safety

Article

Nudging Safety in Elementary School Zones: A Pilot Study on a Road Sticker Intervention to Enhance Children's Dismounting Behavior at Zebra Crossings

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Abstract

In this pilot study, the crossing behavior of elementary school students commuting on bicycles was investigated with the objective of enhancing safety around pedestrian crossings within school zones. With a noticeable increase in crashes involving young cyclists near schools, this research assessed the effectiveness of visual nudges in the form of red strips displaying "CYCLISTS DISMOUNT" instructions. Initial observations indicated a lack of compliance with dismounting regulations. After the initial observations, a specific elementary school was selected for the implementation of the nudging intervention and additional pre- (N = 91) and post-intervention (N = 71) observations. The pre-intervention observations again revealed poor adherence to the regulations requiring cyclists to dismount at specific points. Following our targeted intervention, the post-intervention observations marked an improvement in compliance. Indeed, the visual nudge effectively communicated the necessity of dismounting at a critical location, leading to a higher rate of adherence among cyclists (52.74% pre-intervention, 97.18% post-intervention). Although it also indirectly affected the behavior of the accompanying adult, who more often held hands with their children while crossing, this effect was weaker than the direct effect on dismounting behavior (20.88% pre-intervention, 39.44% post-intervention). The findings of the current pilot study underscore the possible impact of nudging on behavior and advocate for a combined approach utilizing physical nudges to bolster safety within school zones. Follow-up research, including, for instance, multiple sites, long-term effects, or children traveling alone, is called for.

Keywords: cyclists; zebra crossing; dismounting; safety; nudging

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1. Introduction

More than 6000 children (age ≤ 14) were killed on the roads between 2011 and 2020 in the EU [1]. In 2023, Belgium recorded 5092 injury crashes involving children aged 0–14, with 8 children (0–14) fatally injured [2]. Indeed, road traffic crashes pose a significant threat to global health, particularly affecting vulnerable road users such as pedestrians and cyclists [3,4]. There are several factors that contribute to the increased risk of injury and fatality in traffic for children, for instance, a smaller stature [5]. Young children, in particular, also show innate difficulty in recognizing potential danger [6,7]. According to Schoeters & Carpentier [8], children's development significantly influences their traffic safety. This developmental theory explains that as children grow, they undergo various developmental stages that affect their physical, cognitive, and social skills related to traffic safety. Children typically have underdeveloped senses, a limited field of vision, and struggle with judging the speed and distance of vehicles. Additionally, their auditory skills are immature, making it challenging to identify cars by sound. These limitations, combined with a short attention span and the difficulty of multitasking, make children particularly vulnerable in traffic. This vulnerability is further increased due to choices made by children while commuting. Children engage in risky behaviors at intersection crossings which can lead to crashes, such as crossing without stopping first [9]. Implementing measures to enhance the safety of crossings for children commuting to and from school is imperative, supported by findings emphasizing the need for meticulous design and planning of school zones to enhance children's safety [10].

In Belgium's Flanders region, where Dutch is predominantly spoken, there is a high inclination towards cycling to school (>30%) [11]. The area surrounding school gates becomes congested during the start and end of the school day, posing risks for children walking, cycling, or using steps to cross the road. Most interactions between vehicles and children occur at zebra crossings, which often lack traffic lights. Of particular concern are cyclists being unaware of the necessity to dismount and walk at zebra crossings, exacerbating the danger. Indeed, according to the Highway Code [12], a key distinction is made between zebra crossings for pedestrians and pedestrian crossings for cyclists. The regulation requires that vehicles stop for pedestrians waiting at zebra crossings. However, the situation differs for cyclists; they need to be aware of oncoming traffic, and drivers are only required to yield to cyclists already crossing. When their speed exceeds the speed of walking, people must adhere to cycling rules. Therefore, cyclists need to dismount at zebra crossings.

