The safety and conspicuity of pedestrian crossing at roundabouts: The effect of median refuge island and zebra markings

Published Version:
Valeria Vignali, M.P. (2020). The safety and conspicuity of pedestrian crossing at roundabouts: The effect of median refuge island and zebra markings. TRANSPORTATION RESEARCH PART F: TRAFFIC PSYCHOLOGY AND BEHAVIOUR, 68, 94-104 [10.1016/j.trf.2019.12.007].

Availability:
This version is available at: https://hdl.handle.net/11585/732425 since: 2024-07-05

Published:
DOI: http://doi.org/10.1016/j.trf.2019.12.007

The safety and conspicuity of pedestrian crossing at roundabouts: the effect of median refuge island and zebra markings

Valeria Vignali, Margherita Pazzini, Navid Ghasemi, Claudio Lantieri, Andrea Simone, Giulio Dondi

Department of Civil, Chemical, Environmental and Material Engineering (DICAM), University of Bologna, Viale Risorgimento 2, 40136, Bologna, Italy

Abstract

Roundabouts are one of the most used road intersections because, compared to signalized ones, they reduce conflict points between traffic flows and moderate driving speed. Great attention should also be paid to vulnerable road users at roundabouts. According to accident statistics, in fact, accessibility of pedestrians and cyclists is not always ensured.

This paper has evaluated the effects on the visibility of pedestrian crossing before and after the displacement of zebra markings, moved before intersections, and the introduction of media refuge islands and "Yield here to pedestrians" vertical signs. The above effects have been assessed by before-after analysis of speed and visual behaviour of drivers approaching the crosswalk.

Moreover, the analysis of the drivers' eye movements has highlighted the most salient elements of the pedestrian crossing. The relation between the drivers' visual behaviour and the vehicle speed have also been calculated. Results have confirmed that the intervention carried out has increased both visibility and safety of the studied pedestrian crosswalks.

Zebra markings and the median refuge island have turned out to be the most glanced elements, respectively seen by 93.75% and 56.25% of the drivers, followed by the ''Yield here to pedestrians" vertical sign. The mean distance of first fixation of the crosswalk increased from 21.98 m before the intervention, to 40.69 m after it. The drivers perceived the pedestrian crossings from a longer distance after the intervention, and they continued to glance at the crosswalk while approaching it, enhancing their visual attention.

Keywords:

Eye tracking; Pedestrians; Driver behavior; Roundabout; Median refuge island; Zebra markings; Urban road; Conspicuity; Road safety; Vertical sign.

1 Introduction

Road safety is influenced by road design and signalling which affect the drivers' perception of the external environment and the possible dangerous situations (Bucchi, Sangiorgi, & Vignali, 2012; Dondi, Simone, Lantieri, & Vignali, 2011). In recent years an increasing attention has been paid to traffic problems which could modify the drivers' cognitive and emotional condition (Chu, Wu, Atombo, Zhang, & Özkan, 2019). Driving is a complex situation, requiring a constant attention and prompt reactions to fast changes. During long trips, the drivers' behaviour might result into stressful responses due to an excessive cognitive workload (Ringhand & Vollrath, 2019).

In order to increase safety, fluidity of road traffic and to reduce the velocity, roundabouts are often built especially in urban areas (Hydén & Várhelyi, 2000). They allow a higher entry capacity than grade intersections and a reduction of conflict points, from 32 for a grade intersection, to 8 in case of a roundabout (Gross, Lyon, Persaud, & Srinivasan, 2013; Turner, 2011). In addition to facilitating the traffic flow, roundabouts also reduce the velocity and the drivers' stress (Hydén & Várhelyi, 2000). The negative aspects of roundabouts are linked to crosswalks which reduce the roundabout capability and are critical points as far as pedestrian safety is concerned (Bergman, Olstam, & Allström, 2011; Meneguzzer & Rossi, 2011; Vijayawargiya & Rokade, 2017). Studies related to roundabout safety have generally focused on drivers, overlooking the importance of safety of the vulnerable users, pedestrians and cyclists (Perdomo, Rezaei, Patterson, Saunier, & Miranda-Moreno, 2014). In urban areas, pedestrians need to cross at intersections, and zebra crossings are often present close to access and exit ramps of roundabouts. Pedestrian crosswalks at roundabouts are useful for pedestrians and increase safety. They should be placed in a proper way both to attract the maximum number of pedestrians, who would otherwise cross the street at random, and to give drivers enough time to stop safely (Cohen, Bar-Gera, Parmet and Ronen, 2013).

Recent studies have shown the importance of a correct design for pedestrian crossings at the intersections. More attention should be paid to pedestrian safety, as the number of victims among people crossing at intersections is constantly increasing year after year (Bungum, Day, & Henry, 2005; Olszewski, Szagała, Wolański, and Zielińska, 2015). Literature does not suggest many countermeasures aimed at reducing the problems for pedestrians crossing at roundabouts (Perdomo et al., 2014). Anyway, a significant reduction of speed of vehicles in a complex road environment, such as collector roads provided with signalled intersections, roundabouts, road circles or stop signs, would be highly recommended and it can only be obtained with different multi-purpose countermeasures.

A refuge island, for example, makes the road narrower thus slowing the traffic. It also helps drivers to realize that pedestrians are crossing the road. Pedestrians may also stop on a refuge island and cross the road in two stages, increasing the attention paid at the traffic in both directions. Refuge islands are widely self-explaining, and they immediately give the idea of a not fast traffic road (Leden, Gårder, & Johansson, 2006; Sanca, 2002). Literature shows evidence of a significant speed reduction of vehicles in the presence of a refuge island (Fildes, Fletcher e Corrigan, 1987; Kolsrud, 1985; Vey & Ferreri, 1968; Yagar e Van Aerde, 1983). Mako (2015) has shown that implementation of refuge islands at pedestrian crossings has reduced the number of fatalities for pedestrians by 64%. Without a refuge island the drivers' movement is 4% more irregular than in presence of a refuge island. As for pedestrians, without a refuge island they tend to cross irregularly instead of waiting for a vehicle to stop giving them the priority.

Curb extensions may also help vehicles to slow down while approaching a pedestrian crossing. Extensions of a sidewalk edge are commonly present along roads with parking areas on the lane side. These extensions increase the visibility of pedestrians and reduce the drivers' speed behaviour inducing prompt yielding (Hawley, Henson, Hulse, & Brindle, 1992; Huang & Cynecki, 2001; Macbeth, 1995; Replogle, 1992). Bella and Silvestri (2015) have proved that more than 80% of the drivers they tested clearly perceived the effectiveness of curb extensions. This means that, in presence of curb extensions, the drivers were much more prompt to yield since pedestrian crossings were better seen.

Prompt yielding is often the response to "Yield here to pedestrians" vertical signs. These are mounted on poles on the right side at crosswalks or on supporting arms over the traffic lanes (Beeber, 2011). To improve their visibility, LED flashes with an irregular flash pattern can be mounted, too. Van Houten, Ellis and Marmolejo (2008) showed that LED flashers installed on simple pedestrian signs, increased the drivers' yielding and reduced evasive manoeuvres as well as the number of pedestrians trapped in crosswalks at the centre of the road without a refuge island. Sherbutt, Van Houten, Turner and Huitema (2009) carried out three different experiments on the effects of flashing pedestrian vertical signs on drivers' behaviour. The results showed an increase of yielding from 18.2% to 81.2%. Bram De Brabander Lode Vereeck have shown that the number of accidents with serious injuries involving vulnerable road users increased at intersections with no signalization before the roundabout.

