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Assessing pedestrian behaviour: evaluation of a survey of Portuguese residents

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The aim of this study was to evaluate the pedestrian behaviour of a sample of Portuguese residents. For this, a questionnaire was published online and disseminated through e-mails and social media to Portuguese residents. It was answered by 502 people (318 women and 184 men) between 15 and 64 years of age. Principal component analysis differentiated four axes into factors: (1) 'transgression', which included violations of the rules of the road and legal errors; (2) 'lapses', referring to errors caused by lack of attention; (3) 'aggressive behaviours'; and (4) 'positive behaviours' in relation to other road users. From the original, a shorter version with 20 items, referring to each factor's four largest factor loads, was developed, and its internal reliability was tested and approved. The effects of demographic variables were investigated alongside how demographic variables could impact the 'transgression' item, as observed from the discussion of the results. This study helps recognise risk behaviours and adapt user-preventive actions.

Keywords: design/developing countries/municipal & public service engineering/planning & scheduling/project management/public policy/safety & hazards/UN SDG 3: Good health and well-being/UN SDG 11: Sustainable cities and communities

1. Introduction

Pedestrian safety is a growing road planning and management concern in many countries. In countries in Europe, despite that there was a 31% reduction in the number of road accidents in a decade, from 33 000 deaths in 2009 to 22 756 in 2019, Figure 1 shows that 20% of these victims were pedestrians, 44% occupants of passenger cars, 16% on motorcycles, 9% on bicycles and 11% in other categories (including heavy and light goods vehicles, buses and mopeds, among others) (Eurostat, 2022).

Overall road fatalities have reduced in the last two decades in the EU, with pedestrians killed in traffic crashes being reduced by the same proportion, such as in Italy (Meocci *et al.*, 2021), where around 20 000 road accidents involving pedestrians occur annually, with a significant number of injuries and deaths. It should be noted that 30% of these accidents occur on pedestrian crossings, where pedestrians should be better protected. Also, in a lower proportion, on rural roads that cross small villages without detours and low-density urban areas in Spain (Pérez-Acebo *et al.*, 2021), fatalities are increasing. Traffic calming

measures are therefore necessary to maintain a calm zone and improve road safety, in addition to allowing to observe a positive effect on driving and speed reduction near pedestrian crossings. Generally, the proportion of pedestrians killed in crashes is between 20 and 30% of the total fatalities.

Portugal is not an exception. It shares the sixth position regarding mortality rate in road accidents per million inhabitants with Lithuania, while Romania is the EU country with the highest number of road deaths, followed by Bulgaria, Poland, Croatia and Latvia, as presented in Figure 2 (Eurostat, 2022). In 2018, 15.4% of road accidents in Portugal involved pedestrians. There were 5652 victims, with 388 seriously injured and 158 fatally injured. Most cases were women over 75 in urban areas, and most accidents occur between 3:00 pm and 9:00 pm (ANSR Road Accident Report, 2018, 2019).

This trend highlights the importance of research in this field to identify risk factors and promote road-safety strategies, particularly for the most vulnerable road users.

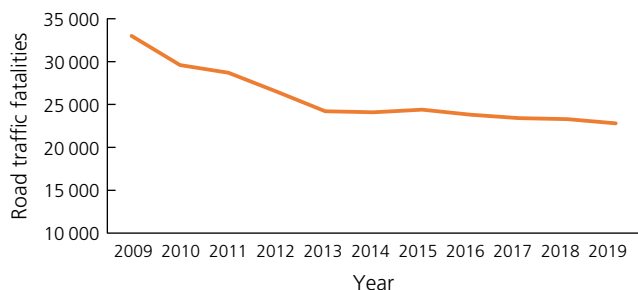


Figure 1. Road traffic fatalities in the EU, 2009–2019, adapted from Eurostat (2022)

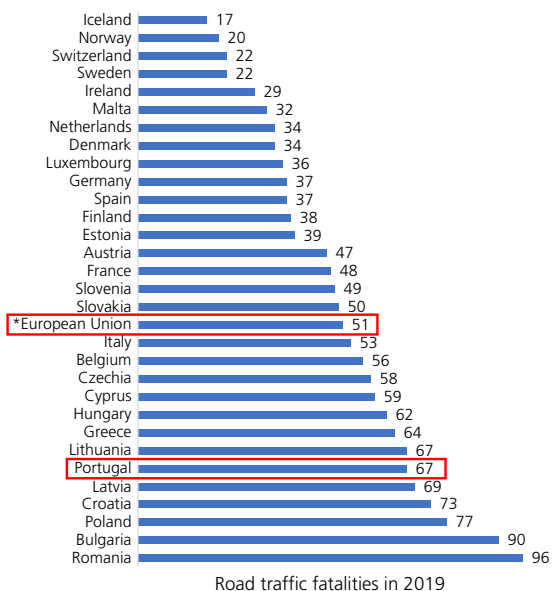


Figure 2. Road traffic fatalities in the EU (per million inhabitants, 2019), adapted from Eurostat (2022). *Europe is not included as a country, what characterises the image is the comparison of the EU countries to the EU average

