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Antonio PRATELLI*, Marino LUPI, Alessandro FARINA, Carmela IANNELLI
University of Pisa, College of Engineering, DICI - Department of Civil & Industrial Engineering
Largo Lucio Lazzarino 2, 56126 Pisa, Italy
**Corresponding author*. E-mail: antonio.pratelli@ing.unipi.it

PEDESTRIAN RULE COMPLIANCE AT SIGNALIZED INTERSECTIONS IN DIFFERENT URBAN CONTEXTS: AN OBSERVATIONAL STUDY

Summary. The purpose of this paper is to examine the rule compliance behavior of pedestrians at signalized intersections located in two different urban contexts in Italy, a tourist context and a typical working urban context, and to highlight if there is any influence, of the specific urban context, on the non-compliance behavior of pedestrians.

Digital video camera images are gathered in two different urban contexts and data are processed using automated software, self-written in MatLab. Both test places are located in Tuscany (Italy) and they are only 20 km apart. The tourist, or recreational, context is the beach town of Viareggio. The typical working, or commuter, urban context is the historical city of Lucca. Factors such as age, sex and group size are analyzed. Pearson's chi-square test has been applied to investigate whether the difference between observed values and expected values of variables is statistically significant. The average crossing speed in tourists is found to be 1.50 m/s and the average 15th percentile is 1.09 m/s, whereas in commuters, the average crossing speed is found to be 1.78 m/s and the average 15th percentile is 1.42 m/s.

The obtained results highlight that pedestrians in a tourist urban context are generally more compliant to traffic lights than in a commuter urban context. Moreover, the results point out that pedestrian behavior is highly linked to the urban context, and the obtained results of this exploratory study on pedestrians, in a recreational context as compared to a working one, raise some interesting questions that deserve further research work.

1. INTRODUCTION

There exist a lot of previous research works addressing many aspects of interest regarding pedestrian injuries. During the last decade, in Italy, out of the yearly total road traffic fatalities, pedestrian fatalities amounted to more than 17–18%, and with each passing year, the percentage of pedestrian deaths is growing. One of the most recurrent reasons for pedestrian injury is pedestrian compliance or lack of compliance with the traffic-light road rules. Koh et al. [1] showed that 22% of pedestrian fatal accidents in Singapore occurred at signalized intersections, and one in three such accidents occurred during the pedestrian red-light phase. Keegan and O'Mahoney [2] reported that 35% of pedestrians, namely more than one in three, entered illegally at a signalized intersection. Behavioral observations conducted at signalized intersections in Sweden and Belgium showed that pedestrians often do not yield when they violate the traffic signal, even though they are at fault [3].

The present study investigates pedestrian behavior at crosswalks with traffic lights: the individuals have been extracted from a working urban context and a tourist context. The road behavior of individual pedestrians belonging to commuters in a traffic-light-controlled intersection is compared to the behavior of pedestrian tourists at a traffic-light crosswalk.

A pedestrian would generally want to cross where it is convenient in order to get to his or her destination with as little delay as possible [1]. There are a lot of previous research works addressing many aspects of interest regarding pedestrian behavior in violating signals at crosswalks. Many factors were identified as having an impact on the proportion of violations, such as age, sex, group size, conflicting vehicle flow, waiting time and times of pedestrian signals [4, 5].

More generally, research works have shown that male pedestrians cross during red traffic light in a higher percentage than women [4, 6, 7, 8]. There are also some studies that have shown that young people tend to violate traffic lights more frequently than other age groups [4, 6]. Nesic et al. [9] observed that over 14% of pedestrians cross the street during a red light, which means a 14% rate of potential conflict situation that can lead to a traffic accident.

Pedestrians may also be affected by the closeness and behavior of others at traffic lights [4]. Pedestrians crossing the road in groups can access to a source of social information: if someone crosses the road, it may indicate that it is possible and there is a sufficiently large gap to permit a safe crossing [10]. Practically, pedestrians embedded in large groups should have a stronger feeling of safety than pedestrians crossing alone, due to the so-called "safety number" effect that they feel when many other individuals are also crossing [11]. Following the theory of social psychology and according to Sun [12], the set of norms, rules and moral standards of a group serve to justify the actions of its individual members when these actions conflict with established social norms.

