved path; stopping due to an unexpected situation.
	Crossing speed	Crossing slowly; crossing fastly.
	Attention shifting	Swiping on the phone; talking on the phone; listening to music; ignoring the car; chatting; wasting time.
	Pedestrian evaluation	Weak security awareness; lack of manners; lack of responsibility.
Age elements	Older people	Speeding; rushing; rushing with children; passing with caution; hesitation; passing slowly; ignoring cars; bossy; following the crowd; talking and staying.
	Young	Crossing casually; swiping phone; chatting; good manners; fling; bossy.
	Children	Obeying rules; ignoring cars; jaywalking; chatting; passing quickly; frolicking.
Improvement methods	Forced restraint	Fining; legal constraints on pedestrians; legal constraints on drivers.
	Publicity and education	Family, school, and social education; quality improvement; safety publicity; media exposure.
	Facility	Pedestrian overpasses, underpasses; traffic lights; traffic signs; other street crossing facilities.

Table 4. The three-level coding (axial coding with two categories) process of interview data.

Selective Coding	Axial Coding (Categorization)		Open Coding (Conceptualization)
	Primary Category	Secondary Category	
Driver characteristics	Driver behavior	Unsafe behavior	Not slowing down; talking on the phone; paying too much concern about curbside passengers.
		External element	Emotionally disturbed; pedestrians obstructing driving; nighttime environment.
		Intrinsic requirements	Driving skills; personal qualities.
	Driver focuses	Transportation environment	Signals, signs; road conditions; vehicle distances, traffic flow; intersections and directions; dead-ends; weather.
		Traffic participant	Motorcycles, electric bicycles; other motor vehicles; pedestrians.
	Security awareness	Sufficient information sources	TV; driving test; traffic police publicity; friends, work exchange; books; Internet.
		Insufficient information sources	no exposure to such traffic safety information; little exposure to such traffic safety information.

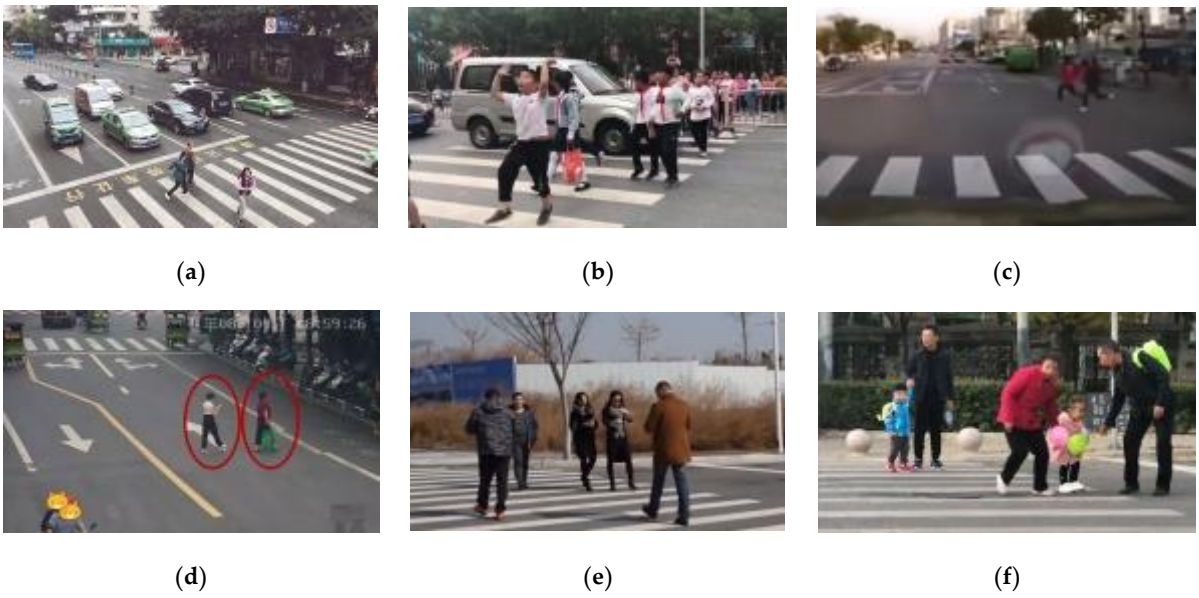

Figure 3. Examples of pedestrian violations. (**a**) Children running; (**b**) playing and chatting; (**c**) children running; (**d**) cross before crosswalk; (**e**) swiping phone; (**f**) rushing with children.