A further countermeasure may be guardrails at roundabouts. These direct pedestrians to safe crossing areas and prevent bursting into the road (Retting et al., 2003). The main benefits of installing guardrails are channeling pedestrians to the crossing (Stewart, 2007) and making footpaths safer. Cohen, Bar-Gera, Parmet and Ronen (2013) have shown that the number of pedestrians jaywalking with no guardrails at a roundabout exceeds 20-30% the number of pedestrians committing the same violation when guardrails are installed.

Although any countermeasures aiming at increasing safety of pedestrian crossings are very important, the drivers' behaviour should also be taken into consideration. Getting closer to a roundabout, drivers are often distracted and do not pay attention to the road environment, including crosswalks. Inattention of drivers causes most of the accidents (Xu et al., 2018). Electronic and radio devices present inside the vehicle and used while driving, in addition to other distractors including the road environment, are the main causes of the drivers' inattention and carelessness (Oviedo-Trespalacios, Haque, King, & Washington, 2017). High speed of vehicles approaching a roundabout along with drivers' lack of attention represent the main problems for the safety of pedestrians crossing at roundabouts (Vijayawargiya & Rokade, 2017; Fortuijn, 2003; Gross et al., 2013). Speed reduction of vehicles is one of the key elements to reduce the probability of death of pedestrians involved in an accident (Gonzalo-Orden, Pérez-Acebo, Unamunzaga, & Arce, 2018; Guo, Liu, Liang, & Wang, 2016; Hakkert, Gitelman, & Ben-Shabat, 2002; Haleem, Alluri, Gan, 2015; Kröyer, Jonsson, Várhelyi, 2014; Rosén & Sander, 2009; Rosén, Stigson, Sander, 2011; Tefft, 2013; Zeeger & Bushell, 2012).
However, the present traffic safety laws (road safety measures) are not to be the only instrument capable of reducing the number of accidents and fatalities (Ward et al., 2010). In fact, a road safety culture should be established, both for drivers and pedestrians (Chu et al., 2019; Obeng-Atuah, Poku-Boansi, & Cobbinah, 2017). A road safety culture, deep-rooted in society, sounds like a long-term project not easy to be achieved, anyway. On the contrary, road infrastructure, especially at crosswalks near roundabouts, might be immediately improved in order to increase pedestrian safety and drivers' perception of the risk. Many studies with positive results have been taken into account aiming at improving road safety while reducing drivers' speed in proximity of pedestrian crossings (Bella &Silvestri, 2015; Gonzalo-Orden et al., 2018a). These studies usually rely on motion parameters, such as the operating speed or the stopping distance. They do not consider the drivers' behaviour in terms of detection and perception of crosswalk elements at the roundabout, whereas these parameters are very important to assess the drivers' attention level and hazard anticipation. An eye-movement recording tool can be very useful for this purpose since it allows a quantitative assessment of the drivers' risk anticipation when approaching a roundabout (Costa, Bonetti, Bellelli, Lantieri, Vignali, & Simone, 2017; Kapitaniak, Walczak, Kosobudzki, Józ´wiak, & Bortkiewicz, 2015; Taylor et al., 2013; Topolseket al., 2016; Ghasemi et al., 2019).
Assessing the driver's vision may be useful to point out safe or unsafe behaviours on roads. Eye tracking is used to evaluate the drivers' perception and acknowledgments of the road elements as well as to develop driving strategies and prevent crashes. According to several studies, the drivers' visual inattention is responsible for a large amount of traffic accidents (Bongiorno, Bosurgi, Pellegrino e Sollazzo, 2017; Costa, Simone, Vignali, Lantieri, Bucchi, & Dondi, 2014; Costa, Bonetti, Vignali, Lantieri, & Simone, 2018; Costa, Simone, Vignali, Lantieri, & Palena, 2018; Costa et al., 2019; Di Flumeri et al., 2018; Inman, 2012; Kapitaniak et al., 2015; Lantieri et al., 2015; Mantuano, Bernardi, & Rupi, 2017; Vignali et al., 2019). In order to prevent those accidents, some studies have been carried out about the driving behaviour using the mobile eye tracking tool. This methodology is particularly interesting when analysing the driver-pedestrian interaction. Only a few studies have applied this method by now (Trefzger, Blascheck, Raschke, Hausmann, & Schlegel, 2018) most of which take only the pedestrian behaviour into consideration (Biassoni, Confalonieri & Ciceri, 2018; Bock, Brustio & Borisova, 2015; Davoudian & Raynham, 2012; Fotios, Uttley, & Hara, 2013; Trefzger et al., 2018; Zito et al., 2015). An exam of the drivers' behaviour when approaching a crosswalk was carried out by Ciceri, Ruscio, Confalonieri, Vangi and Virga (2013). They set different road situations and the outcome was that a complex street environment, with a lot of road signs, resulted into a lack of attention from the driver towards the pedestrian. The driver, in fact, realized the movement of pedestrians on the crosswalks quite late.
Moreover, using the eye tracking measurements Grüner et al. (2017) studied the difference between the driver's behaviour in urban and rural roads. The results showed a higher number of driver's eye movements in residential areas compared to city roads. This means that the less the traffic is, the higher the driver's expectation of a careless behaviour of pedestrians when crossing roads will be.
In addition to this, according to the studies carried out by Dukic, Ahlstrom, Patten, Kettwich and Kircher (2013) and Maxera, Kledus and Semela (2015), eye tracking measurement proved that drivers always detected pedestrians late when driving at night. Increasing size and visibility of an object, making it more illuminated and salient for example, proved to be useful to avoid the problem. This can be applied both to objects and pedestrians by using different marking patterns (Muttart, Dinakar, Vandenberg, & Yosko, 2016; Crescenzo et al., 2019).
Using a simulator, Fisher and Garay-Vega (2012) compared the drivers' behaviour at crosswalks signalized by mid-blocks, advanced yield markings and "Yield here to pedestrians" vertical signs to crosswalks showing just standard markings. In the former situations the drivers' behaviour consistently changed reducing pedestrian-vehicle crashes and increasing the drivers' attention towards pedestrians. The distance at which a pedestrian was first seen increased and the drivers performed a prompt yielding. Gómez et al. (2013) confirmed the above issues. With advance yielding markings fewer accidents occurred and drivers payed a higher attention to pedestrians. Most of these studies, anyway, used eye-movement tracking with simulators but not in real traffic environments. Moreover, while using the same methodology, these research studies have analysed the detection of pedestrians by drivers but only few of them focused the attention on factors improving the real crosswalk conspicuity.

The aim of the present study, on the contrary, was a before-after evaluation of a combined intervention on pedestrian crossings near roundabouts in a real road context, assessing both vehicle speed and eye-movements approaching a sequence of crosswalks before and after the intervention.
Four crosswalks were included in the study. Specifically, the crosswalks were moved further before the intersection, median islands were added, and a “Yield here to pedestrians” vertical sign was added. This intervention at roundabouts is of simple installation and it may be of high effectiveness on the drivers’ behaviour.