On the basis of earlier research, Deb *et al.* (2017) recognised that among all types of road users pedestrians have the greatest flexibility and respond most quickly to threats. This capacity helps to minimise the number of pedestrians hit, but reactions of pedestrians are highly unpredictable (De Lavalette *et al.*, 2009; Jian *et al.*, 2005), and most accidents occur due to pedestrian disobeying traffic rules (Ward *et al.*, 1996; Zhuang and Wu, 2011). For example, Zhuang and Wu (2011) observed that most pedestrians did not check for cars coming before crossing the street and, in some cases, when crossing (16.4%). Of those who observed a vehicle approaching, 40.6% stopped, 11.4% retreated to let the vehicle pass and 31.9% rushed to cross. Pedestrians may also not be paying full attention when crossing roads. The use of cell phones and headphones are the two most common distractions

recorded. Another reason is walking in a group as pedestrians tend to keep conversing with their companions and involuntarily violate the rules or have a higher probability of not checking for the approach of vehicles before crossing the street, as reported by Elliott and Baughan (2004).

It should be noted that pedestrians are not generally the ones responsible for the traffic accidents in which they are involved. However, it is essential to understand pedestrian behaviour when adopting solutions, whether engineering or educational, for the use of urban road surveillance in preventing the growing number of occurrences.

Unlike the research tools available to measure risk behaviours of drivers, the structures used to investigate pedestrian behaviour still need to be developed. Granié *et al.* (2013) developed a complete questionnaire, the pedestrian behaviour scale (PBS), and it was modified further as pedestrian behaviour questionnaire (PBQ) in France and the USA (Deb *et al.*, 2017) and Greece (Papadimitriou *et al.*, 2016). The original PBS included research items for five different types of behaviour combined into four components: transgressions (violations and errors), lapses, aggressive behaviours and positive behaviours. In Greece, researchers grouped pedestrian crossing behaviours into three components:

- risk-taking and optimisation (violations, errors, aggressive behaviours and lapses),
- conservative (positive behaviours),
- walking for pleasure (filter items included in the results).

In the USA, earlier validated models were developed into a factorial structure, with a five-factor model (violation, errors, lapses, aggressive behaviours and positive behaviours). The score from the scale was also compared to the intended behaviours of pedestrians on the street, collected from five different scale responses based on scenarios (Deb *et al.*, 2017). These researchers came to the same conclusion as the French study (Granié *et al.*, 2013), namely, that positive behaviours have a higher frequency. They reached this conclusion after consideration of the analysis of different scenarios to assess the questionnaire's effectiveness under different situations.

As far as the authors' are aware, there is no study in Portugal on this matter. Therefore, the current study presents another evaluation of PBS, this time in Portugal, adding knowledge to the understanding of risk behaviours among pedestrians. The method follows a principal component analysis (PCA).

2. Pedestrian behaviour classification

2.1 Methods of pedestrian behaviour classification

A study on the behaviour of pedestrians is relevant at different levels: the structural level (road design, signalling, traffic light

systems, pedestrian support measures); the environmental level (speed limits, type of vehicle, population density, time of day, climatic conditions) and also, at the individual level, both for drivers and pedestrians (mistakes in decision making, alcohol use, age, lack of adequate training and personality) (Deb *et al.*, 2017). However, there are limited tools to observe pedestrian behaviour and few relations between them.

Although ethological observations are still the best way to understand the effect of the road environment on the behaviour of pedestrians in each context (Sisiopiku and Akin, 2003), only some tools provide a complete view of everyday risk behaviours for road traffic injuries of pedestrians in different contexts. Under daily traffic conditions, pedestrians exhibit a wide variety of self-organising behaviour. However, they are still the most vulnerable in the road environment in the event of a vehicle–pedestrian collision.

Earlier research examining pedestrian behaviour, including walking speed (Fitzpatrick *et al.*, 2007; HCM, 2010), assumed that there is a comfort zone, defined as ‘gap acceptance’ from other conflicting users or objects on the road (Meng and Kang, 2015; Wang *et al.*, 2010). It also assumes that each pedestrian has a purpose for their journey and has developed a choice of route (De Lavalette *et al.*, 2009; Hoogendoorn and Bovy, 2004; Robin *et al.*, 2009). However, these studies considered pedestrian behaviour in different situations, not only when crossing roads. A stated behaviour questionnaire is a practical method for studying pedestrian behaviour, providing a self-report on travel and other related behavioural aspects.

The branch of research that uses observational studies and the corresponding historical data is not extensive due to its limitations: there is no guarantee that all types of pedestrian behaviour are collected. Moreover, there are some safety issues related to the pedestrians’ continuous exposure to unsafe scenarios in a natural environment if these experiments are not controlled, and some city councils might not permit those experiments.

There are other alternative methodologies when studying the behaviour of pedestrians when crossing the street, such as observational studies (Deluka-Tibljša *et al.*, 2021; Ištoka Otković *et al.*, 2021; Pratelli *et al.*, 2017), declared preferences based on hypothetical scenarios (Bellizzi *et al.*, 2021), a combination of observation and surveys (Cloutier *et al.*, 2022), eye-tracking technology (Gruden *et al.*, 2022) or a combination of real research and video acquisition (Xing *et al.*, 2022).

In order to investigate risk behaviour, the use of questionnaires on different road users (drivers, cyclists, motorcyclists and pedestrians) appears as a promising, low-cost, safe and comprehensive method (Åberg and Rimmö, 1998; Lawton *et al.*, 1997; Özkan and Lajunen, 2005; Papadimitriou *et al.*, 2016; Reason *et al.*, 1990). However, the answers must be considered with care because behaviour is stated (and not revealed). Table 1 synthesises these studies.