3.2. Theoretical Saturation Test

In order to ensure the validity of the conceptual model, it is necessary to test the saturation of the theory. According to [39], when the reserved interview materials are encoded at three levels, no new categories and relationships are found, and the theoretical model can be considered to be saturated. In this study, two randomly selected interview materials are used for the saturation test, and the results of the data analysis are presented in Table 5.

Table 5. Saturation test.

Selective Coding	Axial Coding (Categorization)	Open Coding (Conceptualization)
Pedestrian characteristics	Crossing status	Sudden intrusion.
	Attention shifting	Eating while crossing, swiping on the phone.
	Pedestrian evaluation	Lack of manners.
Age elements	Older people	Passing slowly; passing fastly; hesitation.
	Young	Swiping on the phone; chatting; wasting time.
	Children	Jaywalking.
Improvement methods	Forced restraint	Legal constraints.
	Publicity and education	Publicity and education.
Driver characteristics	Driver focuses	Vehicle speed; pedestrians.
	Sufficient information sources	Phone; TV.

As can be seen from Table 5, no new important categories and relationships were found formed for any of the four main categories (pedestrian characteristics, age factors, improvement methods, and driver characteristics), and no new initial concepts were found within the four main categories. Therefore, after testing, it can be considered that the theoretical model of pedestrian crossing is saturated.

4. Discussion

Pedestrian crossing behavior occurs in a traffic system consisting of people, vehicles, roads, and the environment, and the subject of the behavior is the pedestrian. Interviews respond that most pedestrians are comparatively aware of safety, but they may have a higher probability and severity of injury when pedestrians behave unsafely. Therefore, this study discusses the pedestrian factors as prevalent and dangerous to pedestrians when crossing streets from the driver's perspective.

4.1. Pedestrian Characteristics

The crossing state includes the physical and psychological state of crossing the street. Walking backward, stopping in the road, forcing through, and bursting in were commonly cited by respondents as unsafe behaviors for pedestrians crossing the street. Stopping in the roadway and walking backward often occurred sequentially and could arise from pedestrian decision-making difficulties, poor mental state, or unexpected circumstances. The forced passage is crossing the street directly regardless of the current road conditions. Suddenly crossing is a situation where drivers encounter pedestrians suddenly without warning, and this behavior is the most frequently mentioned crossing condition by respondents and one of the most feared situations by drivers [40]. For example, a participant (civil servant, driving age: 6 years) "There was a sudden appearance of pedestrians when driving, which was our most fearful encounter; we have to pay attention to these people".

There are two types of crossing speeds: fast crossing and slow crossing, where fast crossing is a behavior that makes drivers more nervous [41]. Respondents mention slow crossing speed as more inclined to be dissatisfied with their lazy attitude when crossing the street and intentionally slow crossing speed without consideration for drivers. Crossing speed is related to the physical fitness of pedestrians and the crossing purpose. Pedestrians with good physical fitness will cross faster than those with poor physical fitness under the same circumstances; pedestrians in a hurry will cross faster than the average pedestrian. In general, fast crossing is more dangerous than slow crossing.

The content of the attention shifting category is the behavior of pedestrians who focus their attention on something other than the act of crossing the street. The respondents mentioned that such attention-shifting behaviors include swiping on the phone, talking on the phone, listening to music, ignoring cars, chatting, and wasting time. Chatting pedestrians tend to look at each other, and attention shifts to the object and content of the conversation, although the sight is not fixed on something such as playing with a phone. However, the lack of concentration on the mind still impacts pedestrian crossing safety [42]. Ref. [43] also confirmed these phenomena. Playfulness is verbal communication and other physical activities with other pedestrians while crossing the street, and this behavior is generally targeted at children and student groups [44]. Pedestrians in pairs of two or more interact with each other, while pedestrians walking alone tend to play with their cell phones, possibly for the reason of hiding their awkward loneliness in the crowd.

The characteristics mentioned above fall under the category of pedestrian distraction and aggressive behavior. Studies have shown that such behavior by pedestrians can cause anger among other road users (e.g., drivers), leading to dangerous confrontations and potential injury or death [45].