2. Materials and methods

2.1 The experimental protocol

Ten drivers, 3 males (M_{age} = 28.87 years, range: 23–39, SD = 8.96) and 7 females (M_{age} = 35.86 years, range: 25–52, SD = 10.79), were recruited and involved on a voluntary basis in this study. They had normal vision and none of them wore eyeglasses or lenses, to avoid artefacts in eye-movement monitoring. All participants had a Category-B driving license (for cars) and no prior driving experience on the road segment object of study, in order to control the effect of familiarization with the road environment.
The experiment was conducted following the principles outlined in the Declaration of Helsinki of 1975, as revised in 2000. Informed consent and authorization to use the video graphical material were obtained from each subject on paper, after the explanation of the study. One car was used for the experiment, with diesel engine and manual transmission. The subjects had to drive the car along a circuit designed to include the four pedestrian crossings object of study placed along the routes via Testi and via Fornarina, a single carriageway-two lanes road, located in Faenza in the north of Italy, in the Emilia Romagna region. These two roads connect the centre of the town to its suburbs. The circuit was 1.52 km long, with a width of about 9.00 m (two 3.00 m wide lanes and one 1.50 m wide sidewalk) and the speed limit was fixed at 50 km/h (Fig. 1). The route also included two mini roundabouts, spaced at 340 m, the first one located between via Testi and via Cesarolo and the second one between via Fornarina and via Saviotti. The pedestrian crossings were placed on straight sections before and after the two roundabouts, at an average mutual distance of about 22 m.

Figure 1. Outline of the experimental route. In red the mini roundabouts object of study.

The route was characterized by the highest number of accidents in the Province of Faenza in the years 2009-2011, with 12 injured, number which involved very high social costs. The main accident causes were the drivers’ distraction and high-speed driving which increased both vulnerability of weak users and car-pedestrian crashes. To solve this problem, different safety countermeasures had been installed in order to slow down vehicles approaching the four pedestrian crossings object of study.
Before the works, all crosswalks had white zebra markings, with stripes which were 1.50 m long, 0.50 m wide and spaced 0.50 m from each other according to the Italian Highway Code (Ministry of Infrastructures and Transports, 1992). These zebra markings were positioned after the roundabout stop line. Only two of them had standard vertical ‘‘Yield here to pedestrians” signs, one for each side, placed on the sidewalk of the road in proximity of the markings (Fig. 2).

Figure 2. Pedestrian crossing design before the works.

After the works, all crosswalks were characterized by (Fig. 3):

- median refuge island, allowing a safer and easier two-stage crossing for pedestrians. According to the Italian Highway Code (Ministry of Infrastructures and Transports, 1992), it was 4 m long and it had a continuous boundary marking and a 0.10 m high curb. A yellow reflective obstacle delineator, coupled with the sign "passage allowed to the right", was installed on the curb nose;
- white zebra markings, which were moved in advance of the intersection and positioned 10 m before the roundabout stop line, in order to increase pedestrian safety with vehicles approaching the intersection;
- kerb ramps, improving mobility of people with disability, on both sides of the road;
- ''Yield here to pedestrians" vertical signs, on the right side of the road, one on each side.

Figure 3. Pedestrian crossing design after the works.

Apart from the introduction of median refuge island, zebra markings displacement in advance of the intersection, and the improvement of "Yield here to pedestrians" vertical sign, the design of pedestrian crossings was the same as before. Each subject had to repeat the driving task two times on different days, before and after the works (Fig. 4).
Data collection started at 9 a.m. and finished at 1 p.m. on two different days, always in summer, in a period with low traffic and good meteorological conditions. The two driving tasks were conducted in the same conditions in terms of weather, visibility conditions and traffic driving scenario. In this study the pedestrian presence near the crosswalk was not considered.
Participants didn't know the route in advance. At the beginning of the "after" study, participants were asked whether they remembered of the "before" task and nobody identified any elements of the route.

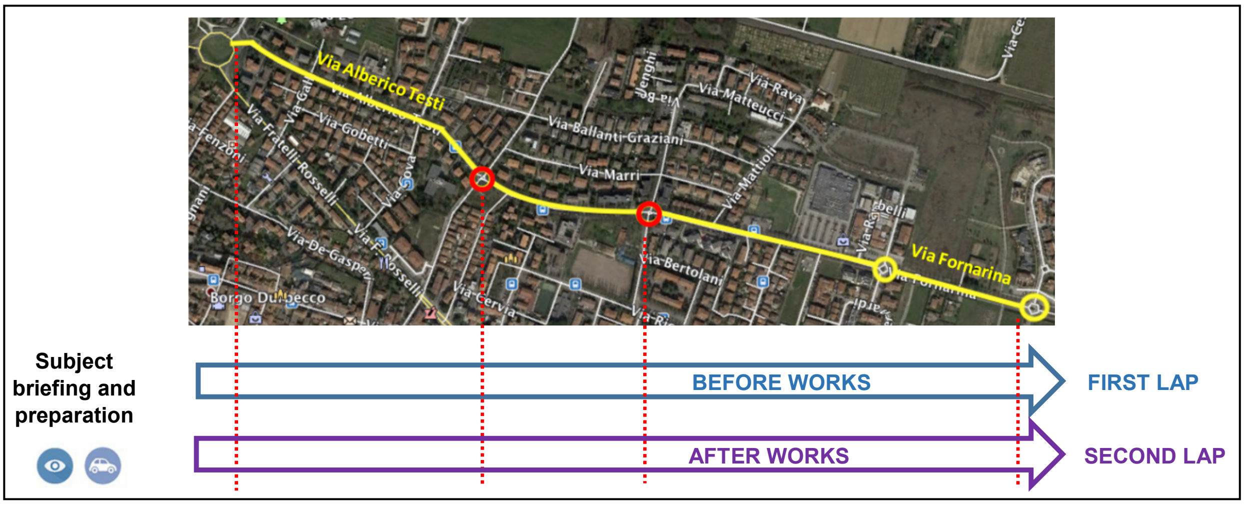

Figure 4. Overview of the experimental protocol, consisting of two driving tasks, 1.5 km from via Testi to the end of via Fornarina, performed before and after the works.

During the whole experimentation, an ET device recorded the eye gazes while a professional device mounted on the car (a Video VBOX Pro) detected data about the drivers' behavior. Eye movements of participants were recorded through an ASL Mobile Eye-XG device (ET), a system based on lightweight eyeglasses equipped with two digital high-resolution cameras, one recording the right eye movements, and the second one recording the visual scene. Not to obscure the normal field of view of the drivers, a mirror capable of reflecting the infrared light was installed in the eye camera recording the activity of the right eye. As already tested in Costa et al. (2014), the sampling rate for the eye-movement recording was 30 Hz (33 ms time resolution) with an accuracy of 0.5÷1° (approximating the angular width of the fovea).
A preliminary calibration procedure was carried out for each subject inside the car before starting driving, asking them to fix their gaze on thirty fixed visual points spread across the whole scene, in order to get a good accuracy of the eye movement recorder. A video for each participant was created using the ASL software with a cross superimposed to the scene showing the eye fixations. This allowed researchers to detect the sequence of points of the scene fixed by the driver. The car was equipped with a Video VBOX Pro (Racelogic Ltd), a system able to continuously monitor the cinematic parameters of the car, integrated with GPS data and videos from four high-resolution cameras. The system was fixed inside the car, in the center of the back floor, in order to put it as close as possible to the car barycentre, while two cameras were fixed over the top of the car. The system recorded speed (accuracy: 0.1 km/h), acceleration (1% accuracy), and distance with a 20 Hz sample rate. The ET and the Video VBOX Pro devices were installed on the back seats of the car, monitored by one of the researchers, who was asked not to talk to the driver except for giving instructions about the direction or assistance in case of necessity.