A systematic review of the literature presented by Vandroux *et al.* (2022) supports the idea that the questionnaire results allow the classification of behaviours of users into several categories. The first differentiation in the risk behaviour of road users is made between intentional and unintentional offenses. Intentional offenses can be classified as violations and aggressive behaviour, whereas unintentional offenses can be classified as lapses and errors. The most frequently reported factor is the positive behaviour, although this usually presents validation difficulties according to Vandroux *et al.* (2022), because positive behaviours involve the tendency to remain for a certain time, before crossing a certain distance above a comfortable limit to the distance crossed.

2.2 Pedestrian behaviour questionnaires

The PBS was the first questionnaire to study different and diverse aspects of pedestrian behaviour on the road for all age groups. This questionnaire was based on the conceptual structure of the driver behaviour questionnaire (DBQ) (Reason *et al.*, 1990) that considers aggressive driver behaviours

Table 1. Definition of types of pedestrian behaviour

Pedestrian behaviour	Definition	Practice example	References
Violation	Deliberate deviation from the social rule without the intention of causing injury or damage	Do not use formal crossing nearby to cross	Reason <i>et al.</i> (1990)
Error	Deficiency in the knowledge of traffic rules and/or inferential processes involved in decision making	Cross the road diagonally, to be faster and more direct	Rasmussen (1980), Reason <i>et al.</i> (1990)
Lapse	Unintentional deviation from practices related to the lack of concentration on the task; forgetfulness	Forgetting to look for vehicles before crossing	Reason <i>et al.</i> (1990)
Aggressive behaviour	Tendency to misinterpret the behaviour of other road users, resulting in the intention to disturb or put at risk	Get angry with another road user and insult him/her	Lawton <i>et al.</i> (1997), Baxter <i>et al.</i> (1990)
Positive behaviour	Behaviour that seeks to avoid violation or error and/or seeks to ensure compliance with traffic rules	Do not cross diagonally or let other road users go first	Özkan and Lajunen (2005)

Adapted from Deb *et al.* (2017)

(Lawton *et al.*, 1997), and positive driver behaviours (Özkan and Lajunen, 2005).

The first record of a behavioural questionnaire for pedestrians is presented by Díaz (2002), who, using the DBQ (Parker *et al.*, 1992), adapted it into a 16 item questionnaire called PBQ, which was applied in Chile. The PBQ measured pedestrian risk behaviours and classified the data into violations, errors and lapses. Similarly to responses by drivers, the pedestrian questionnaire found that young male pedestrians commit road behaviour violations more frequently than females. Moreover, the PBQ was used in Brazil (Torquato and Bianchi, 2010) and Turkey (Yildirim, 2007), and in both cases, a similar gender effect was found in the commission of violations.

Elliott and Baughan (2004) developed an adolescent road user behaviour questionnaire (ARBQ) in the UK. This study differentiated pedestrian behaviour into three components: unsafe crossing, dangerous street play and planned protective behaviour. ARBQ was presented in the long (43 items) and short (21 items) versions, and it was supported by complementary studies in New Zealand (Sullman and Mann, 2009). These experiments have shown that adolescents present the same risk-causing variables as other groups. In addition, the shortened version (21 items) of the ARBQ was also applied in Spain (Sullman *et al.*, 2011) and Belgium (Sullman *et al.*, 2012).

The ARBQ was created to evaluate the behaviour of pedestrians and cyclists, with half of the items relating to pedestrian behaviour. Granié (2008) then developed a scale of perception of user behaviour on the road – the Road User Behaviour Perception Scale (RUBPS) – with 14 items in France and trialled it with adult and adolescent pedestrians (Granié, 2009). The scale measured pedestrian behaviour in terms of danger and transgression.

In 2013, Granié *et al.* (2013) used RUBPS to develop and validate a classification of pedestrian behaviour, the PBS, a comprehensive self-report for all ages, to differentiate pedestrians in terms of violations, errors, lapses, aggressive and positive behaviours. The researchers tested and validated extended (37 items) and shorter (23 items) versions of this scale for the French population.

In 2016, Papadimitriou *et al.* (2016) applied PBS in Greece to develop models for pedestrian crossing choices based on road infrastructure, traffic components and characteristics, and human factors. For the Greek population, the classification differentiated the behaviour of pedestrians into three categories: pedestrians taking risks (e.g. a tendency to cross in the mid-block – between intersections – to save time); conservative pedestrians (e.g. with an increased perception of the risk of crossing mid-block) and pedestrian for pleasure (e.g. a tendency to walk frequently for health purposes). In 2017, Deb *et al.* (2017)

applied the classification to the US population, comparing PBS with five other models associated with different scenarios. As in the original model, an extended version (32 items) and a short version (23 items) were made available and differentiated pedestrian behaviour in the five initial categories.