Nudging strategies provide a framework for influencing behavior through subtle interventions that preserve the autonomy of the individual [13]. A recent review by [14] on nudging better lifestyle behaviors (i.e., sleep, physical activity, and sedentary behavior) in children determined that studies that employ nudges as a single component instead of a multicomponent intervention are scant and that more studies on nudging should be implemented to improve lifestyle behaviors of children. Nudging has already been identified as a useful technique to improve road safety behaviors. These nudges may concern in-vehicle alerts or infrastructural changes in the roadway environment. For instance, the H2020-funded i-dreams project used real-time interventions to target headway, speed, fatigue, and illegal overtaking via symbols on a display [15]. Concerning infrastructural changes, optical pavement markings have already been studied to influence speed and lateral position on the road [16]. Recently, the MeBeSafe project, funded by the EU, developed and tested nudging strategies to promote safer behavior among car drivers and cyclists in traffic situations accompanied by an elevated risk [17]. An example of a nudging strategy from the MeBeSafe project concerned the implementation of lights in the roadway environment that move towards the driver. These lights provide the illusion that you are driving faster, thereby aiming to reduce speed [18,19]. With respect to cycling, flat stripes across the road that gradually get closer give an illusion of speed, with the aim of reducing speed and increasing attention (e.g., towards hazards) [19,20].

Similar to research on other lifestyle behaviors, studies concerning nudging strategies explicitly designed to improve road safety for children appear to be less common. However, this strategy can also be used to gently guide school children to desired behavior, such as dismounting at zebra crossings. An example of a practical nudge could be implementing visual cues to prompt children to dismount from bicycles or scooters at zebra crossings. Considering the issues of young children recognizing danger, as described above, focusing on elementary school zones first appears pivotal. Children attend elementary school from the year they turn 6 until the year they turn 12. To learn if a visual cue can nudge the dismounting behavior of elementary school children, a pilot study was set up within an elementary school environment of the Flanders region in Belgium, aiming to achieve two primary objectives:

1. To observe the crossing behavior of elementary school children with bicycles within the school vicinity.
2. To examine the effectiveness of a nudging approach in improving the crossing behavior of elementary school children.

Considering that elementary school children are often accompanied by their parents or other adults, a secondary objective was posed:

3. To examine whether accompanying adults also adjust their behavior by holding their children's hands more while crossing.

2. Materials and Methods

This research forms part of a broader student project of Hasselt University to identify and address transportation and safety issues in elementary school zones. This study employed an observational approach to document and analyze pedestrian and vehicular interactions at designated zebra crossings within three strategically selected school environments in Geel, Flanders. The project's goal was to develop targeted interventions for identified problem behaviors. The current manuscript focuses on one of the identified issues, dismounting behavior at zebra crossings, together with an identified solution (i.e., visual nudge).

2.1. Preliminary Observation

Observations at the three elementary schools were conducted during peak school hours (i.e., morning, noon, and the end of the school day) to ensure the collection of data reflective of typical school zone traffic conditions. The methodology focused on direct observation of bicycle dismounting at zebra crossings. The observation times started at 08:15 AM in the morning and 15:20 PM in the afternoon. The observer then waited for 10 min after the last child crossed the street and entered the school building.

This study encompassed three elementary school zones, each offering different characteristics.

Top@Punt school: This school is situated in a primarily residential area, designated as a 30 km/h traffic zone, featuring a two-way bicycle path that approaches a zebra crossing, which does not extend over the cycle path. Observational data noted an average of 69 vehicles passing the zebra crossing within a 30 min observation period. Sint-Hubertus school (Saint Hubertus school): This school is located near community hubs that increase pedestrian traffic. The school zone is also marked by a 30 km/h speed limit. Unique to this location is the diversity of vehicle types, including agricultural and freight vehicles, with an average of 220 vehicles observed crossing the zebra crossing during the study period. Sint Dimpna school (Saint Dimpna school): This school is positioned in the city center, characterized by a higher density of zebra crossings within a short distance. Four zebra crossings were present within a span of 85 m along a road where the speed limit is consistently set at 30 km/h. This zone does not feature a separate bicycle path; cyclists share the road with vehicles and are expected to dismount at crossings.