The waiting time was found affecting pedestrian behavior [13, 14]. For instance, Asaba [15] has determined a time threshold of 21–28s, more than this time, pedestrian's patience will be greatly reduced, and waiting for 40-45s, the pedestrian noncompliance rate will be increased significantly. There exist risk behaviors that are linked to distraction factors, such as drinking or eating, cell phone use, and speaking animatedly with others [16]. Thompson et al. [17] found that using technological devices while crossing is a common activity of pedestrians and they cross the street relatively slower than those who are undistracted, and technological distraction is associated with highest risks. Pedestrians distracted by listening to music, talking and text messaging with a cell phone have increased crossing times compared to undistracted pedestrians. Pedestrians using cell phones pay less attention to traffic control devices before beginning to cross and they have a tendency to become impatient while waiting for the traffic to stop, and they walk more slowly while crossing [16].

As pedestrian behavior changes significantly from a place in the world to another, so is the crossing speed that changes with location and time. As walking speed is a crucial input for traffic design goals, there exist a lot of studies dealing with the calibration of walking speed at a local level. A good and updated overview is reported by Wu et al. [18] as well as by Onelcin and Alver [19].

A large part of these studies suggests design walking speed values for signalized intersections and recommended values ranging from 1.0 to 1.2 m/sec This range is related to values of the 15th percentile. In areas where older pedestrians, over 65 years, are frequently encountered, a design speed ranging from 0.67 to 1.07 m/s is recommended for design purposes. Such a range of values accommodates at least 85% of this slower segment of older pedestrians. By reviewing literature [20], it was noticed that after the installation of countdown displays at signalized intersections, the walking speeds of crossing pedestrians increased by 3%–10%.

Noncompliance behavior with signals at traffic-light intersections is quite generalized for pedestrians. Individual behavior differs from place to place, and factors that involve pedestrians' subjective willingness are found to play an important role in street crossing behavior [7, 21]. The environmental context can also be very important [22].

From the point of view of both traffic safety and road design, it is important to understand pedestrian crossing behavior because it is reported as the main factor in many pedestrian accidents. If the reasons for noncompliance are understood, appropriate countermeasures can be suggested to increase safety. This research hypothesizes that an additional factor to compliance behavior might be the urban context. Consequently, in the study, pedestrian behavior was observed in two different contexts: working urban and tourist; two different main groups were considered, namely commuters and tourists.

The paper has been divided as follows. Observed locations and data recording methodology are described in section 2. Section 3 is related to a statistical analysis of Viareggio data, and Lucca data are considered separately, whereas in Section 4, the sampled crossings speeds are analyzed. Section 5 is related to the comparison of the two classes of data and respective results. Finally, section 6 resumes the main results and the conclusions are drawn.

2. METHODOLOGY

Field observation data were collected through video recording. In the tourist context, observations were conducted at a signalized intersection located on the main beach avenue of Viareggio, a popular tourist location in Tuscany, in morning (10:00–13:00 a.m.) and late afternoon (05:00–06:30 p.m.), during few days of summer vacation in August 2015, typical periods when tourists visit the beach [23].

The signal cycle was 50 s, the crosswalk was 12 m in length and there were four lanes marked (Fig. 1, top). In the commuter, context data were gathered at a large signalized intersection located on the main urban arterial of Lucca, a historical city in Tuscany, during a weekday midday peak period (11:30–14:00 a.m.) in February 2017, typical period in which the workers move for lunch break and the students return home. The signal cycle was 130 s, there were four lanes marked and the crosswalk length was 17 m (Fig. 1, bottom).

In both cases, video recording was performed for several hours. Videos had been processed successively, and data extracted, by automated software, self-written in MatLab^{TM}. The video analysis had developed separately, leading to two different samples, for tourists and for commuters. For each one of the two samples, the video analysis gave information about pedestrian gender and age (estimated); pedestrian walking alone or in groups; crossing movement (like walking, or running, or plodding, that is, pushing a trolley, or having a dog on a leash, or walking with a stick, or holding a child by the hand); crossing direction (that is, straight or diagonal); pedestrian crossing phase light (whether pedestrians cross during green phase or not).

3. DATA COLLECTION AND RESULTS

The Italian Highway Code states that in a traffic light, the different phases appearing one by one appear to pedestrians are steady red man, steady yellow man, and green walking man. In Italy, a pedestrian commits a dangerous violation when he/she starts crossing during the red or the yellow phases. In previous research, the behavior of tourist pedestrians at the same large signalized intersection, located in Viareggio, was analyzed [22].