2.2 Performed analysis

The performed analysis aimed to evaluate the effect on safety and visibility of the studied pedestrian crossings produced by the introduction of median refuge island, the displacement of zebra markings in advance of the intersection, and the improvement of "Yield here to pedestrians" vertical sign. To this end, both vehicle speed and drivers' eye-movements approaching crosswalks were analysed and compared before and after the works. The recording of driver's eye-movement allowed an assessment of the more salient visual elements along the road and near the pedestrian crossing as well as an evaluation of the driver's visual behaviour related to the vehicle speed. The experimental route was a back-and-forth trip, so each of the four crosswalks was crossed twice and the average value between the two directions for each crosswalk was taken into consideration.
A before-after operating speed comparison is commonly used to evaluate the safety of a road modification (World Road Association, 2003). Therefore, in the present study, the Video VBOX Pro output video was analysed for each participant before and after the works in order to evaluate the operating speed. The ET video, on the contrary, was analysed frame-by-frame, in order to verify the target fixed by each participant. The targets under analysis were "Yield here to pedestrians" vertical sign, zebra markings and median refuge island (only in the after-intervention condition). For each target the number of fixations and the duration of fixation were computed, multiplying by 33 ms the number of frames in which a single target object was fixated. An object was considered as fixated when it was fixed for a minimum duration of two frames (66 ms), as defined by the intersection area of the cross on the video (Fig. 5). The threshold of 66 ms, which is lower in comparison to a common filtering of 100 ms or higher as usually found in eye-tracking studies (Holmqvist et al., 2015), was dictated by the specific setting of this study that involved the recording of eye movements while driving. Although lower values are shown in literature (Velichkovsky et al., 2000; Domhoefer et al., 2000; Sodhi et al., 2002), Lantieri et al. (2015), Costa et al. (2018) and Costa et al. (2018) reported that in real traffic situations, that are highly dynamic driving contexts, fixation duration is much lower than in other contexts or in

experimental settings. In a real driving setting with a dynamic visual scene, as in the case of the present study, rapid fixations may occur. Since the distribution of fixation duration is positively skewed and not normal, medians are reported instead of means (Costa, Bonetti, et al., 2018; Costa, Simone, et al., 2018). For each studied pedestrian crossing target the distance of first fixation was computed, considering any element of the crosswalk (zebra markings, ‘‘Yield here to pedestrians” vertical sign, or median refuge island). The first fixation for each crosswalk was assessed thanks to the synchronization of the speed data and the ET data, obtained by the methodology used in Costa, Bonetti et al. (2018) and in Costa, Simone et al. (2018) (Fig. 5). The obtained values were compared to the operative stopping distance which was computed using a mathematical equation in accordance with the Italian regulations (Ministry of Infrastructures and Transports, 2001). The operative stopping distance depended on the travelling speed (the vehicle speed at the first-fixation position), on coefficient of available friction, and on road average longitudinal slope (4%).

In order to avoid conflicts between vehicles and pedestrians entering the road area from any side of it, the first fixation distance should be longer than the operative stopping distance so that the driver has enough space for a prompt yielding. The comparison between the distance of first fixation and the operative stopping distance allows a correct evaluation of the yielding space under safe conditions (World Road Association, 2003; Jurecki et al., 2014). When the distance of first fixation was shorter than the stopping distance, the driver’s behaviour was classified as ‘‘unsafe”, while when the distance of first fixation of the crosswalk was longer than the operative stopping distance the driver’s behaviour was considered as ‘‘safe”.

To assess the behaviour of drivers in the two situations before and after the combined intervention of pedestrian crossings near the roundabouts, univariate ANOVA was used. The parameters that were evaluated with the univariate ANOVA are the difference in median fixation duration of each pedestrian crossing element, the distance of first fixation of crosswalks and the operating stopping distance at each single crosswalk and for each participant.

Figure 5. Synchronization of the ASL eye-tracking mobile video output with the VBOX PRO video output.

3. Results

The Video VBOX Pro results showed that the drivers’ average speed when approaching the crosswalk (0 m distance condition) was 32.64 km/h (SD = 6.35, N = 74) before and 27.04 km/h (SD = 9.19, N = 48) after the intervention, with a reduction of 5.6 km/h. An ANOVA tested a significant difference: $F(1, 138) = 2.97$, $p = .04$, $\eta^2 = 0.02$.

Figure 6 shows the results of the comparison between the percentage of drivers that looked at zebra markings, at ‘‘Yield here to pedestrians” vertical sign and at median refuge island, before and after the works.

The results were determined by 80 observations (10 participants $\times$ 4 crosswalks $\times$ 2 sides).

The performed statistical analysis revealed a significant increasing of drivers that looked at zebra markings (+31.25%, $\chi^2 = 7.11$, $p = .002$) and at ‘‘Yield here to pedestrians” vertical sign (+8.75%, $\chi^2 = 6.32$, $p = .002$). After the intervention 56.25% of drivers glanced at median refuge island which was not part of the crosswalk design before the works.

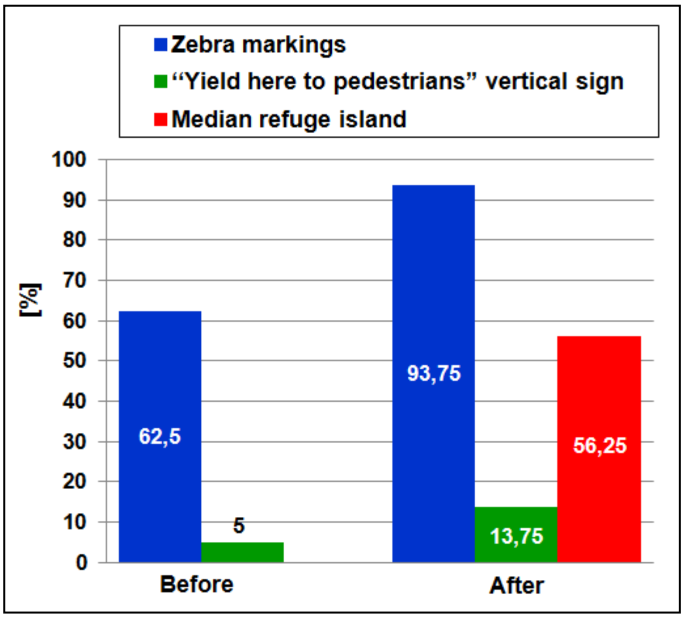

Figure 6. Percentage of drivers that looked at zebra markings, at "Yield here to pedestrians" vertical sign and at median refuge island, before and after the works, N = 80 observations (10 participants × 4 crosswalks × 2 sides)

Univariate ANOVAs were applied in order to test the difference in median fixation duration of each pedestrian crossing element before and after the works (Figure 7). The difference was significant for "Yield here to pedestrians" vertical sign: $F(1, 27) = 4.02$, $p = .02$, $\eta^2 = 0.12$. The average fixation time was 150 ms (SD = 46) before and 300 ms (SD = 200) after the works.
The difference was also significant for zebra markings: $F(1, 62) = 9.17$, $p = .002$, $\eta^2 = 0.12$. Before the median fixation was 267 ms (SD = 122), after the works it increased to 700 ms (SD = 317).
The average fixation time at the median refuge island was 700 ms (SD = 62).