After approval by the municipality of Geel, all three schools provided permission for the observations as well, after being informed about the methods used and parameters observed and collected, together with the efforts made to be GDPR compliant. At each of the three schools, multiple observations were made at different times and on different days. At each school, at least one observation was made in the morning, and one observation was made on Wednesday afternoon or in the afternoon. Several parameters were collected (e.g., looking behavior, accompanying adult, and dismounting behavior). For the preliminary observations, bicycle and step riders were considered as one group to observe with respect to dismounting, since the dismounting rules for both groups are the same.

The preliminary observation facilitated the selection of a specific elementary school for the targeted intervention that should improve dismounting behavior. Sint-Hubertus school (Saint Hubertus school) (Figure 1) was chosen because the results indicated that the children at this school demonstrated the poorest dismounting behavior. During observations at this location, only 29 out of 130 children on bicycles or steps dismounted before crossing the zebra crossing. A significant 78% (101 out of 130 children) did not dismount to cross. A concerning trend was noted among children accompanied by an adult: 82% did not dismount, and the accompanying adults often failed to encourage them to do so. The situation was better at the other two schools, although not all children dismounted before crossing the road either. The highest compliance was observed at the busier Sint Dimpna school (Saint Dimpna school), where 83 out of 102 children dismounted their bicycles or steps. However, even here, 19% (19 out of 102 children) did not comply. At the Top@Punt school, 25.5% (12 out of 47 children on bicycles or steps) failed to dismount before crossing.

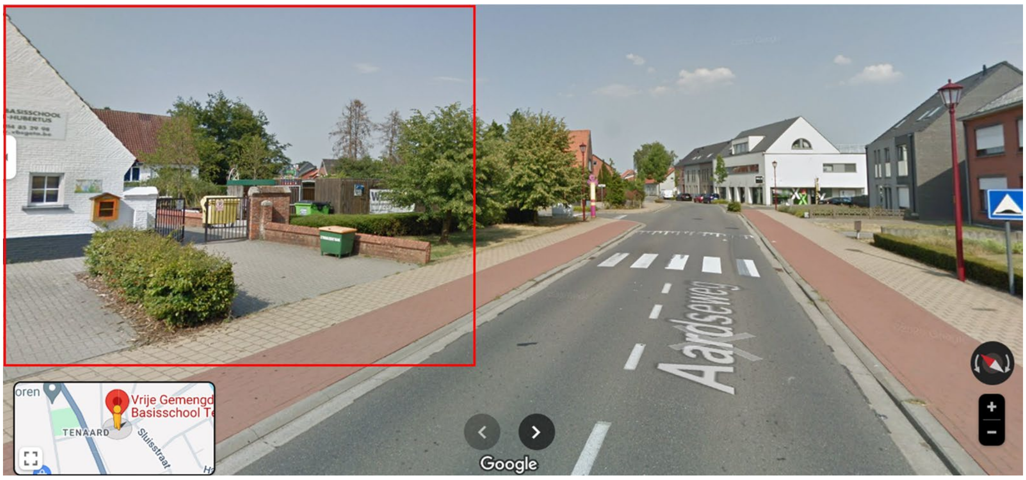

Figure 1. Location of the observed zebra crossing at Sint-Hubertus school (Saint Hubertus school) (the school location is indicated by the red square) (Google, 2019).