Now, the present study considers an enlarged sample, from 289 to 605 tourist pedestrians, and practically gives a confirmation of the results reached by the previous one. The tourist sample analysis shows that only 2.98% of pedestrians start crossing during the red phase and 5.79% on the yellow one, whereas 91.24% start crossing on the green light, so only a few of pedestrians analyzed commit a violation. However, the commuter sample comprises of 323 pedestrians, and it shows that only 15.95% of them start crossing during the red phase and 20.55% on the yellow phase, whereas 63.50% start crossing on the green light, so a large percentage (36.50%) of observed pedestrians commit a violation.

In Table 1, traffic-light phase and a number of approaching and crossing pedestrians are reported, both for the tourist and commuter samples. Chi-square test has been applied to investigate whether there is a significant association between variables by comparing, under the hypothesis of independence, observed values with expected values. The comparison according to gender (Table 2) shows no statistically significant difference between male and female in noncompliance behavior for tourists ($\chi^2 = 0.664 < \chi^2_{0.05} = 3.841$).

On the contrary, among the observed commuters, about 43% men made a noncompliance crossing, against 31.5% of women (Table 2). It results in a statistically significant difference between male and female in noncompliance behavior for commuters ($\chi^2 = 4.522 > \chi^2_{0.05} = 3.841$). Therefore, male commuters were more prone to illegal crossing than females; similar results have been found in Belgrade by Nesic et al. [9]. Besides, quite different results have been found in a study developed in the commuter urban contexts of some cities in Greece where Galanis and Nikolaos [24] noticed a more illegal crossing behavior in women than in men.

Fig. 1. Street view of the two research signalized intersections: in the tourist context of Viareggio (top); in the commuter context of Lucca (bottom)

The comparison of differences, in noncompliance behavior (Table 3), among pedestrians who are crossing alone and pedestrians who are crossing in group (i.e., two or more) shows that in the observed tourist sample, a higher percentage, 11.24%, of noncompliance crossings is recorded for pedestrians crossing alone, whereas a lower percentage, 7.80%, of non-compliance crossings is recorded for pedestrians crossing in group. Nevertheless, these differences in tourists behavior were not statistically significant ($\chi^2 = 1.808 < \chi^2_{0.05} = 3.841$).

The same comparison for the commuter sample shows that there is about 40% of noncompliance crossings for pedestrians crossing alone, whereas about 33% of noncompliance crossings is recorded for pedestrians crossing in groups. As for tourists, also for commuters, these differences were not statistically significant ($\chi^2 = 1.396 < \chi^2_{0.05} = 3.841$).

Some pedestrians walk across the street following a straight line, others follow a diagonal direction traveling a longer path. There can be a dangerous situation when crossing finishes after the red light appearance.

Table 4 shows that, out of the observed tourist sample data, 19.54% of pedestrians cross in straight line, and 19.32% of pedestrians follow a diagonal path. Comparison of differences, per the direction of crossing for tourists shows no statistically significant difference between straight line and diagonal path ($\chi^2 = 0.002 < \chi^2_{0.05} = 3.841$).

Equally, the commuter sample has observed that 27.48% of pedestrians cross in a straight line, and 7.69% of pedestrians follow a diagonal path. As for tourists, also for commuters, the comparison as per the direction of crossing (Table 4) resulted in no statistically significant difference ($\chi^2 = 2.497 < \chi^2_{0.05} = 3.841$).

Table 1

Traffic-light phase and number of approaching and crossing pedestrians

Tourists	*Red*	*Green*	*Yellow*
Arrival	338 (55.87%)	218 (36.03%)	49 (8.10%)
Started	18 (2.98%)	552 (91.24%)	35 (5.79%)
Finish	118 (19.50%)	349 (57.69%)	138 (22.81%)

Commuters	*Red*	*Green*	*Yellow*
Arrival	212 (65.03%)	48 (14.72%)	66 (20.25%)
Started	52 (15.95%)	207 (63.50%)	67 (20.55%)
Finish	87 (26.69%)	30 (9.20%)	209 (64.11%)

