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Urban environments, pedestrian-friendliness and crossing decisions

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ABSTRACT

2 The objective of this experimental study is to identify the differentiation made by pedestrians, in their
crossing decision, between various urban environments, notably in terms of perception of walking
4 pleasantness and safety. This experiment further aims to identify the environmental features that
pedestrians use and the inferences they develop to explain their road crossing decision. Sets of five
6 photographs presenting five different environments (city center, inner suburbs, public housing in the
outskirts, commercial zone in the outskirts and countryside) have been presented to 77 participants shared
8 in three age groups (pre-adolescents, young and middle adults). Their decision to cross or not, their
perception of pleasantness and safety, and the elements they take into account to take a decision were
10 collected for each environment presented. The results show the pedestrians' perceptions of the
pleasantness and safety of public spaces, in terms of walking, largely vary with urban environments.
12 Moreover, the crossing decision significantly varies according to the environment. Pedestrians were
significantly more inclined to take the decision to cross in city center than in the other sites presented. The
14 presence and function of the buildings and quality of the sidewalks are key factors to explain their
crossing decision, by enabling them to infer the density of pedestrians and traffic and vehicle speed.

16

Keywords: pedestrian, road crossing, built environment.

18

INTRODUCTION

2 Providing urban spaces that benefit to all users is a major challenge for urban designers and planners. This
concern requires to deal with roadway, roadside and road environment. Such approaches need knowledge
4 on the influence of environment characteristics on users' trips.

Concerning pedestrians, the relation between built environments (street network, land use) and
6 walking or pedestrian flow has been widely studied (1-3). But it is also needed to have a better
understanding of pedestrians' perceptions of the surrounding environment, and the way these perceptions
8 influence their use of public space.

Pedestrians' perceptions of the road environment have been studied to improve risk evaluation (4-
10 6), or to make this environment more favorable to pedestrian and to develop walking (7-9) in terms of
feeling of comfort, safety and security. All these studies are focused on "walkability" of urban spaces.
12 They provide a better understanding of the determinants of pedestrian mobility.

However, the way in which the built environment influences (or does not influence) pedestrian
14 behavior in interaction with other types of users, notably when crossing a street, is not taken into account
for now. These studies do not indeed permit to determine whether pedestrians' perception and
16 interpretation of urban environments lead them to be able to take faster, better suited decisions when they
are faced with a crossing situation.

Some works suggest that the environment influences the pedestrian crossing through its
18 topographical, infrastructural and regulatory aspects (10-12). Other physical elements in the environment,
20 however, such as the nature and spatial distribution of buildings, pedestrian and traffic density, could
influence pedestrian (13) when crossing. Empirical evidence on these subjects is limited, however.

A better grasp of the "crossability" of urban environments is needed. A better understanding of
22 pedestrians' perceptions of the built environment of crossing, both in terms of general feeling
(pleasantness, safety feeling) and in terms of road potentiality to be crossed, could help practitioners to act
24 more effectively when designing urban spaces.

The objective of this experimental study is to identify the differentiation made by pedestrians
26 between various urban environments, notably in terms of perception of pleasantness and safety in walking
and crossing decision. This experiment further aims to identify the environmental features that pedestrians
28 use and the inferences they develop to explain their road crossing decision.

METHOD

Material

34 Five different urban environments were presented to each participant:

- One city center environment
- 36 • One inner suburbs environment
- One public housing environment in the outskirts
- 38 • One commercial zone in the outskirts
- One countryside environment

40 These environments have been selected to represent a variety of urban environments in France.
This selection was a result of focus groups where 20 environments were presented (14). The experimental
42 material used five sets of five photographs, each of these sets presenting one of these environments (see
an example in figure 1). Each set, presented on a 297x420 mm (11.69x16.54 in.) page, shows left-hand,
44 right-hand and central views of a site — providing a 180° view of a street. These photographs were taken
from the pedestrian's point of view (height of the view and position on the sidewalk in a pre-crossing
46 position). The sites were photographed under normal conditions of use (in terms of traffic, number of
pedestrians, etc.). The photos were taken during working hours but outside rush hours.