2.2. Intervention

The intervention was developed and implemented during the academic year following the preliminary observation. New observations were planned before the implementation of the intervention since some time had passed since the previous observations. Moreover, based on the previous results, Sint-Hubertus School (Saint Hubertus school) posted an item in their newsletters to parents concerning the correct dismounting behavior of cyclists at zebra crossings, which could also lead to improved dismounting behavior compared to the preliminary observations. The newsletter item stated the following: "A zebra crossing is called a pedestrian crossing in the highway code. Therefore, our cyclists, children and parents, must get off their bikes and cross with their bikes in hand at the zebra crossings at the school even if an authorized supervisor is taking care of the crossing. This way, car drivers must give you priority." After the implementation of the intervention, additional observations were conducted. Again, the municipality of Geel and the school approved both the intervention implementation and the observations.

As previously mentioned, the observation times started at 08:15 AM in the morning and 15:20 PM in the afternoon. The observer then waited for 10 min after the last child crossed the street and entered the school building. This time, cyclists and step riders were not merged into one group since the intervention focused on cyclists. Moreover, the number of step riders during the pre-intervention observations was too low to be considered for meaningful analyses (N = 5).

Four pre-intervention observations were carried out (total N = 91) on a Monday and a Tuesday, with one in the morning when the children arrive at school and one in the afternoon when the children leave school on each day. After these observations, a novel intervention was implemented to nudge cyclists to dismount at the respective zebra crossing. This intervention featured a clear red asphalt sticker (size 300 × 40 cm) positioned at the beginning of the zebra crossing (Figure 2). Notably, this red strip was designed to signal potential danger and was accompanied by large, reflective white letters spelling out "CYCLISTS DISMOUNT". This directive served as a reminder for cyclists to dismount and cross while holding their bicycles. The stickers were applied in 2021, 19–23 November, on a Thursday afternoon and removed five days later on Tuesday after a final afternoon observation.

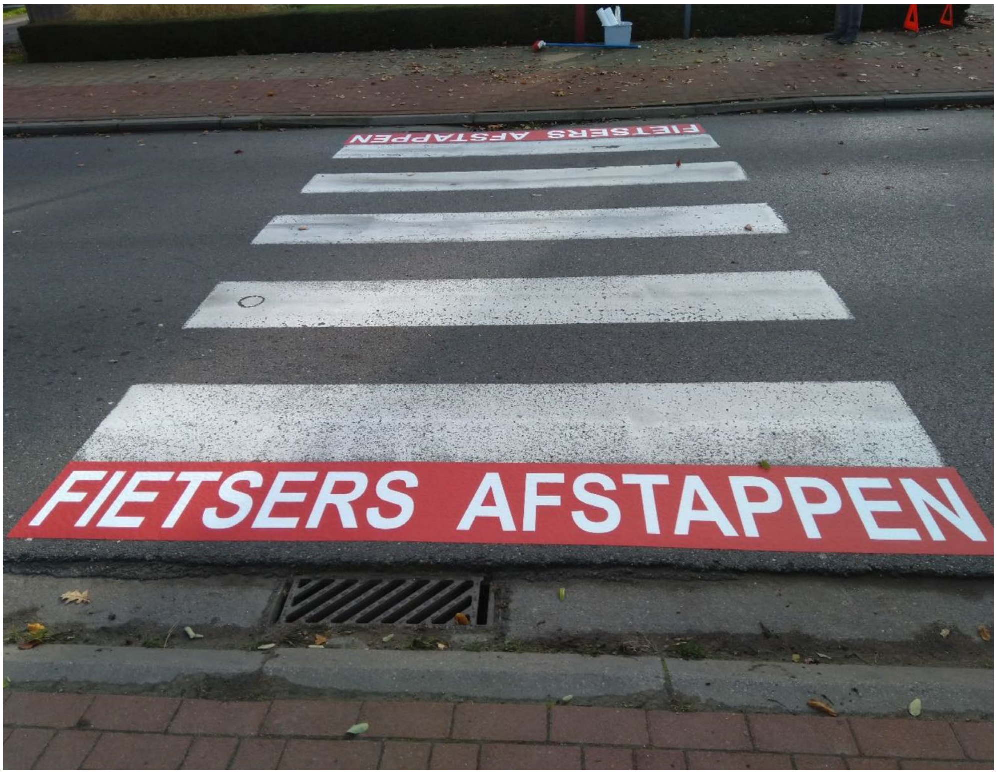

Figure 2. Zebra crossing at Sint-Hubertus school (Saint Hubertus school) with red strips with white letters stating "CYCLISTS DISMOUNT" in the form of asphalt stickers.