Vandroux *et al.* (2022) carried out the most recent study concerning PBS, a systematic literature review around the development of PBS from 1997 to 2021, including the different local validations for the scientific evaluation of the different dimensions of pedestrian behaviour. To be considered a modified version of the PBS, a study needed to use at least 15 items from the original study; contain its factor analysis (ranging from PCA, exploratory factor analysis and confirmatory factor analysis (CFA)); and present the internal consistencies defined by Cronbach's α . The studies identified were in the European, eastern Mediterranean, African, American, southeast Asian and western Pacific regions and the number of participants varied between 112 and 968. Moreover, in this systematic review, the authors intended to assist directly in decision making regarding syntheses of the methodology and the factors adopted in the different studies, when promoting improvements and recommendations.

In Portugal, no study is available using the PBS developed by Granié *et al.* (2013), which justifies the development of the current research. Moreover, the study applies behavioural differentiation in the long- and short-scale versions, proving that the conclusions are the same. In addition, the study explored socio-demographic influences on different pedestrian behaviours.

3. Analysis of pedestrian behaviour

3.1 Methodology

After an extensive literature review, it was decided to use PBS in this paper, following the process shown in Figure 3.

This methodology consists of two essential steps: the definition and application of the questionnaire and the development of a PCA for the questionnaire results. Therefore, the four axes differentiated into factors are:

- (a) 'transgression', which includes violations of the rules of the road and legal errors,
- (b) 'lapses' which refers to errors caused by a lack of attention,
- (c) 'aggressive behaviours' and
- (d) 'positive behaviour' towards other road users.

Concerning the questionnaire adopted, the focus is on demographic information (seven questions: gender, age, education, occupation, country of origin, country of residence and whether the respondent had any disability) and questions related to pedestrian behaviour, using the PBS, developed by Granié *et al.* (2013). The questionnaire was available in Portuguese, Brazilian Portuguese and English, through the Lime Survey tool, and the

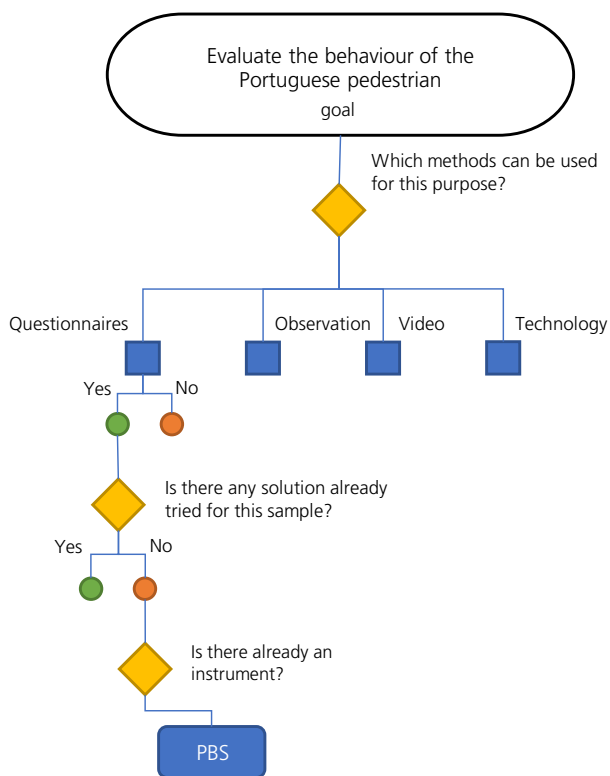


Figure 3. Conceptual approach

adoption of these three languages aims to ensure the validity of the instrument for the population living in Portugal. The questions related to behavioural issues were divided into five groups: violations (11 items), errors (ten items), lapses (eight items), aggressive behaviours (six items) and positive behaviours (five items). Participants were asked to answer questions using a 5-point scale (1 – never, 2 – rarely, 3 – often, 4 – very often, 5 – always). In addition to demographic data and behavioural research items, seven filter items were used to indicate attitudes towards walking and determine whether respondents were qualified to answer subsequent questions. At an early stage respondents who answered ‘never’ to the filter question F1 (I walk outdoors) would be removed from the analysis. However, there was only one such occurrence. The questionnaire was made available online and disseminated through social networks and emails. Participation was voluntary, and the questionnaire took an average of 8 min to complete. Statistical analysis was carried out using SPSS, version 26.0, and Microsoft Excel.

This statistical analysis makes use of the methodology of PCA carried out in SPSS. PCA is a handy tool in data analysis in many fields, including engineering. For example, Hair *et al.* (2010) explain PCA as a multivariate technique to transform a set of related (correlated) variables into independent variables

that explain the decrease in the proportions of variation of the original observations. For Sanguansat (2012), the technique of dimensionality reduction, which transforms data in the high-dimensional level to space of lower dimensions, presents the following advantages:

- Reducing the dimensions has the effect of retaining most of the valuable information while reducing noise and other undesirable factors.
- The time and memory used in data processing are shorter.
- It provides a way to understand and visualise the structure of complex data sets, which helps identify new meaningful underlying variables.

The factor analysis carried out using data analysis software presents the analysis elements (or tables) in the output as shown in Figure 4.

4. Results and discussion

4.1 Sample characterisation

Among 719 registered participants, 66 respondents were excluded for not completing the questionnaire and 151 for not residing in Portugal. The sample of 502 included Portuguese residents from 19 countries and Portugal, which creates limitations in the study because some of the respondents did not participate in their native language, creating uncontrolled differences between respondents. It is essential to point out that only foreigners with residence in Portugal were considered in the sample, and therefore the English version was made available to include people who do not speak the country’s language.