48 The situations of crossing in each presented environment are similar: a two-lane infrastructure
environment (one lane in each direction), no nearby crossroad, one vehicle (the same in each
50 environment) 35 meters (38.28 yd) away from the point of observation, on the left part of the scene. In
French law, pedestrians are required to cross the road on a marked crosswalk when there is one less than

50 m (54.68 yd) from them. In the other cases, they can cross the road while taking into account the visibility, the distance and speed of the vehicles. According to the French law, driver must yield to pedestrians starting to cross or indicating their intention to cross. Thus, crossing the road requires interactions with drivers in any cases. As there is no marked crosswalk less than 50 m from the crossing sites studied, the participants had not to refer to the rules related to such a marking when they decided to cross or not.

Participants

In all, 77 participants took part in this experiment. Three groups were compared:

- 26 pre-adolescents (10-14 years old). They are used to walk on their own, without adult, and aren't used to drive motorized vehicle;
- 26 young adults (18-24 years old) at the end of their driving training;
- 25 middle adults (25-63 years old), experienced drivers.

Procedure

The five sets of photographs were presented one after the other, in a random order, to each participant. The participants were asked to assume they had to go to the other side of the road. No other detail on the conditions of their trip was given to the participants. For each environment, the question was: "In this environment and this situation, do you cross the road or not?"

The five sets of photographs are then presented once again, one by one, and the participants were asked to explain why they decided to cross or not to cross in this environment.

Participants were also asked to say to what degree they would find it pleasant to walk in the environment presented. They estimated the degree of pleasantness by putting a mark on a non-graduated 10 centimeter-long scale from "not pleasant at all" (scored as 0) to "very pleasant" (scored as 10). In the same way, they were asked to say to what extent they would find it safe to walk in the environment presented, by putting a mark on a non-graduated 10 centimeter-long scale from "not safe at all" (scored as 0) to "very safe" (scored as 10).

RESULTS

Degree of Pleasantness and Feeling of Safety

The dataset contains, for each participant, a pleasantness score and a feeling-of-safety score (ranging from 0 to 10) for each of the five environments. The results are given in tables 1 and 2, in terms of mean and standard deviation of the scores obtained, for each environment and each of the three groups of participants.

TABLE 1 Pleasantness Scores (Mean and Standard Deviation) Obtained from the Groups of Middle Adults ($n = 25$), Young Adults ($n = 26$), and Pre-Adolescents ($n = 26$)

	Countryside Environment	Commercial Zone Environment in the Outskirts	Public Housing Environment in the Outskirts	Inner Suburbs Environment	City Center Environment
Middle adults	5.29 (3.24)	2.81 (2.31)	4.09 (2.70)	4.95 (2.29)	8.69 (1.15)
Young adults	4.59 (3.26)	3.33 (2.05)	4.09 (2.48)	4.85 (1.88)	8.54 (1.27)
Pre-adolescents	5.50 (3.62)	2.79 (1.50)	3.70 (1.91)	4.91 (2.33)	7.90 (1.76)

TABLE 2 Feeling-of-Safety Scores (Mean and Standard Deviation) Obtained from the Groups of Middle Adults ($n = 25$), Young Adults ($n = 26$), and Pre-Adolescents ($n = 26$)

	Countryside Environment	Commercial Zone Environment in the Outskirts	Public Housing Environment in the Outskirts	Inner Suburbs Environment	City Center Environment
Middle adults	1.71 (1.93)	4.33 (2.44)	5.30 (2.46)	5.39 (2.23)	8.51 (1.26)
Young adults	1.53 (1.51)	4.49 (2.08)	5.25 (2.54)	5.71 (2.13)	8.23 (1.66)
Pre-adolescents	3.13 (2.95)	3.17 (2.06)	4.38 (2.16)	6.16 (1.88)	7.64 (1.83)

The test of a significant difference among the sites was carried out using the Friedman test, which makes it possible to take into account the fact that data are paired (each participant gave five scores, one per site). A highly significant p -value was obtained ($p < 10^{-7}$), whatever the group of participants considered (and for the three groups considered as a whole).