During the intervention, again, four post-intervention observations were made (total N = 71). In analogy with the previous observations, these were made on a Monday and a Tuesday, with one in the morning when the children arrived at school and one in the afternoon when the children left school on each day. As mentioned in the objectives, since adults often accompany children, the behavior of their supervisors was observed as well. Table 1 displays the parameters that were collected during the pre- and post-observations. With respect to the children, it was observed whether they dismounted or not. Furthermore, if a supervising adult was present, it was observed whether they held their children's hands.

Table 1. Parameters related to the crossing behavior of children at the Sint-Hubertus school (Saint Hubertus school) zebra crossing.

Children	
Does the child get off before crossing?	1: Yes, 2: No
Is there a supervisor present with the child?	1: Yes, 2: Yes, and the supervisor holds the child's hand, 3 = No

2.3. Data Analyses

To investigate the difference between the distributions of the categories related to children's dismounting behavior between the pre-test and post-test, the Chi-square test was employed (i.e., dismounting by time). The Chi-square test was also applied to investigate the difference between the distributions of the categories related to the behavior of the accompanying adult (i.e., dismounting by supervisor). The Chi-square test was used because both variables under investigation were categorical. This test is appropriate for assessing whether there is a statistically significant association between two categorical variables by comparing the observed frequencies in each category with the frequencies expected under the assumption of independence. Given the sample size and the data structure, the Chi-square test provided a suitable method to evaluate differences in distributions across groups. Since there was only one instance where the child crossed the street without a supervisor present (see Table 2), this category was excluded from the analyses. The significance level was set at $p < 0.05$ (two-sided). In case of significant effects, Cramer's V was used as an effect size. Cramer's V should be interpreted as follows: weak effect ($0.10 \leq V < 0.30$), medium effect ($0.30 \leq V < 0.50$), and strong effect ($V \geq 0.50$).

Table 2. Descriptive statistics.

		Pre-Intervention	**Post-Intervention**
Dismounts	Yes	48 (52.75%)	69 (97.18%)
	No	43 (47.25%)	2 (2.82%)
	Total	91 (100%)	71 (100%)
Supervisor	Yes	71 (78.02%)	43 (60.56%)
	Yes, with handholding	19 (20.88%)	28 (39.44%)
	No	1 (1.10%)	0 (0%)
	Total	91 (100%)	71 (100%)

3. Results

Table 2 includes the descriptive statistics related to dismounting and supervisor behavior. The difference in children's dismounting behavior between pre- and post-intervention was significant ($\chi^2 = 39.25$, $p \leq 0.01$), with a higher bound medium effect size ($V = 0.49$). A total of 52.74% of the children dismounted before the intervention, while a total of 97.18% dismounted after the intervention. The difference in the handholding behavior of the accompanying adults was significant as well between pre- and post-intervention ($\chi^2 = 6.45$, $p \leq 0.01$). A total of 20.88% of the supervisors held their children's hands before the intervention, while 39.44% held hands after the intervention. However, the effect size was weak ($V = 0.20$).

4. Discussion

In the current pilot study, visual nudges were investigated as a means to improve cyclists' dismounting behavior at zebra crossings in elementary school zones. This intervention fits well within the Safe Systems approach that highlights shared responsibility to prevent or minimize injury, with safer roads being one of the initial pillars [21]. More research should investigate the use of nudging techniques to improve the well-being of child road users.