4.2. Age Factor

The older people are a headache for drivers from the respondents' comments about them. Older people are the most complex, with each of the three types of seniors having characteristics and differences in unsafe behavior. The first kind is comparatively bold; they cross the street very fast and lack traffic safety awareness with a strong attitude, even with children crossing the street at will. Such as a participant experienced (traffic police, driving age: 4 years) "I have met a very insecure older adult, who not only crossed the street at will, but also rushed with the children". Although some studies have shown that older adults have the slowest average crossing speed [46], this crossing characteristic does exist among them. The second type is very timid; they cross the street cautiously and slowly or even hesitate to stay while crossing, making it difficult for drivers to anticipate. The third type is blindly following the crowd. The quality of many older adults still needs to be improved. Most of the pedestrians crossing the street in Chinese style are older adults who start to cross the street indiscriminately when there are many people. For example, a participant (traffic police, driving age: 6 years) "Many older people are still the Chinese crossing the road, many people will not care, this aspect of awareness will be poor".

Nearly all respondents cited using cell phones by pedestrians while crossing the street, with cell phones playing most prevalent among young people while crossing the street. As mentioned above, playing with a cell phone is distracting, and it is essential to focus on the road and vehicles when crossing the street to ensure safety. However, there are also many young people with high quality. Their awareness of traffic safety is perfect, used to observe left and right before crossing the street, safe before passing, some will even yield to vehicles. For example, a participant (full-time driver, driving age: 13 years) "Most young people will look at the availability of vehicles before deciding to cross the street". Although some drivers mentioned that they are also afraid of such courteous behavior, pedestrians just need to cross the street and do not need to yield to vehicles instead of giving drivers trouble. However, on the whole, traffic safety awareness of pedestrians is still welcomed by drivers.

Like other age groups of pedestrians, children will also chat, not look at the car, and frolic. However, children are also playful, jaywalking, and engaging in dangerous behavior due to the nature of their age. One study comprehensively summarized four types of childhood injuries: childhood medical/developmental factors, family and community factors, psychological/behavioral factors, and traffic factors [47]. The results of our interviews are also included. Most children behave in a more disciplined manner and will cross the street carefully, especially when crossing the street with young parents. This is in agreement with the study of [48]. However, some children do not look at cars when crossing the street, run quickly and playfully, and lack awareness of traffic safety. Several interviewees mentioned

that children's street crossing behavior is related to family education. For example, a participant (company employees, driving age: 10 years) "Children's behavior depends on the family. Some families educate children to cross the road to pay attention to safety, while the children without family education are also rampant running across the street". Children are petite and have unstable behavior trajectories, so they are easily overlooked when they cross the street quickly. Many interviewees believe that children are the most dangerous group among the three groups of older people, young, and children.

4.3. Improvement Methods

Compulsory restraints include restraints on pedestrians and restraints on drivers. At present, Chinese legal restraints on drivers are very sound and strict, while restraints on pedestrians tend to be moral restraints [49]. Although most interviewees hope to have strict legal restrictions on pedestrians, it is not easy to achieve in the actual operation process. The traffic police department can only impose lighter punishments on pedestrians who violate the rules, focusing on education. The means of publicity and education include volunteer guidance, media exposure, home, school and social education, and quality improvement. At the crosswalks in need, arranging volunteers to guide pedestrians to cross the street correctly and safely can improve the quality of pedestrians and the consciousness of crossing the street safely, and at the same time play an educational role. Many pedestrian crossing problems are due to pedestrians' negligence. Educational investment can enhance pedestrians' trust, safety, and comfort [50]. Parents are the children's first teachers, and whether parents educate their children on traffic safety, there are apparent differences in their performance when crossing the street [51,52]. Family and school education should be developed together to create a good atmosphere of traffic safety awareness. Parents' correct guidance and behavioral demonstrations when crossing the street are more effective than other methods [53].

The collisions are caused by the interaction of pedestrians, vehicle drivers, and the environment. In addition to the restrictions on pedestrians and drivers, the street crossing environment such as traffic facilities should be improved. In the unsignalized crossings, traffic facilities are usually set up more straightforwardly, with pedestrian crossing markings as the main. Pedestrian crosswalk markings can guide pedestrians across the street on a safe road, so drivers can see pedestrians and remind drivers to encounter pedestrians there, which plays a vital role in traffic safety. Many interviewees suggested installing signal lights at intersections to separate pedestrians from motor vehicles in time or setting up overpasses or underpasses on roads with heavy traffic to separate pedestrians from motor vehicles in space. In the case of traffic rules, the safety of pedestrians can be guaranteed to the greatest extent. Some interviewees also suggested that signs and markings such as crosswalks should be improved to facilitate the visual recognition of drivers and pedestrians.