Table 2

Noncompliance behavior for pedestrian gender category

Tourists			
Gender	Start on Red	Start on Yellow	Total noncompliance
Male	10 (3.62%)	17 (6.16%)	27 (9.78%)
Female	8 (2.43%)	18 (5.47%)	26 (7.90%)

Commuters			
Gender	Start on Red	Start on Yellow	Total noncompliance
Male	29 (20.42%)	32 (22.54%)	61 (42.96%)
Female	23 (12.50%)	35 (19.02%)	58 (31.52%)

Table 3

Noncompliance behavior for pedestrians crossing alone against pedestrians crossing in groups

Tourists			
Ped. Comp.	Start on Red	Start on Yellow	Total noncompliance
Alone	8 (4.73%)	11 (6.51)	19 (11.24%)
Group	10 (2.29%)	24 (5.50%)	34 (7.80%)

Commuters			
Ped. Comp.	Start on Red	Start on Yellow	Total noncompliance
Alone	39 (23.78%)	26 (15.85%)	65 (39.63%)
Group	13 (8.02%)	41 (25.31%)	54 (33.33%)

Table 4
Dangerous situation for the direction of crossing

Tourists	
Dir.	End on Red
Straight line	101 (19.54%)
Diagonal path	17 (19.32%)

Commuters	
Dir.	End on Red
Straight line	86 (27.48%)
Diagonal path	1 (7.69%)

Table 5
Noncompliance pedestrian behavior for different age groups

Tourists			
Age	Start on Red	Start on Yellow	Total noncompliance
< 20	2 (2.11%)	9 (9.47 %)	11 (11.58%)
20-40	11 (4.01%)	15 (5.47%)	26 (9.49%)
40-65	5 (2.51%)	11 (5.53%)	16 (8.04%)
> 65	--	--	--

Commuters			
Age	Start on Red	Start on Yellow	Total noncompliance
< 20	17 (10.90 %)	41 (26.28 %)	58 (37.18%)
20-40	18 (21.43 %)	19 (22.62 %)	37 (44.05 %)
40-65	17 (20.48 %)	7 (8.43 %)	24 (28.92 %)
> 65	--	--	--

Finally, to test if age has an influence on the attitude towards traffic signal violations, noncompliance behavior of young pedestrians has been compared to noncompliance behavior of both adult and old pedestrians. Table 5 resumes the observed percentages both in the tourist sample and in the commuter one.

The differences among the age groups in the tourist sample were not statistically significant ($\chi 2 = 4.808 < \chi^2_{0.05} = 7.815$). Similarly, the differences among the age groups in the commuter sample were not statistically significant ($\chi^2 = 5.880 < \chi^2_{0.05} = 7.815$).

4. ANALYSIS OF CROSSING SPEEDS

Several studies have shown that the pedestrian crossing speed characteristics are influenced by many factors related to the pedestrians, the intersection and its surrounding environment. Such factors are related to person (age, gender, etc.), trip (purpose, path length, etc.), facility (type, grade, etc.) and environment (geometry, weather conditions) [18, 19, 24, 25].

Table 6

Average and 15th percentile crossing speeds of observed pedestrians

Tourists					
		N	Avg. speed (m/s)	Std. dev. (m/s)	15th perc. speed (m/s)
Gender	Male	276	1.53	0.44	1.09
	Female	329	1.48	0.41	1.09
Age	< 40	369	1.56	0.46	1.20
	> 40	236	1.41	0.34	1.09
Direction	Straight	517	1.52	0.43	1.09
	Diagonal	88	1.41	0.36	1.00
Group consist.	Alone	169	1.58	0.46	1.20
	Group	436	1.47	0.41	1.09

Commuters					
		N	Avg. speed (m/s)	Std. dev. (m/s)	15th perc. speed (m/s)
Gender	Male	142	1.82	0.61	1.31
	Female	184	1.75	0.44	1.42
Age	< 40	240	1.79	0.51	1.40
	> 40	86	1.76	0.56	1.42
Direction	Straight	313	1.78	0.53	1.42
	Diagonal	13	1.71	0.30	1.39
Group consist.	Alone	164	1.93	0.61	1.55
	Group	162	1.63	0.35	1.31

To compute crossing speed, the distance covered by the pedestrian was divided by the difference between the ending (reaching of the sidewalk) and the starting (entry into the lane) time of crossing.

