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Which factors are related to crossing speed and road violations? A virtual reality study on young people's crossing behavior.

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Abstract

In the literature, numerous studies examined pedestrian behavior within road environments, aiming to contribute to injury prevention. Nevertheless, significant gaps remain, particularly concerning the behavior of young individuals.
The present Virtual Reality experiment aimed at two main objectives: (1) understanding the factors associated with the likelihood of young people violating traffic laws and (2) identifying factors influencing their crossing speed, who faced various pedestrian crossing scenarios designed to induce violations are administered to 63 participants aged 11-17. Three main factors are considered in the analysis: socio-economic characteristics, travel patterns, and behavioral tendencies while walking. The results reveal that students who commute on foot and those residing in larger cities are less inclined to violate traffic laws. Furthermore, individuals who report frequent real-life misconduct are more likely to disregard red lights when crossing a signalized crosswalk in the virtual environment. Differences in average crossing speeds are observed between middle school and high school students, as well as between one-lane and two-lane crossing speeds.

Keywords: Pedestrians, Road Safety, Crossing Violations, Virtual Reality.

1. Introduction

The safety of vulnerable road users is a critical issue in today's transportation system analysis. This group of individuals, which includes pedestrians, micromobility users (e.g., cyclists and scooter drivers), motorcyclists, and individuals with disabilities who use wheelchairs or mobility devices, faces an increased risk of sustaining injury or even fatalities while traveling on roadways. They encounter a complex and dynamic environment characterized by mixed traffic and a diverse range of vehicles, making their vulnerability even more pronounced. These users are more vulnerable due to their lack of physical protection and the limited attention they receive from road safety policies and infrastructure development (OCDE, 1998). In recent years, the issue of road safety for these vulnerable road users has received growing attention from researchers, policymakers, and advocacy groups. The urgency of addressing their unique risks has spurred an expansion in research efforts, aiming to better understand the various factors contributing to their vulnerability.

1.1 Aims of the study

The study is part of the SID project "Safety of Vulnerable Road Users: Experiments in Virtual Environment" (2020–2022), funded by the University of Padua. It represents a unique opportunity to tackle mobility issues using cutting-edge technology. In Italy, such technologies are rarely utilized in this field, and road safety education in schools is limited. This research is innovative in its educational objectives and the tools employed.

Moreover, the project aligns with Sustainable Development Goal, aiming to enhance road safety by 2030 (Agbedahin, 2019; Wismans, Jac; Thynell and Lindberg, 2017). It offers an opportunity to raise awareness about this vital concern among young people. By fostering a culture of safe and sustainable mobility, we can cultivate vigilant road users who are attuned to evolving transportation modes, services, and environmental considerations.

The project's objectives encompass:

- Structuring a process for developing immersive virtual road scenarios for analyzing the safety of vulnerable road users.
- Creating and testing effective immersive virtual road scenarios for assessing the safety of vulnerable road users.
- Identifying strategies to promote road safety culture, including teaching children safe road-crossing methods through risk-free virtual reality experiences.
- Developing a procedure to validate virtual reality as a tool for preventing road accidents.
- Gathering data to design safer real-world infrastructures, such as traffic-calming measures near schools.

While this is an essential first step, students are unlikely to take an interest in the subject until they obtain a driving license. Moreover, as reported by Wang et al. (2020) children are more likely to violate at crosswalks.

The analysis of the behavior of children at intersections in a virtual environment, has not yet been carried out in the literature. Therefore, this work is innovative in both its educational objectives and the techniques used to achieve them, specifically the application of immersive virtual reality.

This works aims to (1) understand which factors are related to the propensity to violate traffic laws among young people at red traffic light and (2) identify which factors affect their crossing speed at signalized and non-signalized intersections. To achieve these goals, violations committed during the “crossing” scenarios with red traffic lights, the crossing speeds of the students in all scenarios and the answers given to a questionnaire were analyzed.