4.4. Driver Characteristics

The category of driver behavior includes three subcategories of unsafe driver behavior, external factors, and internal requirements. Drivers' common unsafe behaviors when passing a crosswalk without signal control include not slowing down, making phone calls, and so on. Taxi drivers are a particular group of drivers who are many traffic participants on the road. It is hazardous for them to focus too much attention on pedestrians on the roadside frequently. Although it is a violation of traffic rules not to slow down when passing a crosswalk, some drivers still have a fluke mentality and intend to cross directly. The external factors include pedestrian obstruction to driving, emotional agitation, and night. Stable emotion is indispensable for the driver to achieve driving safety, and emotion affects how the driver handles and reacts to internal or environmental factors [54].

The respondents said that the driver's mood is easily affected by the behavior of pedestrians. For example, a participant (doctor, driving age: 7 years) "There are also pedestrians who scold the street. If you encounter such a pedestrian, I will frustrate him".

Due to the lack of understanding or even verbal abuse from pedestrians or passengers, the driver's mood and psychological state can significantly fluctuate and produce aggressive driving behavior [55,56]. According to a traffic police officer (driving age: 6 years), the night is the time when the most severe traffic crashes occur. At night, the driver's visual adaptation ability is worse and the visual distance is shorter [57], and they are prone to fatigue driving. In particular, drunk pedestrians will appear at night. As a result, the conflicts between drivers and pedestrians are more likely to occur at night [58]. The United States traffic crashes statistics report shows that 70% of pedestrian crashes occur at night [59]. Intrinsic requirements include driving skills and personal qualities. The most basic requirement for a qualified driver is to have good driving skills. Furthermore, a highly qualified driver can have rapid response, self-control, and adjustment capabilities in various complex environments. Be able to respond quickly in emergencies and strictly abide by traffic rules. For example, the driver should decelerate before the pedestrian crossing to ensure that the distance between the driver and other vehicles is greater than the parking sight. The brake can be completed safely and effectively when encountering pedestrians.

Drivers' focuses mainly include the traffic environment and traffic participants. The traffic environment refers to the multi-dimensional and multi-dimensional road traffic driving environment. The traffic environment mentioned by the respondents includes signal lights, traffic signs, vehicle distance, traffic volume, intersections and directions, blind spots, and weather. Vehicles are driving on the road and facing a complex and mobile environment. Most of the interviewees said that they are most concerned about the conditions of pedestrians and surrounding vehicles. In recent years, the food delivery and express delivery industries have risen. The demand for time-sensitive work has caused many food messengers and couriers to drive electric cars or motorcycles fast on the road. For example, a participant (traffic police, driving age: 5 years) "Pedestrians, motorcycles, and electric vehicles broke out suddenly, which is commonly known as the 'ghost probe'". Electric vehicles suddenly turned off at intersections often catch motor vehicle drivers by surprise and cause traffic crashes. Therefore, more attention should be paid to such traffic participants.

Most of the interviewees can obtain sufficient traffic safety information from the Internet. Many interviewees also supported the offline publicity work of the traffic police department. An example is a participant (sole trader, driving age: 12 years) "The traffic police all do safety publicity, such as 122 (a kind of public activity), publicity week, etc". Only two interviewees thought public information on traffic safety was insufficient and had not seen traffic police publicity. Since the two interviewees both live in the suburbs, it can be inferred that traffic police and community publicity are mainly in the main urban areas. On the streets, ignoring the suburban driver groups, the promotion and education of all sectors of society still need improvements.

5. Conclusions

We investigated drivers' perceptions of vulnerable road users (i.e., pedestrians) using qualitative data analysis techniques. The main contribution of this study is the construction of a three-level theoretical model of pedestrian crossing behavior on unsignalized crosswalk roadways based on the driver's perspective by analyzing drivers' open-ended responses and classifying their perceptions and expected regulations of pedestrian crossing behavior.