The pedestrian crossing speed (m/s) observed in both cases under exam is presented in Table 6. The average pedestrian crossing speed has been analyzed according to gender, age, direction of crossing, alone or in groups [26, 27]. Such analysis has been performed relating to both tourists in Viareggio and commuters in Lucca.

The values of Table 6 clearly show the crossing speeds of commuters and tourists in any category (gender, age, group, type of crossing). The reciprocal crossing speed distributions are depicted in Figs. 2– 5. In particular, alone commuters walked faster (15th percentile 1.55 m/s) than alone tourists (15th percentile 1.20 m/s) when crossing the street. It should be noted that pedestrians less than 40 years (young people) and greater than 40 years (adults) crossed faster when commuters (on average: 1.79 m/s young people; 1.76 m/s adults) than tourists (on average: 1.56 m/s young people and 1.41 m/s adults).

Statistical tests were conducted to check out the different factors that influenced the crossing speed. The t-Student test has been applied, and the results show that the observed sample difference in gender is statistically significant both for tourists ($t = 1.21 < t_{0.05,603} = 1.96$) and commuters ($t = 1.12 < t_{0.05,324} = 1.97$). The hypothesis that the tourist samples of men and women belong to the same population has been accepted because the ratio of their respective variances is lower than the critical value ($F = 1.17 < F_{0.05,275,328} = 1.25$). On the contrary, the same test on commuter samples of male and female is rejected because the ratio of their respective variances is higher than the critical value ($F = 1.97 > F_{0.05,141,183} = 1.36$).

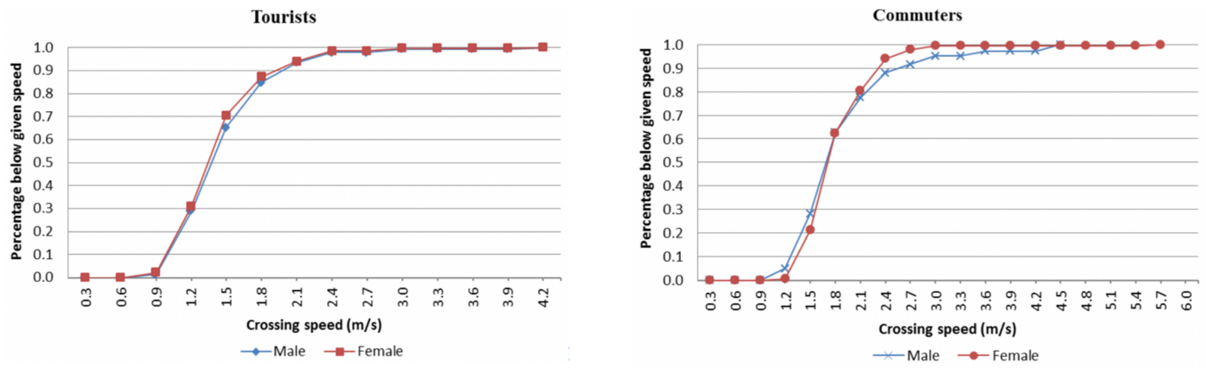

Fig. 2. Crossing speed distributions based on gender

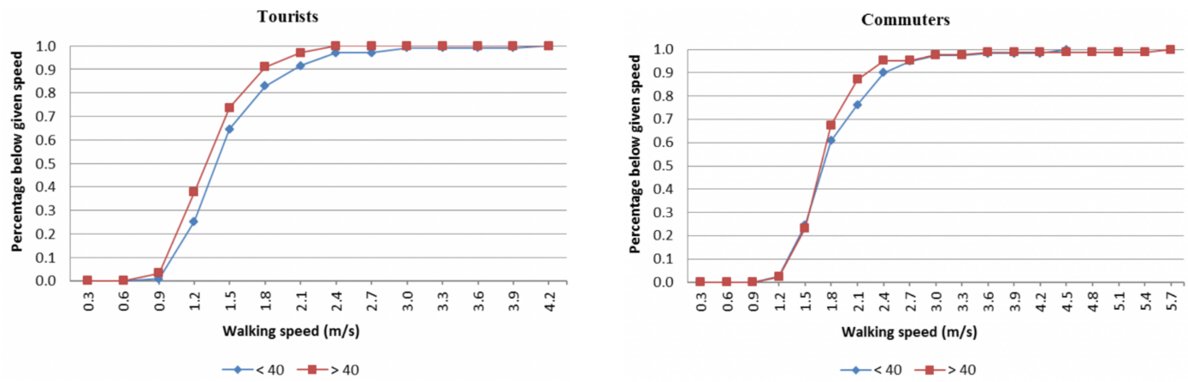

Fig. 3. Crossing speed distributions based on young people (< 40 years old) and adults (> 40 years old)