For each site, a Kruskal-Wallis test was carried out in order to test the statistical significance of the differences between groups of participants. None of these differences was statistically significant at the 0.05 level. Given these results, it is reasonable to assume that, for each site, the scores obtained from the three groups of participants are issued from the same statistical distribution. Under this assumption, the estimates of the mean scores corresponding to the different sites were calculated and are given in table 3, based on the three groups of participants taken as a whole. Due to the number of individuals in this aggregated group ($n = 77$), the estimates of the mean scores can be considered as approximately normally distributed, which made it possible to calculate corresponding confidence intervals (see table 3).

TABLE 3 Mean Pleasantness Scores and Feeling-of-safety Scores (with 95% CI) for the Three Groups of Participants Taken as a Whole ($n = 77$)

	Countryside Environment	Commercial Zone Environment (Outskirts)	Public Housing Environment (Outskirts)	Inner Suburbs Environment	City Center Environment
Pleasantness score (95% CI)	5.12 (4.36; 5.89)	2.98 (2.53; 3.43)	3.96 (3.42; 4.50)	4.90 (4.41; 5.39)	8.38 (8.05; 8.70)
Feeling-of-safety score (95% CI)	2.13 (1.60; 2.65)	3.99 (3.48; 4.50)	4.97 (4.42; 5.52)	5.76 (5.28; 6.23)	8.12 (7.75; 8.49)

Overall, the degree of pleasantness of the environment (for walking) was rated high for the city center site, medium for the inner suburbs and countryside sites, and low for the sites located in the outskirts (commercial zone and public housing environments). As regards the feeling of safety, it was rated high for the city center site, medium for the inner suburbs and public housing sites, and low for the countryside and commercial zone sites.

Environments and Pedestrian Crossing Decision

For each environment presented, participants were asked to say whether, in such conditions, they would have taken the decision to cross the roadway, or not. Thus, the response variable is binary. A logistic regression was carried out in order to relate this binary response to the variables of the experiment: the variables SITE and GROUP. The variable SITE corresponds to the site presented (countryside environment, commercial zone environment in the outskirts, public housing environment in the outskirts, inner suburbs environment, city center environment). The variable GROUP represents the group of participants (middle adults, young adults, pre-adolescents).

The data obtained, however, are clustered, since each participant gave five responses (one per site). Given the number of participants (77), the dataset contains 385 (77×5) observations grouped into

77 clusters. Applying ordinary logistic regression to these data would imply to neglect the intra-cluster correlation, which could lead to under-estimate the standard errors on the coefficient estimates (15). In such situations, applying a random intercept logistic regression model is preferable. A random component of the intercept, a_i , depending on the cluster i (participant), is added to the usual regression formula, which becomes $\alpha + a_i + \sum \beta_j x_{ij}$, where the a_i are assumed to follow a normal distribution $N(0, \sigma^2)$. The a_i take into account a participant-specific effect. The parameter σ^2 is to be estimated, in addition to the usual estimation of the fixed effects (β_j) and the constant α .

Thus, a random intercept logistic regression was applied. For the sake of simplicity, only the main results of this modeling are presented here (a more complete account is given in (16)). The model adjusted includes, beyond the constant and random effect (random intercept), the variables SITE and GROUP. The estimates of the fixed-effect coefficients of the model are given in table 4. The estimate of the random effect parameter (σ^2) is 1.86. The categories “middle adults” and “countryside environment” are taken as levels of reference for the variables GROUP and SITE respectively, which means that their effects are contained in the value of the constant α .