Conflicts between vehicles and pedestrians at unsignalized crosswalks are one of the leading causes of reduced roadway capacity [60]. Therefore, research on the perception of pedestrian crossing behavior through the driver's perspective has important implications. In this study, we obtained the original data through semi-structured interviews, processed the data using Nvivo11 software, constructed a theoretical model of pedestrian crossing at unsignalized pedestrian crossings based on grounded theory, and proposed improvement measures for the pedestrian crossing environment. In summary, the findings of this study are as follows:

At unsignalized crosswalks, most pedestrians crossed in an orderly manner, looking left and right before crossing and waiting for safety before entering the crosswalk. However, unsafe crossing behaviors still existed, predominately shifting attention to unrelated crossing behavior.

The crossing behaviors of older people, young and children, differ significantly under different age conditions. However, the main reason is not physiological age but non-physiological factors such as educational background, social environment, personality, and safety awareness. As a result, older adults have the most prominent and diverse unsafe behaviors, while children are the most dangerous and young people are the most safety-conscious.

Another reason pedestrians dare to cross the street at will is that they rely too much on drivers, whom they believe are safe drivers and will surely yield to pedestrians. Although drivers have the responsibility and obligation to ensure the safety of pedestrians, drivers are also ordinary people who make mistakes and get distracted at times. Unfortunately, many pedestrians are unaware of this and let their guard down when crossing the street.

At present, China's urban pedestrian crossing facilities have been relatively perfect. The legal constraints on drivers are strict enough, and the fundamental problem lies in traffic safety awareness. Unsafe crossings mainly have weak safety awareness, poor population quality, schools, families, training institutions, and other relevant units should further strengthen the publicity and education. Furthermore, government departments should also actively formulate policies to encourage safety education and improve pedestrian crossing safety facilities according to local conditions, such as adding traffic lights, overpasses, optimizing and adjusting lighting conditions, etc.

This study laid a solid foundation for in-depth pedestrian crossing behavior at unsignalized crosswalks based on rooting theory. However, the study has some limitations. The participants are only from Fuzhou, Fujian, and may not represent other cities in China, and further research may be conducted in various cities. In addition, future developments may focus on the identification of conflicts between self-driving vehicles and the pedestrians crossing the road.

Author Contributions: Conceptualization, Y.Y. and Y.W.; methodology, Y.Y.; software, Y.W.; validation, Y.Y., Y.W. and X.Z.; formal analysis, Y.Y. and S.M.E.; investigation, Y.W.; resources, Y.Y.; data curation, Y.W.; writing—original draft preparation, Y.Y.; writing—review and editing, S.M.E.; visualization, Y.Y.; supervision, X.Z.; project administration, Y.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was approved by the University Human Research Ethics Committee.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Rod, J.; Oviedo-Trespalacios, O.; Senserrick, T.; King, M. Older adult pedestrian trauma: A systematic review, meta-analysis, and GRADE assessment of injury health outcomes from an aggregate study sample of 1 million pedestrians. *Accid. Anal. Prev.* **2021**, *152*, 105970. [CrossRef] [PubMed]
2. WHO. *Global Status Report on Road Safety 2018: Summary*; World Health Organization: Geneva, Switzerland, 2018.
3. Heilig, G.K. *World Urbanization Prospects: The 2011 Revision*; United Nations, Department of Economic and Social Affairs (DESA), Population Division, Population Estimates and Projections Section: New York, NY, USA, 2012; Volume 14, p. 555.
4. Ishiyama, R.; Goto, A.; Nakamura, H. Evaluation of the Unsignalized Two-stage Crossing on Basic Road Sections. *J. Traffic Eng.* **2018**, *4*, A8–A16.
5. Gitelman, V.; Hakkert, S.; Carmel, R.; Pesahov, F. *An Examination of the Influence of Crosswalk Marking Removal on Pedestrian Safety*; Transportation Research Institute Technion-Israel Institute of Technology: Haifa, Israel, 2012.