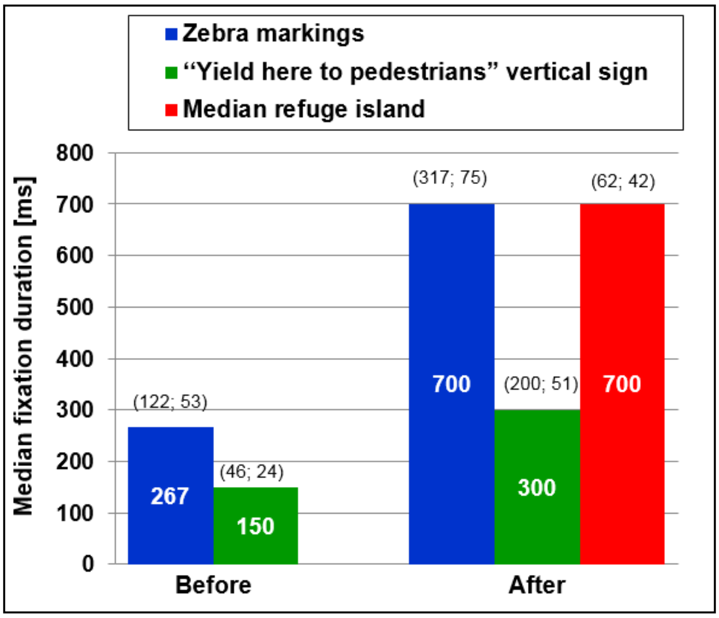

Figure 7. Before-after analysis of median fixation duration at the pedestrian crossing elements (standard deviation and number of observations are reported between parentheses).

Univariate ANOVAs were also applied in order to test and compare distance of first fixation of the crosswalks in before and after conditions. The mean distance increased from 21.98 m (SD = 16.76, N = 48) to 40.69 m (SD = 19.66, N = 73), showing a significant difference: $F(1, 85) = 108.19$, $p < .001$, $\eta^2 = 0.37$.
The operative stopping distance at each single crosswalk and for each participant was tested using ANOVA. The average operative stopping distance before was 39.30 m (SD = 17.22), while after the works it was 34.42 m (SD = 13.97), with a significant difference: $F(1, 73) = 3.59$, $p = .02$, $\eta^2 = 0.04$.

Obtained values showed that before the intervention 78.1% of the cases were ‘‘unsafe”, with operative stopping distances far exceeding the distance of first-fixation. After the intervention the ‘‘unsafe” cases decreased to 30.1%, with a significant reduction of 48.0%. The difference was tested by a Chi-square test as follows: χ^2 = 18.02, $p < .001$. After the zebra markings displacement and the installation of the median refuge island and of the ‘‘Yield here to pedestrians” vertical sign the crosswalk conspicuity and visibility increased and the drivers' first-fixation was at a distance that allowed a safe stop in case of pedestrians entering the crossing area.

At the moment of first fixation of the crosswalk, the drivers' mean speed changed was 37.94 km/h (SD = 10.91, N = 74) before and 31.03 km/h (SD = 11.25, N = 48) after the works, with a reduction of 7 km/h. The difference was significant: F (1, 85) = 4.73, $p = .02$, $\eta^2 = 0.04$.

The effect of driving speed on first-fixation distance was tested with a linear regression considering operating speed as independent variable and distance as dependent variable. The regression value was significant: t = 2.004, $p < 0.001$, $R^2 = 0.067$. The standardized coefficient between the two variables amounted to $\beta = 0.21$, showing that the less speed was, the longer the distance at which the drivers saw the crosswalk was.

4. Discussion

In the present study different engineering countermeasures, aimed to increase conspicuity and visibility of pedestrian crossings at roundabouts, have been tested in order to assess their impact on road safety. These countermeasures included installation of a median refuge island, displacement of zebra markings in advance of the intersection, and placement of ‘‘Yield here to pedestrians” vertical signs. The safety evaluation was performed by a before–after analysis of both speed and drivers' visual behaviour approaching the crosswalks in a real road experimental setting. All obtained results confirmed that adopted countermeasures increased conspicuity and safety at pedestrian crosswalks, because drivers' attention to the road increased and the speed decreased accordingly. The analysis of the drivers' eye movements was very useful to assess the visibility of pedestrian crossings as well as to study the drivers' behaviour and the data obtained may help to improve the crosswalk design in order to prevent accidents.

Statistical analysis of the number and duration of fixations confirmed that they were significantly higher after the new elements had been installed near the crosswalks. The drivers' attention focused on the roadway with a decrease of distraction caused by the surrounding road environment. According to Bichicchi et al. (2017), zebra markings and median refuge island were the best perceived elements by all drivers, with a median fixation duration respectively of 700 ms, followed by “Yield here to pedestrians” vertical sign (300 ms).

The elements near the centre of the road were fixated longer than the vertical sign, probably because of their position and their angular distance from the line straight ahead the driver. This was also confirmed by Costa et al. (2014, 2018) and by Yuan et al. (2011), who found that vertical signs, falling outside the foveal visual field of the driver, required specific saccadic movements or peripheral vision to be seen. The more the angular distance increased, the poorer the visibility was, since the sign was seen at a shorter distance. On the contrary, zebra markings and median refuge island were placed on the road, directly in front of the drivers, and so they had a higher effectiveness in influencing the drivers' behaviour.

These data are more significant considering that participants had never driven along the study route before. Previous studies, in fact, have shown that novice drivers have a longer eye-fixation duration than expert drivers, but the fixation location is differed between novice and expert drivers. Novice drivers tend to focus on roadside longer than expert drivers, to determine the position of their vehicles (Shinohara and Nishizaki, 2017; Mourant and Rockwell, 1972; Satoh, 1993; Laya, 1992). Drivers who are familiar with the route spend more time looking ahead and can better detect events that may lead to situations that affect traffic flow or cause collisions. The results lend support to the hypothesis that the peripheral area of the eye is used to monitor other vehicles and the road lane markers in order to direct the fovea for closer examinations when the situation demands it (Shinohara and Nishizaki, 2017).

After the intervention all the drivers detected the crosswalks in advance, since the mean distance of first fixation of crosswalk increased accordingly. They were seen at a longer distance increasing hazard anticipation and detection. Before the works, drivers saw the crosswalk at a very shorter distance (21.98 m), which didn't allow them to adjust speed and slow down their velocity. After the countermeasures, drivers perceived the pedestrian crossings from a longer distance (40.69 m), and they continued to glance at the crosswalks while approaching them, enhancing their visual attention. This was due also to the average speed reduction approaching the crosswalk. After the works, in fact, the drivers perceived in advance the crosswalk presence and therefore they decelerated earlier reducing the probability of fatal accidents. The drivers' average speed reduction was of 5.6 km/h after the intervention.

The lower the speed, the longer the distance of crosswalks detection was. At a low speed the driver may tend to look at and monitor the road more carefully than at a high speed, better perceiving any critical element placed ahead. The longer the distance of first fixation of crosswalk, the longer the operative stopping distance of the drivers was. After the works, a reduction of 48.0% of the ‘‘unsafe” cases were obtained.

As said above, these data are very interesting considering that participants had never driven the study route before.

Several previous studies, in fact, have found that familiarity with the driving situation has a great influence on the driving speed. Expert drivers tend to drive faster than the novice drivers and, under increased speed

conditions, subject tended to fixate relevant items near the centre of the road with increased frequency (Spijkers, 1992). Drivers detect fewer elements in the central visual field when driving slowly and they detect fewer elements in peripheral vision when driving fast (Kayser and Hess, 1991; Miura, 1985 and 1987; Rogé et al, 2004).
A relatively small sample of drivers and situations was considered in this study and future studies will test the effects of a similar intervention on a larger sample. Nevertheless, the significant variations in the drivers' behaviour recorded after the works were particularly remarkable in terms of crosswalk visibility and conspicuity. Future researches might evaluate drivers' behaviour in the presence of a pedestrian on the crosswalk area.

Acknowledgements
This work was supported by the Municipality of Faenza. The authors thank Davide Parmeggiani and Patrizia Barchi for their support in this study.