The age of the individuals ranged from 15 to 64 years: 45.0% were in the 15–24 age group, 28.9% were in the 25–34 age group, 13.9% were between 35 and 44 years old and 11.4% were older than 45 years. The female gender represented 63.3% of the sample, and the males 36.7%. It is important to note that it is common to use a non-probabilistic sampling called ‘convenience sampling’ in the application of online questionnaires. However, most respondents tend to be younger because this group uses more communication channels to spread this questionnaire. Therefore, the sample representativity is limited.

Most participants walk for pleasure ‘sometimes’ or ‘often’ (63.5%), and most reported walking ‘rarely’ or ‘sometimes’ when they have no other option (65.1%).

Appendix 1 shows the descriptive statistics, averages, mode, standard deviations (SD) and the distribution of absolute frequencies for each of the 40 behavioural items analysed and the seven filter items classified in the descending order by the average value and the frequency of each of the answers. The most frequently reported behaviours (mode response = 4) involved some filter items and positive interactions with vehicle drivers:

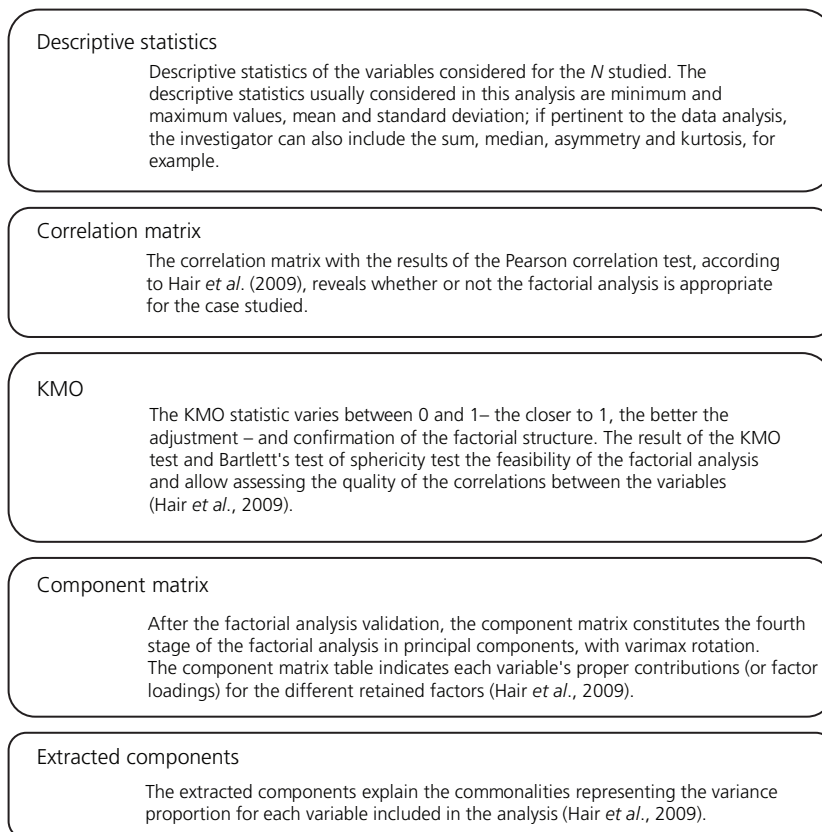


Figure 4. Outputs of a PCA

(a) giving way to another pedestrian, (b) thanking a driver who stops to let a pedestrian crossing, (c) walking on the right side of the side-walk and (d) users of public transport. Less frequent behaviours (mode response = 1) mainly include lapses or aggressive behaviour towards other road users. Violations and errors were found between these two extremes.

4.2 PBS validation

4.2.1 PCA results

A PCA was carried out for the five different behaviour scales in the PBS, excluding the seven filter items, to test the factorial structure of pedestrian behaviours reported by the sample. The extraction method with varimax rotation was applied to all 40 items on the scale, excluding the seven filter items for the PCA.

As the results of this study were compared with earlier studies in this area (Deb *et al.*, 2017, Granié *et al.*, 2013, Papadimitriou *et al.*, 2016), similar approaches were used for rotation and estimation. Rotation performs without fixing factors, which

explained 40.94 and 43.74% of the variance for four and five factors, respectively, indicating that the data fit better into a four-factor solution, as revealed in earlier studies. The Kaiser–Meyer–Olkin (KMO) test used as a measure of adequacy showed a fair value (0.871), Bartlett's sphericity test was significant (0.0001) and the determinant of the matrix obtained was close to zero (3.787×10^{-7}). Four axes with self-values >1 are identified, and a cut-off point of 0.40 was used for the item loading values, following the guidelines of the PBS creators.

From the output, estimated matrices and modification indexes were used to guide the revision of the model. The PCA suggested the elimination of nine items (V1, V2, V3, V5, E5, E7, E8, E10, A1) due to low factorial loads (i.e. <0.40).

The first axis explained 21.57% of the variance and was defined by 11 items (five errors and six violations). As reported by Granié *et al.* (2013), the behaviours carried on axis 1 referred to both errors and violations, according to the classification of aberrant behaviours elaborated by Reason *et al.* (1990), which is why the

authors call them 'transgressions'. On this axis, the intentional nature of the dangerous behaviour is evident, from deliberate offenses against legal rules (e.g. 'I cross diagonally to save time', factorial load: 0.794) or an erroneous or careless decision regarding the place or time of crossing, without offense contrary to legal rules (e.g. 'I start to cross on a pedestrian crossing, and I finish crossing diagonally to save time', load factor: 0.747).