6. Tezcan, H.O.; Elmorssy, M.; Aksoy, G. Pedestrian crossing behavior at midblock crosswalks. *J. Saf. Res.* **2019**, *71*, 49–57. [CrossRef] [PubMed]
7. Marić, B.; Lipovac, K.; Nešić, M.; Đerić, M. The influence of a countdown display on pedestrian behavior at a signalized pedestrian crossing equipped with a pedestrian refuge island. *Transp. Res. Procedia* **2021**, *55*, 1720–1728. [CrossRef]
8. Brosseau, M.; Zangenehpour, S.; Saunier, N.; Miranda-Moreno, L. The impact of waiting time and other factors on dangerous pedestrian crossings and violations at signalized intersections: A case study in Montreal. *Transp. Res. Part F Traffic Psychol. Behav.* **2013**, *21*, 159–172. [CrossRef]
9. Chebanyuk, K.; Prasolenko, O.; Burko, D.; Galkin, A.; Lobashov, O.; Shevchenko, A.; Usami, D.S.; Persia, L. Pedestrians influence on the traffic flow parameters and road safety indicators at the pedestrian crossing. *Transp. Res. Procedia* **2020**, *45*, 858–865. [CrossRef]
10. Haghighi, M.; Nadrian, H.; Sadeghi-Bazargani, H.; Hdr, D.B.; Bakhtari Aghdam, F. Challenges related to pedestrian safety: A qualitative study identifying Iranian residents' perspectives. *Int. J. Inj. Control Saf. Promot.* **2020**, *27*, 327–335. [CrossRef]
11. Thompson, L.L.; Rivara, F.P.; Ayyagari, R.C.; Ebel, B.E. Impact of social and technological distraction on pedestrian crossing behaviour: An observational study. *Inj. Prev.* **2013**, *19*, 232–237. [CrossRef]
12. Jiang, K.; Ling, F.; Feng, Z.; Ma, C.; Kumfer, W.; Shao, C.; Wang, K. Effects of mobile phone distraction on pedestrians' crossing behavior and visual attention allocation at a signalized intersection: An outdoor experimental study. *Accid. Anal. Prev.* **2018**, *115*, 170–177. [CrossRef]
13. Hanan, S.A.; Said, N.F.; Kamel, A.A.M.; Amil, S.A.F.C. Factors that influences pedestrian intention to cross a road while using mobile phone. *Int. J. Econ. Financ. Issues* **2015**, *5*, 116–121.
14. Wang, T.; Wu, J.; Zheng, P.; McDonald, M. Study of pedestrians' gap acceptance behavior when they jaywalk outside crossing facilities. In Proceedings of the 13th International IEEE Conference on Intelligent Transportation Systems, Funchal, Portugal, 19–22 September 2010; pp. 1295–1300.
15. Marisamynathan; Perumal, V. Study on pedestrian crossing behavior at signalized intersections. In Proceedings of the CICTP 2014: Safe, Smart, and Sustainable Multimodal Transportation Systems, Changsha, China, 4–7 July 2014; pp. 2641–2652.
16. Zito, G.A.; Cazzoli, D.; Scheffler, L.; Jäger, M.; Müri, R.M.; Mosimann, U.P.; Nyffeler, T.; Mast, F.W.; Nef, T. Street crossing behavior in younger and older pedestrians: An eye-and head-tracking study. *BMC Geriatr.* **2015**, *15*, 1–10. [CrossRef] [PubMed]
17. Li, K.Z.; Lindenberger, U. Relations between aging sensory/sensorimotor and cognitive functions. *Neurosci. Biobehav. Rev.* **2002**, *26*, 777–783. [CrossRef]