The paper is organised as follows. Section 2 is a review of the theoretical and empirical background for this study. Section 3 reports the methodology followed for this study, describing sample's characteristics, scenarios' characteristics, and experiment design. Section 4 describes the obtained results from the analysis. Section 5 reports the discussion on results. Section 6 concludes the paper with a summary and the possible future activities related to this work.

2. Background

The consensus among reports in the literature is that the likelihood of pedestrian fatalities increases steadily as the speed at which a car collided with them increases (Rosén et al., 2011).

Efforts to improve road safety have indeed been ongoing, with a particular focus on the safety of vulnerable road users. Despite these dedicated efforts, vulnerable road users continue to be involved in a disproportionately high number of accidents and fatalities worldwide. The persistent vulnerability of these individuals calls for a multifaceted approach that combines insights from transportation engineering, psychology, and urban planning to develop more effective protective measures and infrastructure enhancements. According to the World Health Organization, road traffic injuries are one of the leading causes of death among children aged 5-14 years worldwide (World Medical Association, 2013). The same problem is reported at European and Italian level (European Commission, 2022; ISTAT, 2022). In addition, the impact of road accidents on children extends beyond physical injuries and can affect their education, social life, and overall well-being. Many children suffer from long-term disabilities and psychological trauma as a result of road accidents (van Meijel et al., 2019). As such, ensuring the safety of children on roads is of utmost importance. Understanding the factors that contribute to their vulnerability is essential for developing effective strategies to reduce the number of accidents and fatalities involving these individuals.

Virtual reality (VR) can be employed for studying children's road-crossing behavior (Schneider and Bengler, 2020). One of the major benefits of VR is the ability to construct scenarios while controlling all relevant variables, thereby minimizing risks for the participants, especially when compared to the risks inherent in naturalistic research. It has also been demonstrated that VR can be effectively used for children's road safety education (McComas et al., 2002).

Koh et al. (2014) examined the crossing behavior of pedestrians at signalized pedestrian crossings in Singapore, focusing on the violating behavior and investigating relationships between variables such as waiting time, the number of conflicting traffic lanes, conflicting vehicular traffic volume, and personal characteristics of the pedestrian. It was found that the number of passing vehicles and the group-following effect significantly affect the subjects' propensity to violate traffic signals. Moreover, as reported by Cinnamon et al. (2011), pedestrians' misbehavior contributes to their involvement in accidents; it is therefore not correct to assume that accidents involving vulnerable users are always caused by vehicles. Equally important, Lipovac et al. (2013) conducted a study that examined pedestrian behavior in relation to countdown displays at signalized intersections. Their research elucidated that the presence of a countdown display at an intersection did not uniformly decrease the total number of pedestrians moving slowly. However, its effect on specific groups of slow-moving pedestrians, such as children and individuals of different gender, as well as on pedestrians who violated traffic laws, may differ depending on the intersection's location and traffic flow. These findings highlight the intricate interplay between infrastructure design and pedestrian behavior, emphasizing the need for context-specific interventions.

3. Methodology

3.1 Participants

A total of sixty-three volunteers, among which 26 were female, were chosen to participate in the research study. The selected participants comprised middle and high school students, with ages ranging from 11 to 17 years, and an average age of 13.7 years. These students were carefully screened to ensure they possessed normal or corrected-to-normal vision, thus eliminating any visual impairment that could potentially affect the study outcomes.

It is worth noting that none of the selected volunteers had prior experience with the simulator employed in the study. This absence of prior simulator experience was a critical aspect of the study, as it helped to eliminate potential bias that might arise from differing levels of familiarity with the experimental equipment.

Remarkably, throughout the course of the study, none of the participants dropped out due to simulator sickness, demonstrating a high level of engagement and commitment among the chosen individuals. The absence of dropouts due to simulator sickness is a significant indicator of the well-designed experimental conditions and its careful consideration of participant well-being.

For a comprehensive overview of the distinctive characteristics of the experimental sample, please refer to Table 1.