The second axis explains 8.28% of the variance and refers to ten items, eight lapses, one error and one violation. To categorise only items related to lack of attention, items related to violation and error were removed from the axis, 'I deliberately walk on the roadway when I could walk on the side-walk or on the shoulder' and 'I run across the street without looking because I am in a hurry', respectively. In Reason *et al.*'s (1990) classification, used in Granié *et al.* (2013), lapses are characterised by the unintended character of dangerous behaviour and the omission of part of the task. These lapses relate either to distraction (e.g. 'I forget to look before crossing because I am thinking about something else', factorial load: 0.802) or focus on a competing task or situation external to the task to be carried out (e.g. 'I forget to look before crossing because I want to join someone on the side-walk on the other side', factorial load: 0.738).

The five aggressive behaviours concerning the other road users were organised on the third axis, which explained 5.50% of the variance. According to Granié *et al.* (2013), this axis is categorised as the expression of negative emotions that lead to aggressive interaction with different types of road users. One example is 'I get angry with another user (pedestrian, driver, cyclist) and I yell at him/her' (factorial load: 0.761), and another example relates specifically to drivers, such as 'I cross very slowly to annoy a driver' (factorial load: 0.529).

Positive behaviours were categorised on the fourth axis, which explained 4.75% of the variance. The five items facilitate interactions with other road users, whether other pedestrians – for example, 'I walk on the right-hand side of the side-walk so as not to bother the pedestrians I meet' (factorial load: 0.627), or relate to drivers – for example, 'I let a car go by, even if I have the right-of-way if there is no other vehicle behind it' (factorial load: 0.592).

The rotated matrix, with the loading of the items on each axis and the respective factorial loads are shown in Appendix 2.

After eliminating the 11 problematic items, another CFA was carried out using the principal components extraction method. With varimax rotation, the 29 items explained 46.87% of the variance.

According to the method adopted, the average scores of the transgression, lapse, aggressive and positive behaviours were

calculated and used as scales composed of the following items. The results of Cronbach's α s for the items corresponding to each category are transgression (0.873), lapses (0.840), aggressive behaviours (0.742) and positive behaviours (0.502). These values indicated that all scales had acceptable internal reliability ($0.7 < \alpha < 0.9$), except for the positive behaviour scale. An α value below 0.7 for the positive behaviour scale may be due to a low number of questions, low interrelationship between items or multi-dimensional constructions.

In addition, Cronbach's α s were calculated for the two sub-axes related to the transgression axis, violation (0.804) and error (0.764). According to Granié *et al.* (2013), the calculation of these scores observes the effect of demography and mobility in these two dimensions: items related to offences against the rules of the road and errors. Cronbach's α showed acceptable internal reliability for error but did not show the same result for the violation.

4.2.2 Short version of PBS

As presented by Granié *et al.* (2013) and Deb *et al.* (2017), the objective of this study was to test the reliability of the questionnaire for measuring risk behaviours through a self-report by pedestrians. Using a questionnaire with 29 or more items (considering the filters) is not practical and effective in response time, mainly using another self-report instrument. Instead, the authors suggest selecting four items in each of the five axes with the highest factor loads, and adding some filter items to the resulting 20 items.

This new questionnaire was subjected to another PCA with the extraction of principal components and varimax rotation. The results explain 49.69% of the variance after the rotation (compared with 40.94% obtained in the lengthy questionnaire). In the first factor, items referring to 'transgressions', errors and violations were loaded. In the second, third and fourth factors, items related to lapses, aggressive behaviours and positive behaviours were loaded, respectively.

Other important parameters presented in this rotation are: KMO = 0.843; Bartlett = 0.0001 and determinant = 0.000. In addition to the CFA, Cronbach's α measurements were calculated for each of the factors and subscales (transgressions = 0.871; violations = 0.804; error = 0.764; lapses = 0.840; aggressive behaviour = 0.742; positive behaviour = 0.502), which showed consistency acceptable to all, except for the positive behaviour scale, as in the long version. For the rest of the analyses used in this paper, however, the long version (29 items + 7 filters) of the PBQ was used to ensure a comprehensive understanding of pedestrian behaviour.

4.2.3 Relationship between scores

To verify the possible effects of age and gender demographic variables on the scales, partial correlations between the

different dimensions of PBS (transgression, lapses, aggressive behaviours and positive behaviours) were calculated.

The correlation matrix, Table 2, showed positive correlations between transgression, lapses and aggression: the more transgressions individuals declared, the more they also declared lapses and aggressive behaviours. On the contrary, positive behaviours were negatively correlated with lapses: the more individuals who reported positive behaviours towards other road users, the less they reported lapses as pedestrians. Regarding the other factors, although there is a positive correlation, its value is low, which points to a weaker relationship between these other different attitudes.

4.2.4 Effect of demographic variables

Appendix 3 shows the average and SD for each score for each gender and age group.

The groups related to positive and aggressive behaviours present the highest and lowest averages concerning the others, respectively. However, disregarding transgression – a composite variable that comprises two behaviours and more variables in their composition – the average of these groups is expected to be high.