References
Beeber, J. (2011). Maximizing safety at signalized intersections through increased yellow and all-red signal phases. Los Angeles: Safer Streets.
Bella, F., & Silvestri, M. (2015). Effects of safety measures on driver's speed behaviour at pedestrian crossings. Accident Analysis and Prevention, 83, 111–124. https://doi.org/10.1016/j.aap.2015.07.016.
Bergman, A., Olstam, J., & Allström, A. (2011). Analytical traffic models for roundabouts with pedestrian crossings. Procedia - Social and Behavioral Sciences, 16, 697–708. https://doi.org/10.1016/j.sbspro.2011.04.489.
Biassoni, M., Confalonieri, F., & Ciceri, R. (2018). Visual exploration of pedestrian crossings by adults and children: Comparison of strategies. Transportation Research Part F, 56, 227–235. https://doi.org/10.1016/j.trf.2018.04.009.
Bichicchi, A., Mazzotta, F., Lantieri, C., Vignali, V., Simone, A., Dondi, G. & Costa, M. (2017). The influence of pedestrian crossings features on driving behavior and road safety. Proceedings of AIIT International Congress TIS Rome 2017, April 10-12, Rome, https://doi.org/10.1201/9781315281896-96.
Bock, O., Brustio, P. R., & Borisova, S. (2015). Age-related differences of the gaze pattern in a realistic pedestrian traffic task. International Journal of Applied Psychology, 5, 13–19. https://doi.org/10.5923/j.ijap.20150501.03.
Bongiorno, N., Bosurgi, G., Pellegrino, O., & Sollazzo, G. (2017). How is the driver's workload influenced by the road environment? Procedia Engineering, 187, 5–13. https://doi.org/10.1016/j.proeng.2017.04.343.
Bucchi, A., Sangiorgi, C., & Vignali, V. (2012). Traffic Psychology and Driver Behavior. Procedia - Social and Behavioral Sciences, 53, 972–979. https://doi.org/10.1016/j.sbspro.2012.09.946.
Bungum, T. J., Day, C., & Henry, L. J. (2005). The association of distraction and caution displayed by pedestrians at a lighted crosswalk. Journal of Community Health, 30(4), 269–279. https://doi.org/10.1007/s10900-005-3705-4.
Ciceri, M., Ruscio, D., Confalonieri, F., Vangi, D., Virga, A. (2013). Hazard detection in driving context and braking reaction time. In Proceedings of the 22nd EVU annual congress. Florence, 17–19 October.
Chu, W., Wu, C., Atombo, C., Zhang, H., & Özkan, T. (2019). Traffic climate, driver behaviour, and accidents involvement in China. Accident Analysis and Prevention, 122(1178), 119–126. https://doi.org/10.1016/j.aap.2018.09.007.
Cohen, Bar-Gera, Parmet, Ronen (2013). Guardrail influence on pedestrian crossing behavior at roundabouts. Accident Analysis and Prevention 59 (2013) 452– 458
Costa, M., Bichicchi, A., Nese, M., Lantieri, C., Vignali, V. & Simone, A. (2019). T-junction priority scheme and road user's yielding behavior. Transportation Research Part F, 60, 770–782, https://doi.org/0.1016/j.trf.2018.12.009.
Costa, M., Bonetti, L., Vignali, V., Bichicchi, A., Lantieri, C. & Simone, A. (2019). Driver's visual attention to di□erent categories of roadside advertising signs. Applied Ergonomics, 78, 127–136, https://doi.org/10.1016/j.apergo.2019.03.001.
Costa, M., Bonetti, L., Bellelli, M., Lantieri, C., Vignali, V., & Simone, A. (2017). Reflective tape applied to bicycle frame and conspicuity enhancement at night. Human Factors, 59, 485–500. https://doi.org/10.1177/0018720816677145.
Costa, M., Bonetti, L., Vignali, V., Lantieri, C., & Simone, A. (2018). The role of peripheral vision in vertical road sign identification and discrimination. Ergonomics. https://doi.org/10.1080/00140139.2018.1508756.
Costa, M., Simone, A., Vignali, V., Lantieri, C., Bucchi, A., & Dondi, G. (2014). Looking behaviour for vertical road signs. Transportation Research Part F, 23, 147–155. https://doi.org/10.1016/j.trf.2014.01.003.
Costa, M., Simone, A., Vignali, V., Lantieri, C., & Palena, N. (2018). Fixation distance and fixation duration to vertical road signs. Applied Ergonomics, 69, 48–57. https://doi.org/10.1016/j.apergo.2017.12.017.
Crescenzo G., Villa C., Brémond R., Vignali V., Lantieri C., & Simone A. (2019). The shape of road markings for visibility computation. Proceedings of the Institution of Civil Engineers – Transport, DOI: 10.1016/B978-0-12-811926-6.00020-8;

Davoudian, N., & Raynham, P. (2012). What do pedestrians look at night? Lighting, Research & Technology, 44, 438–448. https://doi.org/10.1177/1477153512437157.

Di Flumeri, G., Borghini, G., Aricò, P., Sciaraffa, N., Lanzi, P., Pozzi, S., Vignali, V., Lantieri, C., Bichicchi, A., Simone, A. & Babiloni, F. (2018). EEG-based mental workload neurometric to evaluate the impact of different traffic and road conditions in real driving settings. Frontiers in Human Neuroscience, 12, 1-18, https://doi.org/10.3389/fnhum.2018.00509.

Dondi, G., Simone, A., Lantieri, C., & Vignali, V. (2011). Bike lane design: The context sensitive approach. Procedia Engineering, 21, 897–906. https://doi.org/10.1016/j.proeng.2011.11.2092.

Dukic, T., Ahlstrom, C., Patten, C., Kettwich, C., & Kircher, K. (2013). Effects of electronic billboards on driver distraction. Traffic Injury Prevention, 14(5), 469–476. https://doi.org/10.1080/15389588.2012.731546.

Fildes, B.N., Fletcher, M.R., Corrigan, J.M, 1987. Speed perception: Drivers' judgements of safety and speed on urban and rural straight roads. Report CR 54. Department of Transport & Communication. Canberra, Australia.

Fisher, D., & Garay-Vega, L. (2012). Advance yield markings and drivers' performance in response to multiple-threat scenarios at mid-block crosswalks. Accident Analysis and Prevention, 44, 35–41. https://doi.org/10.1016/j.aap.2010.11.030.

Fortuijn, L. G. H. (2003). Pedestrian and Bicycle-Friendly Roundabouts; Dilemma of Comfort and Safety. Annual Meeting 2003 of the Institute of Transportation Engineers (ITE), 1–20.

Fotios, S., Uttley, J., Hara, N. 2013. Critical pedestrian tasks: Using eye-tracking within a dual task paradigm. In Proceedings of the CIE centenary conference ''Towards a New Century of Light". Paris, 15–16 April.

Ghasemi N., Acerra E., Vignali V., Lantieri C., Simone A., Imine H. (2019). Road safety review update by using innovative technologies to investigate driver behaviour. AIIT 2nd International Congress on Transport Infrastructure and Systems in a changing world (TIS ROMA 2019), 23-24 September 2019, Rome, Italy;

Gómez, R. A., Siby, S., Romoser, M. R. E., Gerardino, L. R., Knodler, M., Collura, J., & Fisher, D. L. (2013). Proceedings of the 16th Road Safety on Four Continents Conference, Beijing.

Gonzalo-Orden, H., Pérez-Acebo, H., Unamunzaga, A. L., & Arce, M. R. (2018a). Effects of traffic calming measures in different urban areas. Transportation Research Procedia, 33, 83–90. https://doi.org/10.1016/j.trpro.2018.10.079.