Table 1: Sample's descriptive statistics.

		N	*%*
Totals		63	100
School	Middle school	35	55.6
	High School	28	44.4
Gender	Male	37	58.7
	Female	26	41.3
Origin	Village	45	71.4
	City	18	28.6
Bike usage	Never	12	19.0
	At least once/week	51	81.0
Means used to commute	Walking	26	41.3
	Car	16	25.4
	Bike	1	1.6
	Bus	20	31.7
Total walking time [hours/week]	1-5	10	15.9
	6-10	33	52.4
	11-15	18	28.6
	16-20	0	0
	21-25	2	3.2
Mean walking time [min]	0-15	39	61.9
	16-30	7	11.1
	31-45	5	7.9
	46-60	6	9.5
	61-90	5	7.9
	91-120	1	1.6
Walking reason	Daily main activities	44	69.8
	Free time	15	23.8

Exercise/training	3	4.8
Extra activities	1	1.6

3.2 Pedestrian simulator

The pedestrian simulation system at the Transportation Laboratory (University of Padua) represents a sophisticated technological solution (see Figure 1). It comprises an HP Reverb VR Headset G2 seamlessly integrated with an external HP Backpack VR G2 PC, resulting in a compact, portable, and highly adaptable system. The resolution of 2160 × 2160 pixels and the full RGB stripe display significantly contribute to delivering visually crisp and true-to-life virtual environments. Complementing these visual aspects are integrated speakers developed by Valve, enhancing the immersive nature of the simulation.

This state-of-the-art simulation device serves as a gateway to comprehensive exploration. It offers an accurate free-roam virtual reality experience, enabling an in-depth analysis of pedestrian behavior, particularly in scenarios involving road risk. This tool plays a crucial role in advancing our understanding and enhancing safety in real-world situations.

The device's credibility and suitability for our research endeavors were underpinned by a validation process conducted by De Cet et al. (2022) and Baldassa et al. (2023). This validation not only affirms the device's reliability but also underscores its appropriateness for our research study.

Figure 1: Pedestrian Simulator of Transportation Laboratory - University of Padua.

3.3 Experimental procedure

Participants were initially asked a series of general questions about their mobility habits, and a specific survey was administered to inquire about their behavior as pedestrians (Granié et al., 2013). Successively, participants were required to cross a street in a virtual environment in different scenarios (see Section 3.4). The research investigations took place in suitable locations made accessible by the host institution in Trento and Monselice (both in Italy) in May and June 2022. The testing process was approved by the University of Padua's Ethical Committee for the Psychological Research (protocol number 4700, 29/04/2022) and the study was conducted in compliance with the Declaration of Helsinki, being the World Medical Association's code of ethics (World Medical Association, 2013). Parental written consent was obtained.

Figure 2: Crossing scenario examples (two-way road above, one-way road below; signalized crosswalks on the left, unsignalized crosswalks on the right).

3.4 Scenarios

The experiment consisted of 14 trials preceded by two training sessions. In the trials, participants had to cross on a crosswalk located in an urban setting. Half of the trials took place on a one-way road, the other half on a two-way road. In both single-lane and dual-lane scenarios, each lane had a width of 3 meters. Detailed information about scenario is reported in Table 2 and virtual environment examples are reported in Figure 2; moreover, an overview of the structure of the experiment is shown schematically in Figure 3. Trials' presentation order was random. Moreover, the participants were separated into two groups, with gender being counterbalanced. The Group 1 conducted the training and trials in 1-way manner first, whereas the subsequent group conducted the training and trials in 2-ways manner first, as seen in Figure 3.

In all scenarios there was no traffic, in order to present the participants in a situation in which the choice of committing a crossing violation was viable: the absence of traffic in the environment allowed students to decide when to cross, cancelling the risk of vehicle interference, even in pedestrian red light crossing scenarios.