TABLE 4 Estimates of the Fixed-Effect Parameters for the Random Intercept Logistic Regression Model Including the Variables SITE and GROUP

Fixed-Effect Parameter	Estimate	Standard Error	p -value (Z-test)
α (constant)	-2.30	0.53	$0.15 \cdot 10^{-4}$
$\beta_{\text{SITE-commercial-zone-outskirts}}$	0.14	0.55	0.80
$\beta_{\text{SITE-public-housing-outskirts}}$	1.73	0.49	$0.39 \cdot 10^{-3}$
$\beta_{\text{SITE-inner-suburbs}}$	0.74	0.52	0.15
$\beta_{\text{SITE-city-center}}$	5.70	0.65	$< 10^{-15}$
$\beta_{\text{GROUP-young-adults}}$	-0.87	0.56	0.12
$\beta_{\text{GROUP-pre-adolescents}}$	-0.27	0.54	0.16

The β_j can be interpreted as log-odds-ratios. As regards the effects of the environment, the coefficients corresponding to the public housing environment in the outskirts and to the city center are positive and significantly different from zero. This means that these environments significantly contribute to increase the probability of a decision to cross the roadway, as compared to the reference category (countryside environment). It appears that the coefficients of the variable GROUP are not significantly different from zero. Moreover, this variable does not contribute significantly to the model: applying a likelihood ratio test to this model compared to a model including only the constant, random effect, and variable SITE leads to a p -value of 0.29, which is not significant at the 0.05 level.

Therefore, the model only including the constant, random effect, and variable SITE seems more relevant. It gives nearly exactly the same coefficient estimates, for the variable SITE, as those given in table 4. The practical outcomes of the model are the probabilities of a decision to cross the roadway, for an average individual ($a_i = 0$), as a function of the variables of this model (here, the variable SITE). These modeled probabilities and their 95% confidence intervals are given in table 5.

An alternative model was also tested, by replacing the variable SITE with the above-mentioned pleasantness score and feeling-of-safety score. The aim was to evaluate to what extent the perceived pleasantness and feeling of safety (for walking) in these environments could be sufficient to explain the responses in terms of crossing decision. Although this alternative model is significantly better than the model reduced to the constant and the random effect, it is clearly less satisfying (log-likelihood: -195.4) than the model including the constant, random effect and variable SITE (log-likelihood: -160.3). This loss in likelihood is not compensated by a corresponding reduction in complexity (the information criteria, AIC and BIC, are both higher for this alternative model).

TABLE 5 Probabilities of a Decision to Cross the Roadway, as Estimated by the Random Intercept Logistic Regression Model Including the Variable SITE

	Countryside Environment	Commercial Zone Environment (Outskirts)	Public Housing Environment (Outskirts)	Inner Suburbs Environment	City Center Environment
Probability (95% CI)	0.06 (0.03; 0.14)	0.07 (0.03; 0.15)	0.28 (0.17; 0.41)	0.12 (0.06; 0.22)	0.95 (0.88; 0.98)

Overall, the probability that participants answer that they would have decided to cross, in the environment and conditions presented through the photographic material, appears to be very high (0.95) for the city center environment, moderate (0.28) for the public housing environment in the outskirts, and low (from 0.06 to 0.12) for the other environments presented.

Qualitative Results

The qualitative analysis of discourses of the interviewed participants enables to portray each presented environment and to better understand the participants' decision to cross or not in each environment presented.