Gonzalo-Orden, H., Pérez-Acebo, H., Unamunzaga, A. L., & Arce, M. R. (2018b). Effects of traffic calming measures in different urban areas. Transportation Research Procedia, 33, 83–90. https://doi.org/10.1016/j.trpro.2018.10.079.

Gross, F., Lyon, C., Persaud, B., & Srinivasan, R. (2013). Safety effectiveness of converting signalized intersections to roundabouts. Accident Analysis and Prevention, 50, 234–241. https://doi.org/10.1016/j.aap.2012.04.012.

Grüner, M., & Ansorge, U. (2017). Mobile eye tracking during real-world night driving. Journal of Eye Movement Research, 10(2), 1–18 https://doi.org/10. 16910/jemr.10.2.1.

Guo, Y., Liu, P., Liang, Q., & Wang, W. (2016). Effects of parallelogram-shaped pavement markings on vehicle speed and safety of pedestrian crosswalks on urban roads in China. Accident Analysis and Prevention, 95, 438–447. https://doi.org/10.1016/j.aap.2015.07.001.

Hakkert, A. S., Gitelman, V., & Ben-Shabat, E. (2002). An evaluation of crosswalk warning systems: Effects on pedestrian and vehicle behaviour. Transportation Research Part F: Traffic Psychology and Behaviour, 5(4), 275–292. https://doi.org/10.1016/S1369-8478(02)00033-5.

Haleem, K., Alluri, P., & Gan, A. (2015). Analysing pedestrian crash injury severity at signalized and non-signalized locations. Accident Analysis and Prevention, 81, 14–23.

Hawley, L., Henson, C., Hulse, A., Brindle, R., 1992. Towards traffic calming: a practitioners' manual of implemented local area traffic management and blackspot devices. Publication No. CR 126. Federal Office of Road Safety. Canberra, Australia.

Holmqvist, K., Nystrom, M., Andersson, R., Dewhurst, R., Jarodzka, H., & van De Weijer, J. (2015). Eye tracking: A comprehensive guide to methods and measures. Oxford: Oxford University Press.

Huang, H., Cynecki, M., 2001. The effects of traffic calming measures on pedestrian and motorist behavior. Federal Highway Administration, FHWA-RD-00- 104.

Hydén, C., & Várhelyi, A. (2000). The effects on safety, time consumption and environment of large scale use of roundabouts in an urban area: A case study. Accident Analysis and Prevention, 32(1), 11–23. https://doi.org/10.1016/S0001-4575(99)00044-5.

Inman, V. W., 2012. Conspicuity of traffic signs assessed by eye tracking and immediate recall. In Proceedings of the human factors and ergonomics society, 56th annual meeting, p. 2251–2255.

Jurecki, R. S., & Stanczyk, T. L. (2014). Driver reaction time to lateral entering pedestrian in a simulated crash traffic situation. Transportation Research Part F, 27, 22–36. https://doi.org/10.1016/j.trf.2014.08.006.

Kapitaniak, B., Walczak, M., Kosobudzki, M., Józ´wiak, Z., & Bortkiewicz, A. (2015). Application of eye tracking in drivers testing: A review of research. International Journal of Occupational Medicine and Environmental Health, 28, 941–954 https://doi.org/10.13075/ijomeh.1896.00317.

Kayser, H. J., & Hess, M. (1991). The dependency of drivers viewing behaviour on speed and street environment structure. In A. G. Gale (Ed.), Vision in vehicles III. North-Holland: Elsevier Publishers

Kolsrud, B., 1985. Speeds in rural traffic: The influence of various factors on car speeds on straight level roads. VTI Meddelande 390, Sweden.

Kröyer, H. R. G., Jonsson, T., & Várhelyi, A. (2014). Relative fatality risk curve to describe the effect of change in the impact speed on fatality risk of pedestrians struck by a motor vehicle. Accident Analysis and Prevention, 62, 143–152. https://doi.org/10.1016/j.aap.2013.09.007.

Lantieri, C., Lamperti, R., Simone, A., Costa, M., Vignali, V., Sangiorgi, C., & Dondi, G. (2015). Gateway design assessment in the transition from high to low speed areas. Transportation Research Part F, 34, 41–53. https://doi.org/10.1016/j.trf.2015.07.017.

Laya (1992). Eye Movements in Actual and Simulated Curve Negotiation Task. ITASS Research, 16(1), 15-26.

Leden, L., Gårder, P., & Johansson, C. (2006). Safe pedestrian crossings for children and elderly. Accident Analysis and Prevention, 38, 289–294. https://doi.org/ 10.1016/j.aap.2005.09.012.

Macbeth, A., 1995. Balliol Street, City of Toronto. Traffic engineering committee workshop. In Proceedings of the Ontario traffic conference, Toronto, Ontario, Canada.

Mako, E. (2015). Evaluation of human behaviour at pedestrian crossings. 2015 6th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), 443–447. https://doi.org/10.1109/CogInfoCom.2015.7390634.

Mantuano, A., Bernardi, S., & Rupi, F. (2017). Cyclist gaze behavior in urban space: An eye-tracking experiment on the bicycle network of Bologna. Case Studies on Transport Policy, 5, 408–416. https://doi.org/10.1016/j.cstp.2016.06.001.

Maxera, P., Kledus, R., Semela, M., 2015. Analysis of drivers' conduct while driving over pedestrian crossing by using eye-tracking method. In Proceedings of the international scientific conference modern safety technologies in transportation. Košice, Slovakia.

Meneguzzer, C., & Rossi, R. (2011). Evaluating the impact of pedestrian crossings on roundabout entry capacity. Procedia - Social and Behavioral Sciences, 20, 69–78. https://doi.org/10.1016/j.sbspro.2011.08.012.

Ministry of Infrastructures and Transports, 1992. Codice della strada [Highway code]. Rome (in Italian).

Ministry of Infrastructures and Transports, 2001. Decreto Ministeriale del 5/11/2001 Norme funzionali e geometriche per la costruzione delle strade. Rome (in Italian).

Miura, T. (1985). What is the narrowing of visual field with the increase of speed? Paper presented at the 10th congress of the international association for accident and traffic medicine.

Miura, T. (1987). Behavior orientation vision: Functional field of view and processing resources. In J. K. OReagan & A. Le´vy-Schoen (Eds.), Eye movements: From physiology to cognition. Elsevier Publishers

Mourant, Rockwell (1972) Strategies of Visual Search by Novice and Experiencedb Drivers, Human Factors. The Journal of the Human Factors and Ergonomics Society, 14-4, 325-335

Muttart, J. W., Dinakar, S., Vandenberg, G., & Yosko, M. (2016). The influence of driver expectation when recognizing lighted targets at nighttime. Proceedings of the Human Factors and Ergonomics Society. https://doi.org/10.1177/1541931213601111.

Obeng-Atuah, D., Poku-Boansi, M., & Cobbinah, P. B. (2017). Pedestrian crossing in urban Ghana: Safety implications. Journal of Transport and Health, 5, 55–69. https://doi.org/10.1016/j.jth.2016.06.007.

Olszewski, P., Szagała, P., Wolański, M., & Zielińska, A. (2015). Pedestrian fatality risk in accidents at unsignalized zebra crosswalks in Poland. Accident Analysis and Prevention, 84, 83–91. https://doi.org/10.1016/j.aap.2015.08.008.

Oviedo-Trespalacios, O., Haque, M. M., King, M., & Washington, S. (2017). Effects of road infrastructure and traffic complexity in speed adaptation behaviour of distracted drivers. Accident Analysis and Prevention, 101, 67–77. https://doi.org/10.1016/j.aap.2017.01.018.