The scenarios were developed with Unity® software (Unity LTS 2020.3.23f1). Variable sampling frequency was set at 10 Hz. To improve immersion, realistic dimensional criteria were adopted. The design standards for crosswalks in Italy recommend a maximum speed of 1 m/s or less to accommodate people with slower movements. This parameter acted as a reference during the design procedures. Measurements were taken on a real road for the setting of traffic lights and the design of crossings.

During the experiment, subjects' spatial coordinates within the virtual environment have been recorded. This data facilitated the calculation of their instantaneous speeds. Of particular significance was the identification of violations at pedestrian crossings when the traffic signal displayed a red light. The precision of this positional data allowed for a comprehensive analysis of subjects' movements and behaviors. Additionally, this data formed the basis for quantitative analysis, including velocity fluctuations and compliance rates. Speed analysis provided preliminary insights into individual behaviors and decision-making within the virtual environment.

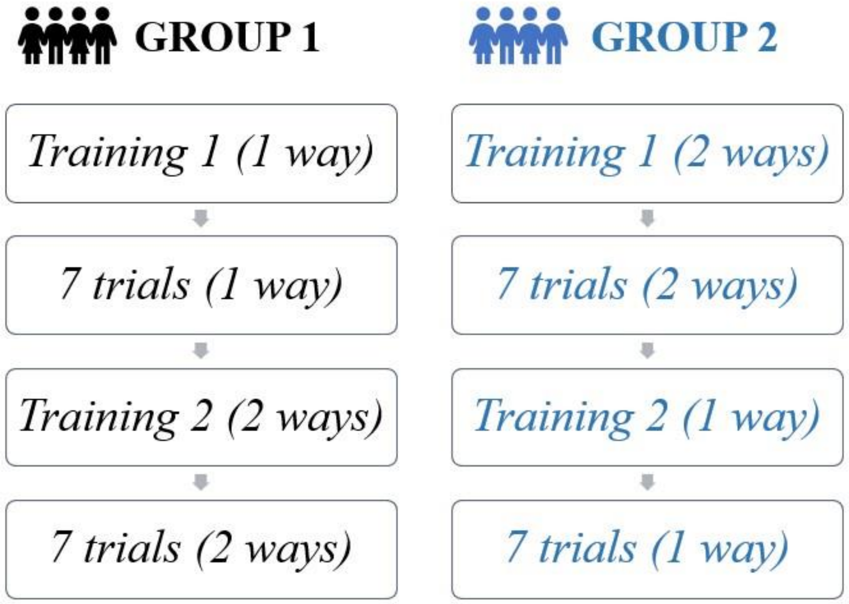

Figure 3: Experimental design.

Table 2: Trials' information.

Type	Ways	Traffic Signal
Training	1 and 2	No
Trial	1 and 2	No
Trial	1 and 2	Turned off
Trial	1 and 2	Green
Trial	1 and 2	Red
Trial	1 and 2	Steady yellow light
Trial	1 and 2	Onset of yellow light when participant is in the middle of the crossing
Trial	1 and 2	Onset of yellow light when the participant steps off the curb

4. Results

4.1 Violation propensity

The following analysis focused only on red traffic light intersection, being the only ones on which a violation is detectable.

During the experiment (see section 3.4), students faced two trials with red light at signalized crossings (one-way and two-way). After 16 seconds, the red light became green. Participants that crossed (at least once) with red light on, have been defined as “violators”. Further considerations and analysis in this Section refer only to such participants. Thirteen violators have been detected (20% of the whole sample). The information gathered through the preliminary survey was used to investigate what factors were related to the propensity to violate. Table 3 shows the list of such factors and their description. ITEM_1, 2, 3 refer to specific items of the self-report questionnaire (Granié et al., 2013). All factors were defined as dummy variables.

Table 3: List of investigated factors – Violation propensity.