The age division is assumed between young people, less than 40 years old, and adults, greater than 40 years old, following the popular Dante's incipit: "*Midway upon the journey of our life*". The second factor analyzed with the statistical test is age. Using the t-Student test, a different result for the tourist sample ($t = 4.69 >> t_{0.05,603} = 1.96$) has been observed, which is strongly significant, whereas a significant result has been observed for the commuter sample ($t = 0.44 < t_{0.05,324} = 1.97$). The null assumption that the tourist samples, young (<40) and adult (>40), appertain to the same population is rejected because the ratio of their respective variances is higher than the critical value ($F = 1.82 > F_{0.05,368,235} = 1.26$). Conversely, the same test on commuter samples, young and adult, is accepted because the ratio of their respective variances is lower than the critical value ($F = 1.20 < F_{0.05,85,239} = 1.36$).

The other analyzed factor such as direction of crossing was statistically significant for tourists ($t = 2.44 > t_{0.05,603} = 1.96$), whereas for commuters, it was not statistically significant ($t = 0.88 < t_{0.05,324} = 1.97$). In the tourist ($F = 1.44 > F_{0.05,275,328} = 1.41$) sample and in the commuter sample ($F = 3.17 > F_{0.05,312,12} = 2.75$), the hypothesis that the straight and diagonal directions belong to the same population is refused because the ratio of their respective variances is higher than the critical value.

The last factor analyzed is group consistence wherein the t-Student test resulted that the observed sample is statistically significant both for tourists ($t = 2.59 > t_{0.05,603} = 1.96$) and commuters ($t = 5.32 >> t_{0.05,324} = 1.97$).

The assumption that the tourist samples crossing alone or in group belong to the same population has been accepted because the ratio of their respective variances is lower than the critical value ($F = 1.27 < F_{0.05,168,435} = 1.28$). In contrast, the same test on commuter samples crossing alone or in group is rejected because the ratio of their respective variances is higher than the critical value ($F = 3.10 > F_{0.05,163,161} = 1.36$).