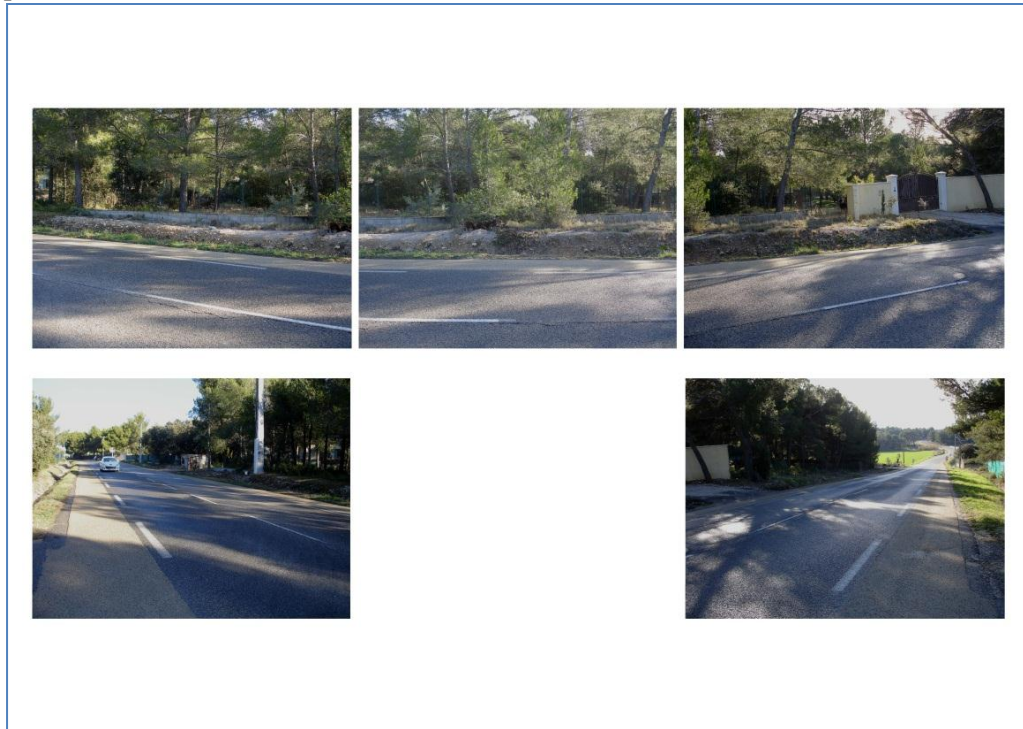


FIGURE 1 Set of photographs of the countryside environment.

Countryside

For this set of photographs (see figure 1), the participants described the road as large. The site was often interpreted as being in the "countryside". The participants often insisted on the lot of vegetation and the lack of buildings, especially the absence of stores. They also stressed the lack of sidewalks, which was viewed as a sign this area was not conceived to receive pedestrians. They judged pedestrians' and traffic density to be low and the road was considered as a through road. The main reason given for not crossing was the high vehicle speed. This element is deduced from the rather straight road alignment and the estimated localization of this area in the exit of the city. The situation was judged to be safe for the driver, focused on the driving task because of the low pedestrians' density. On the contrary, the situation was

perceived as unsafe for the pedestrians because of the assumed driver's lack of attention to the pedestrians in this context.

Commercial Zone in the Outskirts

For this set of photographs (see figure 2), most of the participants labeled this area as a commercial zone, located in urban outskirts. Participants noted the quantity of supermarkets and large stores, their spatial scattering and the lack of dwellings. Parking spaces on the both sides of the road led participants to perceive the traffic density as high, to deduce a lot of vehicle maneuvers and heterogeneous drivers' behavior. All the participants agreed that this type of area is not suitable for the pedestrians. Participants considered that, in such an environment, drivers drive fast and do not expect pedestrians' crossing, thus the situation was perceived to be unsafe for pedestrians.