Name	Description	Levels
BIKE	Student uses bike at least one/week	0 (no), 1 (yes)
CARRIED	Student commutes with parents (by car)	0 (no), 1 (yes)
COMMUTE	Student commutes on foot	0 (no), 1 (yes)
GENDER_F	Female	0 (male), 1 (female)
HIGH	High school student	0 (middle school), 1 (high school)
ITEM_1	"I look at the traffic light and start crossing as soon as it turns red", sometimes or more	0 (no), 1 (yes)
ITEM_2	"I cross the street even though the pedestrian light is red", sometimes or more	0 (no), 1 (yes)
ITEM_3	"I cross outside the pedestrian crossing even if there is one less than 100 m away", sometimes or more	0 (no), 1 (yes)
LONG_30	Student usually walks more than 30 minutes	0 (no), 1 (yes)
ORIGIN	Student lives in big village/city	0 (no), 1 (yes)
VEHICLE	Student commutes with motorized vehicle (car or bus)	0 (no), 1 (yes)
WALK_10H	Student usually walks more than 10 hours/week	0 (no), 1 (yes)

In order to study the independence (or lack thereof) between the investigated factors and the propensity to violate, Chi-square tests were performed. Table 4 shows contingency table related to each factor. A marginally significant relation has been detected with the habits of commuting on foot (COMMUTE, $\chi 2$ (1, N=63)=3.69, p=.055) and with the habits of strolling more than 30 minutes (LONG_30, $\chi 2$ (1, N=63)=3.06, p=.080). Moreover, several dependencies have been detected: ITEM_2, $\chi 2$ (1, N=63)=7.81, p=.005; ITEM_3, $\chi 2$ (1, N=63)=5.87, p=.015; ORIGIN, $\chi 2$ (1, N=63)=5.43, p=.020.

Table 4: Contingency table – Violator vs. Factors.

	BIKE		CARRIED		COMMUTE		GENDER_F		
VIOLATOR	0	1	0	1	0	1	0	1	Total
0	8	42	38	12	13	37	30	20	50
1	3	10	10	3	7	6	7	6	13
Total	11	52	48	15	20	43	37	26	63
	HIGH		ITEM_1		ITEM_2		ITEM_3		
VIOLATOR	0	1	0	1	0	1	0	1	Total
0	29	21	24	26	44	6	22	28	50
1	6	7	6	7	7	6	1	12	13
Total	35	28	30	33	51	12	23	40	63
	LONG_30		ORIGIN		VEHICLE		WALK_10H		
VIOLATOR	0	1	0	1	0	1	0	1	Total
0	39	11	8	42	24	26	33	17	50
1	7	6	6	7	4	9	10	3	13
Total	46	17	14	49	28	35	43	20	63

In order to understand and interpret the causal relation between these factors and the propensity to violate, a logistic regression was performed with R software (R Core Team, 2020). Obtained results, from an automatic stepwise procedure, are reported in Table 5.

As expected, results were consistent with Chi-square tests. Students who said they commute on foot were less likely to violate laws at signalized crossings (COMMUTE has negative sign); the same goes for those who declared to go to school accompanied by adults and for those who lived in bigger villages or cities. On the contrary, students who declared to cross outside crosswalks even if there is one less than 100 meters away, were more likely to be violators.

Table 5: Propensity to violate – estimated parameters and model statistics.

Variable Name		Coefficients	Std. Error	p-value
Intercept		-1.197	1.343	0.373
WALK_10H		-1.807	1.164	0.120
COMMUTE		-2.040	1.052	0.052*
CARRIED		-2.018	1.218	0.098*
ORIGIN		-2.435	1.142	0.033**
ITEM_2		1.379	0.886	0.120
ITEM_3		4.118	1.781	0.021**
*significance codes: ** p-value <0.05; * p-value <0.10;*				
N. of observation	Null log likelihood	Final log likelihood	Rho-square-bar	AIC
63.00	-32.07	-19.90	0.50	53.80

4.2 Crossing speed

The following analysis focused on all trials described in Table 2. The average crossing speed was calculated on the basis of the speeds of the participants while occupying the roadway, resulting equal to 1.13 m/s. In order to investigate which factors influence crossing speed, several Linear Mixed Models were built with R software, manually selecting independent variables. This modelling approach was chosen because it allowed us to account for the potential dependencies in the data brought about by different participants (Singmann and Kellen, 2019) and because of the distribution of the dependent variable (speed was not normal distributed). Table 6 shows the list of factors used to build the models and their description.