The results showed that stickers including a message for cyclists to dismount before crossing were effective in improving short-term dismounting behavior. Our findings also showed an indirect effect on the behavior of the adults who accompanied the children to school, as the intervention led to increased handholding. The effect size of this finding was small. However, this is not surprising considering the intervention was not targeted at increased handholding while crossing. Moreover, even though the effect size was small, it can still be considered a positive finding since the handholding of accompanying adults results in safer crossing behaviors of child pedestrians (e.g., less distraction [22]). In further support of the intervention, three different superintendents who were present during the observations expressed support for the sticker and noticed that more children dismounted at the zebra crossing because of it. These findings support the use of visual nudges to improve road safety behaviors. This is in line with research performed in the general population. For instance, the above-mentioned experiment by Kovaceva et al. [23] found that visual flat-stripe nudges reduced the speed of leisure cyclists, although the effect was less for commuter cyclists. Related to car drivers, Köhler et al. [24] found that driver speed at highway exits can be reduced by placing lights on both sides of the exit. As another example, in the Netherlands, road signs that contain children's book illustrations were employed to reduce speeds on urban roads. These signs positively influenced drivers' intention to reduce their speed. However, the practical application showed that the actual speed-reducing results were short-lived, with the largest effects appearing in the first week after the intervention [25]. Despite practical initiatives of nudging in the context of road safety, other examples beyond the MeBeSafe project include a Footprint Trail to School (UK) that guides children and aids special-needs kids [26] or colorful art on crosswalks (US) that highlights pedestrian space and should slow down traffic [27]; however, scientific research concerning the use of visual nudges in traffic to improve safety is still limited, especially in children. Although this contributes to the relevance of the current manuscript, follow-up research is called for to draw firmer conclusions on the effectiveness of the current approach. For instance, infrastructural design choices could influence the effect of a visual nudge. In our study location, a 30 km/h speed limit was imposed, and a sidewalk was adjacent to the cycling path. This allowed cyclists to safely dismount and cross the street. Possibly, the nudge would have less effect in more rural areas. Although we specifically aimed at school zones in an urban area, future research should investigate the impact of visual nudges in different settings, including infrastructural roadway environments.