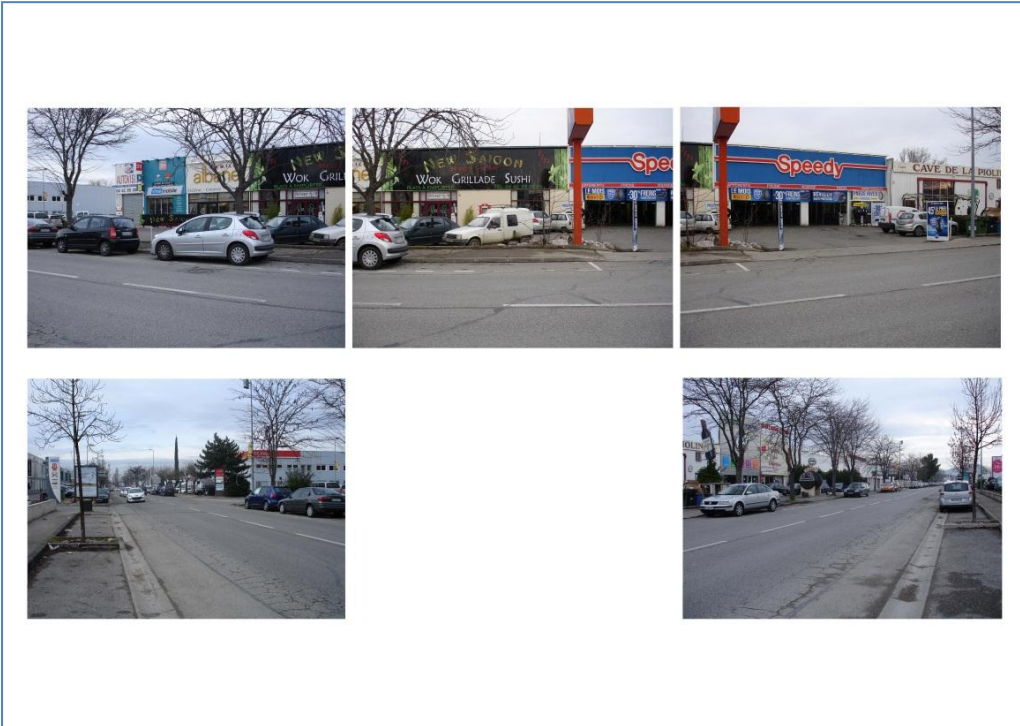


FIGURE 2 Set of photographs of the commercial zone in the outskirts.



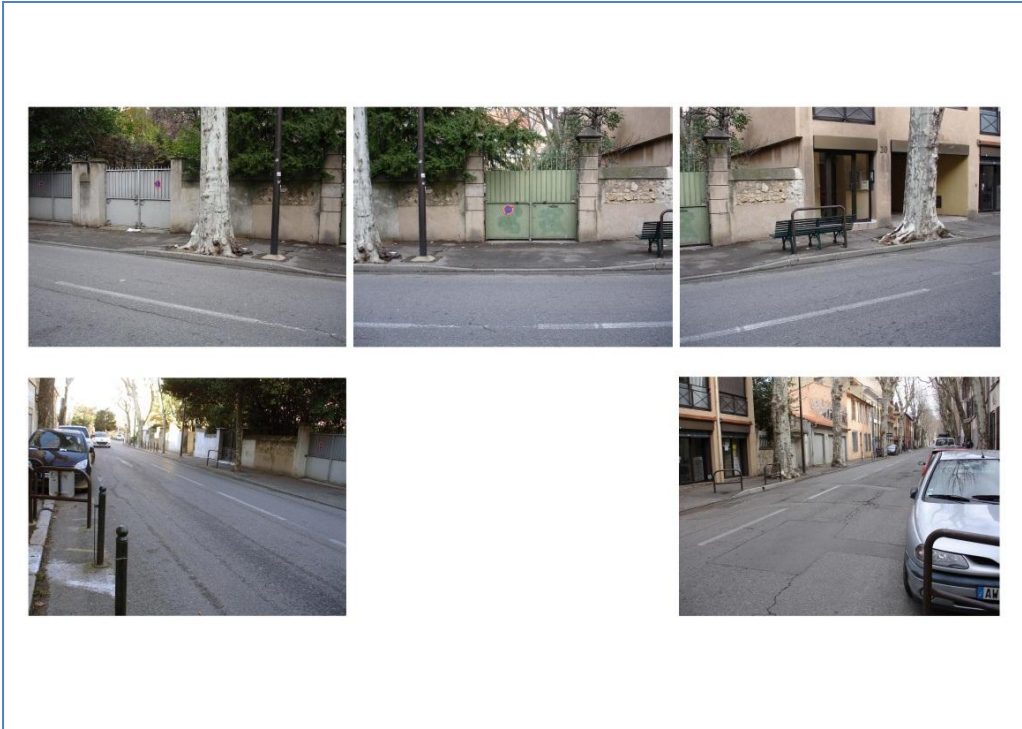
2 **FIGURE 3 Set of photographs of the public housing environment in the outskirts.**

4 *Public Housing Environment in the Outskirts*

6 For this set of photographs (see figure 3), the site was labeled as a residential zone in the fringe of an
 8 urban area. Participants noted the many dwellings and the lack of stores. The road was viewed as an
 10 access road with marked parking spaces. The participants predominantly judged that it is not a road for
 12 strolling: pedestrians' movements were rather qualified as comings and goings between parked cars and
 14 housings. According to participants, pedestrians' and traffic densities were judged to be low to medium
 16 and to vary depending on business hours. For this reason, participants considered that, in this
 18 environment, drivers do not expect pedestrians' crossing and deduced that speed limit is disregarded.