Table 6: List of investigated factors – Crossing speed.

Name	Description	Levels
HIGH	High school student	0 (middle school), 1 (high school)
LANES_MONO	One-way street scenario	0 (two-way scenario), 1 (one way scenario)
LIGHT	Type of traffic signal	see Table.2 for levels
VIOL	Student violated at least one red traffic light	0 (non-violator), 1 (violator)

Results of the estimation process for the best linear mixed model are reported in Table 7. Factors up to the third interaction level were considered. The estimated parameters are not reported in this work; the comment on the significant effects will be interpreted through the analysis of fixed factors and the difference of the marginal means. As it can be seen, a main effect of type of school was detected, F(1,59.18)=7.6, p=.008, with slower speed for younger participants (1.07 m/s for middle school vs. 1.25 m/s for high school). The width of the carriageway significantly influenced the speed of the subjects F(1,69.1)=4.90, p=.030, who moved more slowly in single lane crossings trials (1.11 m/s for single lane crossing vs 1.20 m/s for two lanes crossing). In addition to the direct effect of these variables, their interactions with other factors were also tested. Considering the traffic light color and road width factors interacting, there was a significant effect F(6,654.76)=3.55, p=.002: student crossed more slowly in the one way-green light scenario than in the two-way, no-traffic light, scenario (1.07 m/s vs. 1.49 m/s). Considering the interaction between being a violator, traffic light color, and road width F(6,654.76)=5.08, p<.001, participant that violated had higher speed in non-signalized two-way intersections than non-violator at green light one-way intersections (1.83 m/s vs 1.04 m/s). Being a violator, traffic light color, gender, and other personal characteristics had no significant impact on crossing speed.

Table 7: Results of Linear Mixed Model for crossing speed.

	NumDF	DenDF	F	p
HIGH	1	59.18	7.63	0.008*
LANES_MONO	1	69.1	4.90	0.030*
LIGHT	6	152.13	1.62	0.145
VIOL	1	59.18	0.72	0.399
LIGHT ✻ LANES_MONO	6	654.76	3.55	0.002*
LIGHT ✻ HIGH	6	152.13	2.01	0.068
LIGHT ✻ VIOL	6	152.13	0.78	0.591
VIOL ✻ HIGH	1	59.18	0.02	0.884
HIGH ✻ LANES_MONO	1	69.1	1.96	0.166
LIGHT ✻ VIOL ✻ HIGH	6	152.13	0.75	0.611
VIOL ✻ LANES_MONO	1	69.1	2.91	0.093
LIGHT ✻ HIGH ✻ LANES_MONO	6	654.76	1.90	0.079
LIGHT ✻ VIOL ✻ LANES_MONO	6	654.76	5.08	< .001*
VIOL ✻ HIGH ✻ LANES_MONO	1	69.1	1.49	0.226