The variables composed of positive and aggressive behaviours also present more minor SD, indicating a reduced variability within the responses. However, they reveal significant differences between them.

To better understand the effects of gender (female and male) and age (five groups: 15–24; 25–34; 35–44; 45–54 and 55+) on the PBS, analyses of variance (ANOVA) were carried out in

Table 2. Partial correlation coefficients between the factors adopted in the PBS

	Lapses	Aggressive behaviour	Positive behaviour
Transgression	0.364* <0.001	0.241* <0.001	0.044 0.325
Lapses		0.354* <0.001	-0.028 0.528
Aggressive behaviour			0.043 0.341

*The correlation is significant at 0.01 level

each of the PBS composite scores: transgressions, lapses, aggressive behaviours and positive behaviours. In addition, analyses were carried out under the subscale's errors and violations (see Table 3).

ANOVA revealed a significant influence concerning age in the violation, error and transgression subscales, to a 95% confidence level. The ANOVAs do not reveal any other significant differences in age for the other scores or in gender for all scores.

4.2.5 Attitudes towards walking

The PBS filter items indicated whether walking was a restriction ('I walk because I have no other choice') or a choice ('I walk for pleasure'). These two items were negatively correlated ($r = -0.211$, d.f. = 500, $p < 0.0001$), as expected. The largest correlation is between the items 'I walk outdoors' and 'I walk for pleasure' ($r = 0.400$, d.f. = 500, $p < 0.0001$).

The average score of people who walk for pleasure is positively correlated with positive behaviours ($r = 0.179$, d.f. = 500, $p < 0.0001$). In contrast, aggressive behaviours are negatively correlated with walking unaccompanied ($r = -0.096$, d.f. = 500, $p < 0.05$) and also positive walking for pleasure ($r = 0.143$, d.f. = 500, $p < 0.001$). Another representative correlation is shown in relation to transgressions and walking outdoors ($r = 0.178$, d.f. = 500, $p < 0.0001$). The composite variable referring to transgressions presented positive and significant correlations with four of the seven filter items, as shown in Table 4.

4.2.6 Discussion considering Granié et al. (2013)

Therefore, although this paper follows the study by Granié et al. (2013), it should be noted that there are a few differences concerning the current application. These differences are essentially in the analysis of the frequencies of the responses. In Granié et al. (2013), results show that risk behaviours for injuries are fixed among pedestrians based on regular interactions and accepted rules. However, in the case of the current study, there is an observation of an additional pedestrian behaviour that tends to disregard those rules and transgress usually accepted social norms. Some additional examples are as follows.

- In Granié et al. (2013), the most frequently reported behaviour concerned a positive interaction behaviour

Table 3. F and p-value statistics to estimate the effects of demographic variables

Demographic	F statistics × sig					
	Violation	Error	Transgression	Lapses	Aggressive behaviours	Positive behaviours
Age	2.958 × 0.012	2.241 × 0.044	3.009 × 0.011	2.213 × 0.052	1.513 × 0.184	0.504 × 0.773
Gender	0.042 × 0.816	0.010 × 0.926	0.004 × 0.950	0.692 × 0.406	0.076 × 0.782	0.664 × 0.416
Age × gender	0.927 × 0.495	0.699 × 0.626	0.852 × 0.514	0.705 × 0.620	0.879 × 0.495	1.718 × 0.129

Table 4. Correlations between filters and composed variables

	Positive behaviours		Transgression		Lapses		Aggressive behaviours	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
I walk outdoors	0.077	0.087	0.178	<0.001	0.056	0.210	0.039	0.338
I take public transportation (buses, metro, tramway, etc.)	0.015	0.736	0.128	0.004	0.061	0.174	-0.061	0.170
I walk without being accompanied	0.036	0.419	0.149	0.001	0.028	0.537	-0.096	0.031
I walk for the pleasure of it	0.179	<0.001	0.049	0.271	0.033	0.459	0.143	0.001
I walk in covered areas (such as shopping centres)	0.009	0.843	0.049	0.271	0.052	0.242	-0.017	0.701
I walk accompanied by other people	0.003	0.946	0.037	0.413	0.062	0.162	0.002	0.967
I walk because I have no other choice	-0.024	0.587	0.155	<0.001	0.081	0.068	0.056	0.210

(mutual respect) with a car driver, whereas in the current study, the most reported behaviour is also positive, but it refers to the pedestrian with other pedestrians.

- In Granié *et al.* (2013), the second most frequently reported categories are errors and violations related to the place and direction of passage (passing diagonally or ending the passage diagonally, passing between stopped or parked vehicles), whereas in this study, the errors are the same. However, the most frequently reported violations were ‘I walk on the curb’ and ‘I cross while talking on my cell phone or listening to music on my headphones’.

In summary, in this study, the most reported behaviours were not the most desirable from a safety point of view. Instead, they relate to problematic behaviours regarding a lack of visibility and behaviours that violate traffic rules.

5 Conclusion

The main objective of this study was to use an existing pedestrian study structure – developed for the French population – to apply a pedestrian behaviour study to the Portuguese population to identify and classify different pedestrian behaviours. After testing several evaluation techniques most results confirmed the usefulness of PBS for Portuguese residents, with only a few necessary modifications.