18. Plumert, J.M.; Kearney, J.K.; Cremer, J.F. Children's road crossing: A window into perceptual–motor development. *Curr. Dir. Psychol. Sci.* **2007**, *16*, 255–258. [CrossRef] [PubMed]
19. Lupton, K.; Colwell, J.; Bayley, M. Aspects of children's road crossing behaviour. *Proc. Inst. Civ. Eng. Munic. Eng.* **2002**, *151*, 151–157. [CrossRef]
20. Rosenbloom, T.; Hadari-Carmi, O.; Sapir-Lavid, Y. Actual and perceived social norms of children's road crossing behavior. *Saf. Sci.* **2012**, *50*, 175–180. [CrossRef]
21. Onelcin, P.; Alver, Y. The crossing speed and safety margin of pedestrians at signalized intersections. *Transp. Res. Procedia* **2017**, *22*, 3–12. [CrossRef]
22. Hashimoto, Y.; Gu, Y.; Hsu, L.-T.; Iryo-Asano, M.; Kamijo, S. A probabilistic model of pedestrian crossing behavior at signalized intersections for connected vehicles. *Transp. Res. Part C Emerg. Technol.* **2016**, *71*, 164–181. [CrossRef]
23. Zhang, W.; Wang, K.; Wang, L.; Feng, Z.; Du, Y. Exploring factors affecting pedestrians' red-light running behaviors at intersections in China. *Accid. Anal. Prev.* **2016**, *96*, 71–78. [CrossRef]
24. Zhao, Y.; Chen, Q.; Qin, J.; Xue, X. Survey of pedestrians' crossing time at non-signalized mid-block street crossing. *J. Adv. Transp.* **2016**, *50*, 2193–2208. [CrossRef]
25. Jamil, R.; Xiong, S.; Kong, X.; Zheng, S.; Fang, Z. Pedestrian crossing patterns preference at a non-signalized crosswalk. *Procedia Manuf.* **2015**, *3*, 3353–3359. [CrossRef]
26. Mohan, D.; Tsimhoni, O.; Sivak, M.; Flannagan, M.J. *Road Safety in India: Challenges and Opportunities*; University of Michigan, Ann Arbor, Transportation Research Institute: Ann Arbor, MI, USA, 2009.
27. Yin, B.; Menendez, M.; Yang, K. Joint optimization of intersection control and trajectory planning accounting for pedestrians in a connected and automated vehicle environment. *Sustainability* **2021**, *13*, 1135. [CrossRef]
28. Owens, J.M.; Greene-Roesel, R.; Habibovic, A.; Head, L.; Apricio, A. Reducing conflict between vulnerable road users and automated vehicles. In *Road Vehicle Automation 4*; Springer: Berlin/Heidelberg, Germany, 2018; pp. 69–75.
29. Combs, T.S.; Sandt, L.S.; Clamann, M.P.; McDonald, N.C. Automated vehicles and pedestrian safety: Exploring the promise and limits of pedestrian detection. *Am. J. Prev. Med.* **2019**, *56*, 1–7. [CrossRef] [PubMed]
30. De Clercq, K.; Dietrich, A.; Núñez Velasco, J.P.; De Winter, J.; Happee, R. External human-machine interfaces on automated vehicles: Effects on pedestrian crossing decisions. *Hum. Factors* **2019**, *61*, 1353–1370. [CrossRef]
31. Cavill, N.; Watkins, F. Cycling and health: An exploratory study of views about cycling in an area of North Liverpool, UK. *Health Educ.* **2007**, *107*, 404–420. [CrossRef]
32. Qi, S.H.; Qiao, Y.S.; Qiao, R.S. Research on the Dimensions of Human Nature Based on Grounded Theory. *Future Dev.* **2020**, *44*, 99–104.