*significance code: * p-value <0.05*

5. Discussion

The results that emerged can be summarized as follows: participants who frequently walk (more than 10 hours a week) are less likely to violate; the same goes for those who declared in the survey to commute on foot or be carried by parents; also, people living in bigger cities are less prone to break the rules. These results confirm the findings of Zhang et al. (2016) since the probability of violating rules at intersections tends to decrease when the subject is more accustomed to walking and for reasons related to study/work. On the contrary, students who declare to often cross even if the light is red or outside the markings, are more likely to be violators also in the VR conditions. As observed by Dommes et al., (2015)gender has no influence on the propensity to violate; this result could be contradictory with most of the literature, usually revealing that men are more inclined to violate (Guo et al., 2011; Poó et al., 2018; Rosenbloom, 2009); this difference could be due to the fact that the present analysis referred to a group of relatively young subjects. Furthermore, since students are very similar in age, a significant effect of age on the propensity to violate was not found; supporting this observation, Wang et al. indicated that younger people are generally more likely to violate than adults (Wang et al., 2020). In this case study, the length of the crosswalk (width of the road) did not produce a significant effect on the likelihood to violate; this result is partially confirmed by Diependaele, pointing out that the probability of crossing illegally decreases with the complexity (specifically, number of lanes) of the intersection (Diependaele, 2019). As regard crossing speed, the mean values recorded are consistent with those reported in the literature (Deb et al., 2017). Furthermore, measured speeds are on average higher for high school students, probably because they are older (which reasonably correlates with their height) and more self-confident; in contrast, the highest speeds were recorded with middle school students, probably because they ignore the rule not to cross the road running. No significantly different behaviors were observed for subjects who crossed the street by running a red light, in contrast to what is reported in the literature (Zhang et al., 2016). Gender was not found to be a significant factor in speed either, as reported by Dommes (2015), in contrast to, Goh et al. who reported that men cross the street faster than women, on average, due to a reduced risk perception (Hoe Goh et al., 2012). Also in this case, the difference could be due to the fact that the analyzed sample was made up of children, generally less able to correctly assess risk levels while crossing roads.

6. Conclusions and future activities

The objective of this study was twofold. Firstly, this study aimed to gain insights into the factors that contribute to the propension of young individuals to disregard traffic regulations. Secondly, the research sought to discern variables influencing the speed at which these young participants walked at pedestrian crosswalks.

To accomplish these dual objectives, the investigation involved a multifaceted approach. The analysis encompassed the examination of traffic law violations occurring during simulated pedestrian crossings under conditions where the traffic signal displayed red lights. Additionally, the study inspected the crossing speeds of the participating students, tracking their variations under different experimental scenarios. Moreover, the gathered data included answers given by participants on a questionnaire; this combined approach allowed us to form a comprehensive understanding of the complex interplay between factors influencing both traffic law compliance and crossing speed among the youth.

Among the most important results of the present study, students who usually walk are the least inclined to commit errors and violations of the law. In addition, the highest crossing speeds are recorded in the most dangerous conditions (no traffic lights, wider roads). It is advisable to intervene through the education of the youngest subjects, making them aware of the risks they run as road users. Furthermore, the administration of a self-report questionnaire has proved to be effective in identifying problematic subjects.

The implications of these findings are of high relevance, emphasizing the critical imperative of implementing effective pedestrian safety measures in urban and suburban areas. Such measures are indispensable for reducing the risk of pedestrian-vehicle collisions, and pursuing the cause of safe, sustainable transportation for diverse populations.

Furthermore, this study shed light on the remarkable potential of virtual reality (VR) technology as a tool for analyzing pedestrian behavior under hazardous conditions. This capability not only can support researchers in the comprehension of pedestrian actions but might improve the learning processes related to road safety.

In forthcoming research activities, we aim to replicate real-world intersections, roads and street environment within the Unity platform. This approach will allow us to comprehensively assess the influence of various road environment and traffic flow characteristics. These considerations encompass factors such as the visibility of pedestrian crossings, adequacy of vertical signs and road markings, vehicle types, and operating speeds. These investigations will provide a holistic understanding of the complex interplay between pedestrian behavior and the surrounding road environment, contributing to the ongoing enhancement of pedestrian safety.

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Author contributions

The authors confirm contribution to the paper as follows: Conceptualization, A.B., F.O., G.D.C., M.T. and M.G; software, A.B., F.O., G.D.C.; formal analyses, A.B., F.O.; investigation, A.B., F.O., G.D.C.; data curation, A.B.; writing—original draft preparation, A.B., and G.D.C.; writing—review and editing, A.B., G.D.C., F.O., M.T., R.R., C.V. and M.G; supervision, M.G.; funding acquisition, M.G.. All authors have read and agreed to the published version of the manuscript.