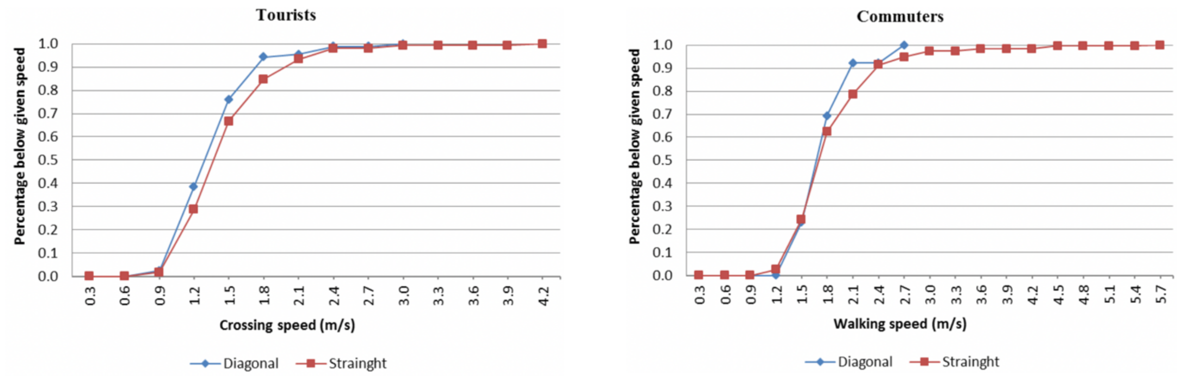

Fig. 4. Crossing speed distributions based on the direction of walking

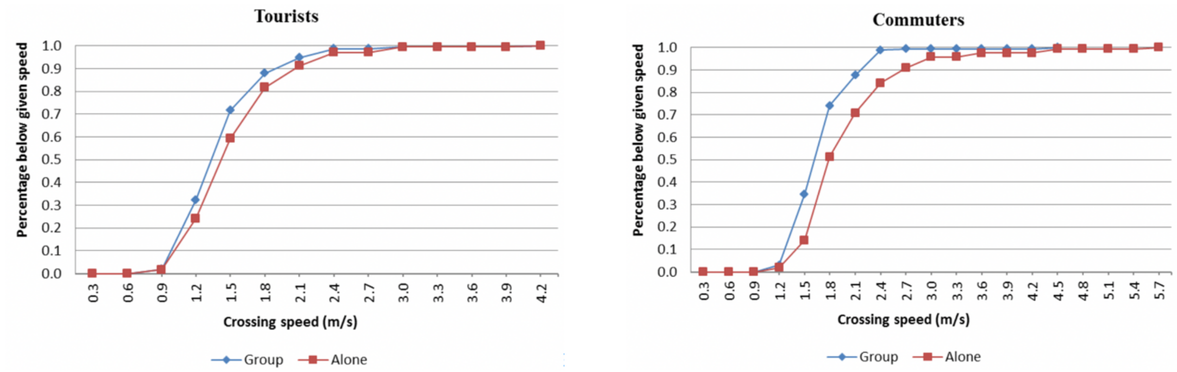

Fig. 5. Crossing speed distributions based on group consistence

Finally, Fig. 6 shows that average crossing speeds were fairly lower in tourists than in commuters.

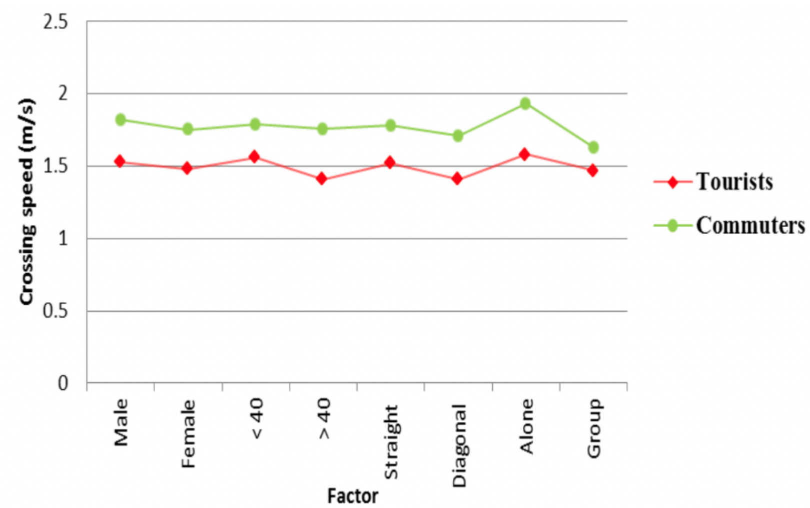

Fig. 6. Comparison of average crossing speeds (m/s)

5. COMPARING CONTEXTS

The Chi-square test has also been applied to investigate whether there is or not a significant association between the analyzed compliance and noncompliance behavior in the two samples of tourists and commuters (Table 7 and Fig. 7).

Table 7

Tourists vs. Commuters: compliance and noncompliance behavior in the two observed samples

	Compliance	Noncompliance
Tourists (Viareggio)	552 (0.91 %)	53 (0.09 %)
Commuters (Lucca)	207 (0.63 %)	119 (0.37 %)

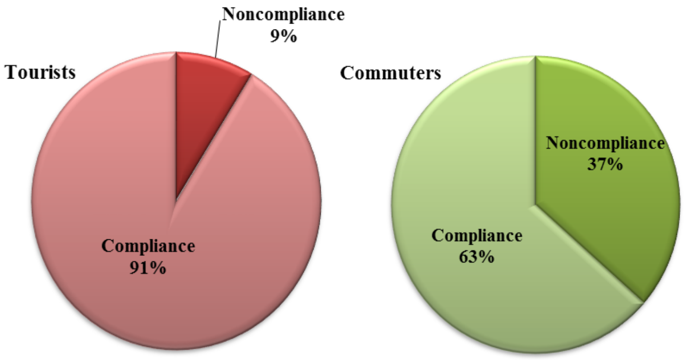

Fig. 7. Percentages of legal and illegal behavior in the two observed samples

Such a comparison points out a quite marked, statistically significant difference between the behavior of tourists and commuters ($\chi^2 = 108.255 > \chi^2_{0.05} = 3.841$). This way it results that differences in pedestrian crossing behavior at lighted crosswalks between tourists and commuters have to be retained as not belonging to random factors.