14 *Inner Suburbs*

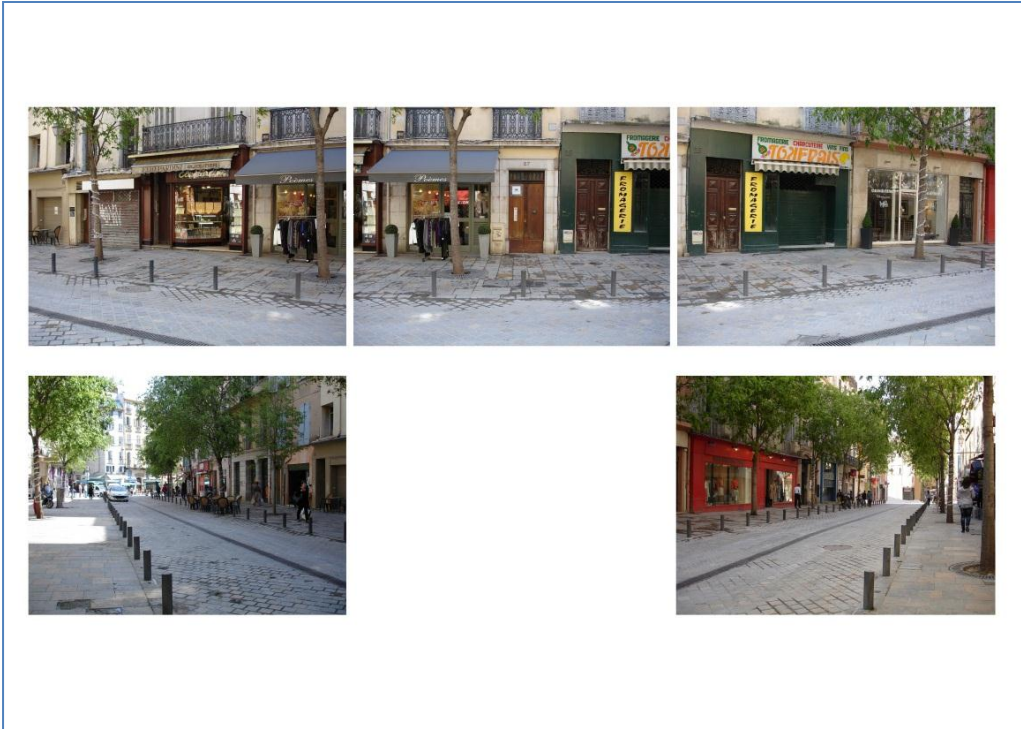
16 For this set of photographs (see figure 4), participants qualified this area as an urban neighborhood but not
 18 in the city center. They noted the numerous mixed dwellings and the lack of stores. Geometric visibility
 20 was judged to be low, due to parked vehicles. The "no parking" zones and the distinction between vehicle
 22 area and pedestrian area were perceived as signs that pedestrians were anticipated. However, pedestrians'
 density was judged to be low or medium. According to participants, in this environment, pedestrians are
 not here for strolling and only inhabitants of the dwellings walk on this road. Traffic density is judged to
 be low or medium but could vary depending on business hours. Participants considered that, in such an
 environment, the driving speed is high, due to the low density of pedestrians and traffic and due to the
 assumed driver's lack of attention towards pedestrians.



2 **FIGURE 4 Set of photographs of the inner suburbs environment.**

4 *City Center*

6 For this set of photographs (see figure 5), the site was often labeled as a pedestrian zone in city center.
 8 The road was often qualified as a pedestrianized street with a narrow roadway and large sidewalks.
 10 Surfaces of sidewalk and roadway and total subsiding of sidewalk were often underlined because they
 12 notably permitted a better accessibility. However, participants also noted the lot of bollards which were
 14 laid out, according to them, to separate roadway from sidewalks. This area was judged as friendly,
 comfortable, pleasant and laid out for pedestrians. The lot of small stores, their variety, their
 concentration and juxtaposition were often underlined. Pedestrians' density, diversity and variety of
 movements were perceived to be linked to the lack of parking spaces and to the presence of stores.
 Participants stressed pedestrians' lack of attention to traffic in this type of area, because crossings are
 facilitated by the low width of the roadway, low traffic density and low vehicle speed. Therefore, drivers
 were estimated far more attentive and yielding towards pedestrians.