The current study comes with some limitations that lead to more avenues for future research. First, the observations were conducted in a naturalistic setting to reduce researcher bias. However, this also means that the researchers could not control the children and accompanying adults who were observed. This led to a different group being observed during the pre- and post-intervention stages, which could have influenced the results. In relation to this limitation, in this study, we used a Chi-square test to examine differences in dismounting behavior between two time points. The Chi-square test assumes independence between observations; however, because we observed the same school population twice and could not track individual children across the two measurements, it is possible that children were observed at both times. As a result, the independence assumption may be partially violated. While this was the most appropriate test given the available data, the results should be interpreted with caution, and future research should use designs that allow individual-level matching to account for repeated measurements. Second, the observations were made during COVID-19, which could have led to different behavioral patterns. For instance, it is possible that more accompanying adults were present. At this point, we cannot generalize the findings to children who travel alone. Third, a superintendent was present during the observations. Therefore, it is possible that the effect of the intervention was larger compared to situations without a superintendent being present. Fourth, only one elementary school was selected for the intervention, considering that this was a pilot study. Multiple site studies would have made the results more robust. For instance, related to the discussion above, it is not clear if the intervention would lead to similar results for school environments without dedicated infrastructure for cyclists, which is often the case in rural environments. Fifth, for privacy reasons, no videos were made. Therefore, the results depended on the performance of the observer at the scene, which could have included human bias in the results. Ideally, future research would make use of multiple trained observers. In this case, observer ID could be included in the analyses to adjust for between-rater variability. Moreover, sensitivity analysis would allow us to determine the robustness of the results. Sixth, the current study did not include a control group. Ideally, future research would involve a no-intervention control group and an active control group (e.g., educational materials). This approach would allow for determining the effectiveness of nudging compared to more traditional measures aimed at influencing behavior. Seventh, one could debate whether our intervention can genuinely be considered a nudge, as it specifically contained the desired target behavior. Indeed, Kovaceva et al. [23] performed a study in Sweden in which they used visual flat-stripe nudges on cycling lanes at uncontrolled intersections to lower the speed of cyclists. They reported that the measure did not serve as a nudge because cyclists were aware of the intervention on a conscious level. However, considering the formal definition of a nudge, "any aspects of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives" ([13], p. 6), the current measure can still be seen as a nudge. Indeed, although a message to dismount was provided, no consequences were tied to the non-adherence of the target behavior. Moreover, according to Hansen & Jespersen [28], four nudge subtypes can be defined based on two dimensions: processing (automatic vs. reflective) and transparency (non-transparent vs. transparent). According to their framework, the current nudge can be considered reflective and transparent, highlighting specific actions, i.e., dismounting at the zebra crossing. Considering that this type of nudge aims to induce reflective processes, it may work best for older elementary school children with additional cognitive capacities compared to their younger counterparts. This point on age differences leads to the following limitation. Eighth, we targeted elementary school children; however, this age range is quite broad. In an experimental road-crossing study, younger children (5–6 years old) were especially less able to make correct and safe judgments while crossing compared to older children [29]. Therefore, future studies should distinguish between different ages in elementary school children. Ninth, only short-term observations immediately following the implementation of the visual nudges were made. Considering the research by Vlakveld et al. [25] in which they mainly found short-term effects, longitudinal observations are required to determine whether visual nudges can reduce the risky dismounting behavior of children cyclists in the long term. Specifically, a longitudinal follow-up in which dismounting behavior is measured at multiple intervals (e.g., immediately post-intervention, 3 months, and 6 months) is recommended. This timeline allows for assessing whether the observed effect of the visual nudge persists, diminishes, or changes over time, thereby providing critical insight into its long-term efficacy. Nevertheless, these short-term results already indicate the promise of visual nudges to positively influence cyclists' behavior at zebra crossings in elementary school zones, leading to positive effects on traffic safety. Finally, infrastructural-related changes do not allow for personalized variation in the used nudges. Meanwhile, recent research by Zadka-Peer & Rosenbloom indicates that personalization of nudges can lead to better effects [30]. However, their research targeted car drivers, a context in which in-vehicle technology more easily allows for the personalization of nudges. Nevertheless, future research should consider testing different types of visual nudges to find the one that best fits the target population. Moreover, Schwartz et al. [31] demonstrated that a simple auditory prompt can boost fruit consumption among elementary school children. Building on this, future research should explore alternative delivery modes, such as verbal or tactile cues. Moreover, multimodal interventions could be considered. For example, Yaqub et al. [32] showed that pairing visual reminders with verbal prompts yielded the highest rates of hand hygiene compliance in a Nigerian tertiary hospital. Combining sensory channels may enhance the effectiveness of nudges, which warrants further investigation in school environments.

5. Conclusions

In this pilot study, the effect of a visual nudge on the dismounting behavior of children cyclists was explored, aiming to promote safety habits. The findings demonstrate that the visual nudge effectively influenced dismounting behavior. Moreover, it indirectly led the accompanying adults to increase handholding behavior while crossing. Unsurprisingly, as handholding behavior was not directly targeted, this effect was weaker compared to the direct effect on dismounting behavior. These findings suggest that visual nudges can be useful in reducing risky dismounting behavior at zebra crossings in elementary school zones. However, only short-term behavioral changes immediately following the implementation of the nudge were assessed. While these preliminary results are promising, more research, including long-term follow-up studies, additional study sites, children traveling alone, attention to age differences, and different types of nudges, is essential to draw firm conclusions on the usefulness of visual nudges on cyclists' dismounting behavior over time.

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