As seen above, to investigate if the crossing speeds observed in the two samples belong to the same population, a statistical test on sample averages difference and variances homogeneity has been performed. The average speed and the speed standard deviation are calculated for each of the two samples (Table 8). The t-Student test has been applied to verify if the difference between the two sample speed averages is statistically significant. The results show that the observed sample difference in crossing speed averages is strongly significant ($t = 8.23 >> t_{0.05,929} = 1.96$).

Furthermore, the hypothesis that the two samples belong to the same population has been rejected because the ratio of their respective variances is greater than the critical value ($F = 1{,}48 > F_{0.05,604,325} = 1$). As it could be expected, the average crossing speed is quite different between commuters and tourists. The main reason for this is that commuters are generally in a hurry to cross, whereas tourists walk in a less stressed mood.

Table 8

Sampled crossing speed averages and standard deviations

	N	Avg. speed (m/s)	Std. dev. (m/s)	15th perc. speed (m/s)
Commuters	326	1.78	0.52	1.42
Tourists	605	1.50	0.43	1.09

6. CONCLUDING REMARKS

This research hypothesizes that an additional factor to compliance in pedestrian crossing behavior might be the urban context. The results of this exploratory research cannot be claimed as generalizable.

The study limits mainly rely in the differences among the observed sites and must be acknowledged. Further research efforts need to be conducted in several places belonging to the two urban contexts.

Nevertheless, the consistency between the two sites may have been due to their deep differences in terms of pedestrian profile and mood (tourist vs. commuter), and different results might be obtained at other sites. Moreover, some interesting issues and insights arose that should be analyzed in more detail in further research works.

Pedestrian crossing behavior at signalized crosswalks has been analyzed in two different instances of urban context, i.e. two different populations: tourists and commuters. The tourist sample addresses that there are no significant differences in pedestrian crossing behavior, with respect to factors such as gender, walking alone or group, direction of crossing, age. Therefore, the observed differences in the tourists are mainly due to random factors [4].

The commuter sample addresses the same above results, except for gender factor wherein men are statistically significant more prone to illegal crossing than women. However, as far as the comparison in noncompliance behavior between the two samples, tourists and commuter, is concerned, it is markedly different, and a statistically significant difference was observed.

On the basis of this statistical evidence, it can be concluded that crossing behavior, at signalized intersection, of a tourist pedestrian is expected to be more legal than that of a commuter pedestrian. It may be that a less stressed person has a more compliant behavior.

Finally, a higher sample crossing speed is observed in commuters, especially in alone pedestrians. Statistical tests highlight how the two samples belong to different populations, enforcing the previous obtained results on crossing behavior. Therefore, at least in the limits of these results, an average walking speed value calibrated in a commuter urban context is not properly well suited for design applications in a tourist recreational context and vice versa. These findings also suggest that pedestrians cannot be assumed to have an attitude of noncompliance towards road safety in their behavior, and that they are more or less compliant depending on several factors.

Nevertheless, there are some limitations to analyze pedestrian behavior through an observational methodology. It only makes a statistical recording of behaviors, limited to local conditions, without any information on motives behind the behaviors by themselves. It is well known that pedestrian behavior is highly dependent on environmental characteristics, road culture and local habits, and according to some researchers, comparing research results from different countries is not very reliable. For that, the kinds of studies coupling field observations with other quantitative methodologies, combining context differences with awareness and traffic control measures [28], can be beneficial.

The conclusions of this research may be useful for local authorities to better understand the pedestrian crossing behavior in developing road safety training programs in order to improve pedestrian safety.

Future implementations can be made in searching for confirmation and improving understanding of the crossing behavior of pedestrians embedded in different urban contexts, faced with various external factors, such as intersection geometry and type of control devices.

It is, however, quite clearly established [29] that the crosswalk safety has to be sought not only on influencing pedestrians' behavior toward traffic lights, but also on adjusting traffic control patterns toward pedestrians by calming traffic devices and improving driver alerts.

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