2 **FIGURE 5 Set of photographs of the city center environment.**

4 **DISCUSSION AND CONCLUSIONS**

6 The results presented show that pedestrians' perceptions of the pleasantness and safety of public spaces,
 8 in terms of walking, largely vary with urban environments. In particular, the site in city center
 10 environment was judged to be pleasant for walking, whereas other sites in public housing or commercial
 12 environments in the outskirts have low scores of pleasantness. The feeling of safety (for walking) seems
 14 to progress from the countryside environment to the outskirts environments first, and then to the inner
 16 suburbs environment and the city center environment. As regards the crossing decisions, significant
 differences between environments are also found: the probability to cross was high in the city center
 environment, perceived as both pleasant and safe, moderate in the public housing environment in the
 outskirts, and low for the other sites. These effects cannot be mainly attributed to the roadway width,
 since all the sites presented to the participants were sites with a two-way two-lane roadway, nor to the
 particular traffic situation, since the vehicle visible on the left photographs was always located at the same
 distance from the point of observation.

18 The qualitative analysis of the interviews provides some explanations of these results. The
 20 principal element used by participants to explain their road crossing decision is the speed of vehicles. As
 22 vehicle movements are not present in the photographs, the speed of vehicles is deduced from different
 24 elements: the infrastructure characteristics (perceived width, straightness, etc.) that are directly available
 in visual scene; the traffic and pedestrian densities; the site location from the center of the city, as inferred
 by the participants. Traffic and pedestrian densities and site location are largely used by the participants to
 build their crossing decision. They are interdependent and also deduced from environmental cues visible
 in the photographs.

26 One of the major cues is the presence and function of the built environment. For example, the
 28 qualitative analysis shows that commercial buildings are a key element to infer the location of the site
 from the center of the city, the pedestrian density, movements and speed of the vehicles. Thus, a high
 density of small stores – but not a high density of dwellings – is considered as a sign of high pedestrian
 density, heterogeneous pedestrian movements and high driver's attention towards pedestrians.

Another key element is the presence and quality of the sidewalks. They are a sign of pedestrian density and heterogeneous pedestrian movements, as taken into account by urban designers and planners. Their width, their height and their delimitation from the roadway are used to deduce the “balance of power” between pedestrians and drivers, drivers’ attention and yielding during pedestrian crossing.

In brief, quantitative and qualitative analyses show that some key elements in the environment are used by participants to deduce some information which influences crossing decisions. This study thus validates the hypothesis that built environment influences pedestrians’ crossing decision. The results also suggest that perceived pleasantness and safety are not sufficient to understand the effect of built environment on crossing decisions.

Elements of built environment and public space design, especially the function of the buildings, presence and type of commercial activity, and width of sidewalks are used by pedestrians to infer the pedestrian and traffic density, attention to pedestrian and vehicles speed and then to decide to cross or not. Thus, the options chosen in terms of urban planning and design are not without consequence and influence the way pedestrians can use public spaces and the possibilities they have to easily cross urban roads.

Conclusions to be drawn from these results for urban design and planning, however, should be cautious. The results have been obtained from European participants, confronted with a few European urban environments, which represent a variety of urban contexts but are not representative of all the diversity of urban environments. Urban fabrics in other countries can be rather different from those encountered in Europe. Moreover, some urban environments or some features of public space or urban organization improve the pleasantness and feeling of safety for pedestrians but that does not mean that such environments or design options necessarily improve their actual safety. Further research is needed in order to study how the various urban environments are understood and interpreted by drivers (see for example (17)), especially as regards pedestrians, and to evaluate their actual levels of safety.

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