Perdomo, M., Rezaei, A., Patterson, Z., Saunier, N., & Miranda-Moreno, L. F. (2014). Pedestrian preferences with respect to roundabouts - A video-based stated preference survey. Accident Analysis and Prevention, 70, 84–91. https://doi.org/10.1016/j.aap.2014.03.010.

Replogle, M., 1992. Bicycle and pedestrian policies and programs in Asia, Australia, and New Zealand: Case Study 17. National Bicycling and Walking Study. Report No. FHWA-PD-93-016. Federal Highway Administration. Washington, DC.

Retting, R.A., Ferguson, S.A., McCartt, A.T., 2003. A review of evidence-based traffic engineering measures designed to reduce pedestrian–motor vehicle crashes. American Journal of Public Health 93 (9), 1456–1463.

Ringhand, M., & Vollrath, M. (2019). Effect of complex traffic situations on route choice behaviour and driver stress in residential areas. Transportation Research Part F: Traffic Psychology and Behaviour, 60, 274–287. https://doi.org/10.1016/j.trf.2018.10.023.

Roge, Pébayle, Lambilliotte, Spitzenstetter, Giselbrecht, Muzet. (2004). Influence of age, speed and duration of monotonous driving task in traffic on the drivers useful visual field, Vision Research 44 2737–2744

Rosén, E., & Sander, U. (2009). Pedestrian fatality risk as a function of car impact speed. Accident Analysis and Prevention, 41, 536–542.

Rosén, E., Stigson, H., & Sander, U. (2011). Literature review of pedestrian fatality risk as a function of car impact speed. Accident Analysis and Prevention, 43, 25–33.

Sanca, M. (2002). Application of design for safer urban roads and junctions: Selected countermeasures. Sweden: Linkoping University.
Satoh (1993). Visual Search and Peripheral Vision Performance by Novice and Experienced Drivers. IATSS Review, 19-3.
Sherbutt, J., Van Houten, R., Turner, S., & Huitema, B. (2009). Analysis of effects of LED rectangular rapid-flash beacons on yielding to pedestrians in multilane crosswalks. Transportation Research Record, 2140, 85–95. https://doi.org/10.3141/2140-09.
Shinohara, Nishizaki (2017) Where do drivers look when driving in a foreign country?. Studies in Computational Intelligence, 721, 151-164
Shinohara, Nishizaki (2017). Effects of Driving Situation and Driving Experience on Ey Information Engineering Express International Institute of Applied Informatics, Vol.3, No.3, P.31 - 40
Sodhi, M., Reimer, B., Cohen, J. L., Vastenburg, E., Kaars, R., Kirschenbaum, S., 2002. On-road driver eye movement tracking using head-mounted devices. In Proceedings of the 2002 symposium on eye tracking research & applications. pp. 61–68.
Spijkers, W. (1992). Distribution of eye-fixations during driving. IATSS Research 16(1),27-34
Stewart, D., 2007. A clearer vision for pedestrian guardrails. Civil Engineering 160 (CE3), 131–136.
Taylor, T., Pradhan, A. K., Divekar, G., Romoser, M., Muttart, J., Gomez, R., Pollatsek, A., & Fisher, D. L. (2013). The view from the road: The contribution of on road glance-monitoring technologies to understanding driver behavior. Accident Analysis and Prevention, 58, 175–186. https://doi.org/10.1016/j. aap.2013.02.008.
Tefft, B. C. (2013). Impact speed and a pedestrian's risk of severe injury or death. Accident Analysis and Prevention, 50, 871–878. https://doi.org/10.1016/j. aap.2012.07.022.
Topolšek, D., Areh, I., & Cvahte, T. (2016). Examination of driver detection of roadside traffic signs and advertisements using eye tracking. Transportation Research Part F: Traffic Psychology and Behaviour, 43, 212–224. https://doi.org/10.1016/j.trf.2016.10.002.
Trefzger, M., Blascheck, T., Raschke, M., Hausmann, S., Schlegel, T., 2018. A visual comparison of gaze behavior from pedestrians and cyclists. In Symposium on eye tracking research and applications, Warsaw, Poland.
Turner, D. (2011). Roundabouts : A Literature Review, (December), 1–17.
Van Houten, R., Ellis, R., & Marmolejo, E. (2008). Stutter-flash light-emitting-diode beacons to increase yielding to pedestrians at crosswalks. Transportation Research Record, 2073, 69–78. https://doi.org/10.3141/2073-08.
Velichkovsky, B., Domhoefer, S.M., Pannasch, S., Unema, J.A., 2000. Visual fixations and level of attentional processing. In Proceedings of the eye tracking research & application symposium, ETRA 2000, Palm Beach Gardens, Florida, 6–8 November.
Vey, A. H., & Ferreri, M. G. (1968). The effect of lane width on traffic operation. Traffic Engineering, 38, 22–27.
Vignali, V., Cuppi, F., Acerra, E., Bichicchi, A., Lantieri, C., Simone, A. & Costa M. (2019). Effects of median refuge island and flashing vertical sign on conspicuity and safety of unsignalized crosswalks. Transportation Research Part F: Traffic Psychology and Behaviour, 60, 427–439, https://doi.org/10.1016/j.trf.2018.10.033.
Vignali, V., Bichicchi, A., Simone, A. Lantieri, C., Dondi, G. & Costa, M. (2019). Road sign vision and driver behavior in work zones. Transportation Research Part F, 60, 474–484, https://doi.org/10.1016/j.trf.2018.11.005.
Vijayawargiya, V., & Rokade, S. (2017). Identification of Factors Affecting Pedestrian Level of Service of Crosswalks at Roundabouts. International Research Journal of Engineering and Technology (IRJET), 4(6), 342–346.
Ward, N.J., Linkenbach, J., Keller, S.N., Otto, J., 2010. White Paper on Traffic Safety Culture.
World Road Association (PIARC), 2003. Road safety manual.
Xu, J., Liu, J., Qu, W., Ge, Y., Sun, X., & Zhang, K. (2018). Comparison of pedestrian behaviors between drivers and non-drivers in Chinese sample. Transportation Research Part F: Traffic Psychology and Behaviour, 58, 1053–1060. https://doi.org/10.1016/j.trf.2018.05.034.
Yagar, S., & Van Aerde, M. (1983). Geometric and environmental effects on speeds on 2-lane rural roads. Transportation Research Record, 17A, 315.
Yuan, W., Fu, R., Ma, Y., & Guo, Y. S. (2011). Effects of vehicle speed and traffic sign text height on drivers' visual search patterns. Journal of Traffic and Transportation Engineering, 11, 119–126.
Zeeger, C. V., & Bushell, M. (2012). Pedestrian crash trends and potential countermeasures from around the world. Accident Analysis and Prevention, 44, 3–11. https://doi.org/10.1016/j.aap.2010.12.007.
Zito, G. A., Cazzoli, D., Scheffler, L., Jäger, M., Müri, R. M., Mosimann, U. P., & Nef, T. (2015). Street crossing behavior in younger and older pedestrians: An eye and head-tracking study. BMC Geriatrics, 15, 176. https://doi.org/10.1186/s12877-015-0175-0.

Valeria Vignali: Conceptualization, Methodology, Investigation

Margherita Pazzini: Investigation, Writing - Original Draft

Navid Ghasemi: Investigation, Data curation

Claudio Lantieri: Writing - Original Draft

Andrea Simone: Data curation Writing - Original Draft

Giulio Dondi: Writing- Reviewing and Editing