33. Fassinger, R.E. Paradigms, praxis, problems, and promise: Grounded theory in counseling psychology research. *J. Couns. Psychol.* **2005**, *52*, 156. [CrossRef]
34. Glaser, B.G.; Strauss, A.L.; Strutzel, E. The discovery of grounded theory; strategies for qualitative research. *Nurs. Res.* **1968**, *17*, 364. [CrossRef]
35. Wilde, B.; Starrin, B.; Larsson, G.; Larsson, M. Quality of care from a patient perspective: A grounded theory study. *Scand. J. Caring Sci.* **1993**, *7*, 113–120. [CrossRef]
36. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]
37. Seidel, J.; Kelle, U. Different functions of coding in the analysis of textual data. *Comput.-Aided Qual. Data Anal. Theory Methods Pract.* **1995**, *5*, 52–61.
38. Thomas, D.R. A general inductive approach for analyzing qualitative evaluation data. *Am. J. Eval.* **2006**, *27*, 237–246. [CrossRef]
39. Pandit, N.R. The creation of theory: A recent application of the grounded theory method. *Qual. Rep.* **1996**, *2*, 1–15. [CrossRef]
40. Bella, F.; Nobili, F. Driver-pedestrian interaction under legal and illegal pedestrian crossings. *Transp. Res. Procedia* **2020**, *45*, 451–458. [CrossRef]
41. Fitzpatrick, K.; Turner, S.; Brewer, M.A. Improving pedestrian safety at unsignalized crossings. *ITE J.* **2007**, *77*, 34–41.
42. Dıaz, E.M. Theory of planned behavior and pedestrians' intentions to violate traffic regulations. *Transp. Res. Part F Traffic Psychol. Behav.* **2002**, *5*, 169–175. [CrossRef]
43. Zhuang, X.; Wu, C. Pedestrians' crossing behaviors and safety at unmarked roadway in China. *Accid. Anal. Prev.* **2011**, *43*, 1927–1936. [CrossRef]
44. Papadimitriou, E. Towards an integrated approach of pedestrian behaviour and exposure. *Accid. Anal. Prev.* **2016**, *92*, 139–152. [CrossRef]
45. Schwebel, D.C.; Stavrinos, D.; Kongable, E.M. Attentional control, high intensity pleasure, and risky pedestrian behavior in college students. *Accid. Anal. Prev.* **2009**, *41*, 658–661. [CrossRef]
46. Cavallo, V.; Dommes, A.; Dang, N.T.; Vienne, F. A street-crossing simulator for studying and training pedestrians. *Transp. Res. Part F Traffic Psychol. Behav.* **2017**, *61*, 217–228. [CrossRef]
47. Christoffel, K.K.; Schofer, J.L.; Jovanis, P.P.; Brandt, B.; White, B.; Tanz, R. Childhood pedestrian injury: A pilot study concerning etiology. *Accid. Anal. Prev.* **1986**, *18*, 25–35. [CrossRef]
48. Li, P.; Bian, Y.; Rong, J.; Zhao, L.; Shu, S. Pedestrian Crossing Behavior at Unsignalized Mid-block Crosswalks Around the Primary School. *Procedia—Soc. Behav. Sci.* **2013**, *96*, 442–450. [CrossRef]
49. Li, S.; Li, S.; Zhang, Q.; Xue, Y.; Liu, B.; Su, M.; Wang, Z.; Wang, S. Predicting geological hazards during tunnel construction. *J. Rock Mech. Geotech. Eng.* **2010**, *2*, 232–242. [CrossRef]
50. Stewart, L.; Musa, M.; Croce, N. Look no hands: Self-driving vehicles' public trust problem. In Proceedings of the World Economic Forum, Davos, Switzerland, 22–25 January 2019.
51. Holm, A.; Jaani, J.; Eensoo, D.; Piksööt, J. Pedestrian behaviour of 6th grade Estonian students: Implications of social factors and accident-prevention education at school. *Transp. Res. Part F Traffic Psychol. Behav.* **2018**, *52*, 112–119. [CrossRef]
52. Thomson, J.A.; Ampofo-Boateng, K.; Lee, D.N.; Grieve, R.; Pitcairn, T.K.; Demetre, J.D. The effectiveness of parents in promoting the development of road crossing skills in young children. *Br. J. Educ. Psychol.* **1998**, *68*, 475–491. [CrossRef] [PubMed]
53. Duperrex, O.; Roberts, I.; Bunn, F. Safety education of pedestrians for injury prevention: A systematic review og randomised controlled trials. *BMJ* **2002**, *324*, 1129–1131. [CrossRef]
54. Fakhrhosseini, S.M.; Jeon, M. How do angry drivers respond to emotional music? A comprehensive perspective on assessing emotion. *J. Multimodal User Interfaces* **2019**, *13*, 137–150. [CrossRef]
55. Sullman, M.J.M.; Stephens, A.N.; Yong, M. Driving anger in Malaysia. *Accid. Anal. Prev.* **2014**, *71*, 1–9. [CrossRef]
56. Mclinton, S.S.; Dollard, M.F. Work stress and driving anger in Japan. *Accid. Anal. Prev.* **2010**, *42*, 174–181. [CrossRef]
57. Gegenfurtner, K.R.; Mayser, H.; Sharpe, L.T. Seeing movement in the dark. *Nature* **1999**, *398*, 475–476. [CrossRef]
58. Keall, M.D.; Frith, W.J.; Patterson, T.L. The influence of alcohol, age and number of passengers on the night-time risk of driver fatal injury in New Zealand. *Accid. Anal. Prev.* **2004**, *36*, 49–61. [CrossRef]
59. NHTSA. *Department of Transportation Releases Policy on Automated Vehicle Development*; National Highway Traffic Safety Administration, US Department of Transportation: Washington, DC, USA, 2013.
60. Yue, L.; Abdel-Aty, M.A.; Wu, Y.; Yuan, J. An Augmentation Function for Active Pedestrian Safety System Based on Crash Risk Evaluation. *IEEE Trans. Veh. Technol.* **2020**, *69*, 12459–12469. [CrossRef]