The behavioural items reported in this study case revealed frequencies close to those in the French sample (Granié *et al.*, 2013) and also taking into account a study carried out in the USA (Deb *et al.*, 2017). Similarly to the French and American studies, the most frequently reported behaviours were positive, and the most minor reported behaviours included aggressive behaviour towards other road users and lapses. It is essential to highlight that, in all PBS versions, the problem of homogeneity of the ‘positive behaviours’ dimension is recurrent. However, these items present the highest frequencies in all contexts.

Concerning the internal structure of the PBS, a CFA grouped the research items empirically into four different aspects of pedestrian behaviour (transgressions, which included items referring to violations and errors, lapses, aggressive behaviour and positive behaviour), as well as in the study by Granié *et al.* (2013).

The research developed by Deb *et al.* (2017) grouped the research items into five factors according to the original idea. This differentiation is acceptable, as each factor relates differently to pedestrian safety. Another evaluation of the French scale was developed by Papadimitriou *et al.* (2016), who decided to group the four behavioural risk factors based on the facilitation of their version of the PBQ. However, the authors failed to effectively prove that the relationships were strong enough (>0.70) to support the combination of risk behaviours into one factor.

Finally, as in similar studies, the self-reporting method proved effective, simple and objective in detecting risky pedestrian behaviour on the roads. Furthermore, developing a reduced version of the questionnaire enables aggregation with other scales that may be relevant to the topic. Once assessed for the Portuguese residents, this instrument can be helpful in the measurement and analysis of behavioural differences, especially in the population of pedestrians at most significant risk, such as young people and the elderly, and be better able to adapt or implement preventive actions for vulnerable road users.

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Appendix 1

Table 5. Average, mode, SD and frequency distribution of the PBS items

Item	Average	Mode	SD	Absolute frequencies					
				1	2	3	4	5	
<i>Filter</i>									
F1	I walk outdoors	4.07	4	0.683	0	9	74	293	126
F2	I walk without being accompanied	3.81	4	0.736	1	23	117	290	71
F3	I walk for the pleasure of it	3.39	4	1.058	19	89	147	172	75
F4	I take public transportation (buses, metro, tramway, etc.)	3.34	4	1.138	20	128	93	181	80
F5	I walk in covered areas (such as shopping centres)	3.23	3	0.830	8	80	226	164	24
F6	I walk accompanied by other people	3.09	3	0.723	9	75	287	123	8
F7	I walk because I have no other choice	2.46	2	1.033	90	191	136	70	15
<i>Positive behaviours</i>									
P1	I stop to let the pedestrians I meet by	3.70	4	0.880	8	33	145	232	84
P2	I thank a driver who stops to let me cross	3.68	4	1.120	23	59	105	183	132
P3	I walk on the right-hand side of the side-walk so as not to bother the pedestrians I meet	3.50	4	0.924	7	64	169	196	66
P4	I let a car go by, even if I have the right-of-way, if there is no other vehicle behind it	3.05	3	0.999	29	118	187	135	33
P5	When I am accompanied by other pedestrians, I walk in single file on narrow side-walks so as not to bother the pedestrians I meet	2.89	3	1.016	48	128	171	139	16
<i>Errors</i>									
E1	I cross the street between parked cars	2.76	3	0.962	41	160	202	76	23
E2	I start to cross on a pedestrian crossing, and I finish crossing diagonally to save time	2.72	3	1.022	52	170	171	84	25
E3	I cross between vehicles stopped on the roadway in traffic jams	2.62	3	0.995	62	174	177	70	19
E4	I look at the traffic light and start crossing as soon as it turns red	2.55	2	1.136	102	156	135	84	25
E5	I cross even though obstacles (parked vehicles, buildings, trees, trash bins, etc.) obstruct visibility	2.29	2	0.926	100	208	151	33	10
E6	I walk on the roadway to be next to my friends on the side-walk or to overtake someone who is walking slower than I am	2.25	2	0.952	112	212	126	44	8
E7	I cross even if vehicles are coming because I think they will stop for me	1.79	1	0.902	231	175	67	26	3
E8	I walk on cycling paths when I could walk on the side-walk	1.56	1	0.781	292	155	43	8	4
E9	I run across the street without looking because I am in a hurry	1.23	1	0.534	410	73	15	4	
E10	I walk on bus lanes when I could walk on the side-walk	1.09	1	0.401	467	28	4	1	2
<i>Violations</i>									
V1	I walk on the curb	4.51	5	0.703	2	13	10	177	300
V2	I cross while talking on my cell phone or listening to music on my headphones	2.73	2	1.166	89	134	131	121	27
V3	On a two-way street, I cross the first part and wait in the middle of the roadway to cross the second part	2.65	3	1.276	123	113	126	96	44
V4	I cross diagonally to save time	2.62	3	1.001	63	174	176	69	20
V5	I avoid using pedestrian bridges or underpasses, even if one is located nearby	2.61	2	1.138	91	155	146	78	32
V6	I cross the street even though the pedestrian light is red	2.60	2	0.908	49	192	184	67	10
V7	I start walking across the street, but I have to run the rest of the way to avoid oncoming vehicles	2.46	2	1.090	101	180	131	68	22
V8	I cross outside the pedestrian crossing even if there is one less than 50 m away	2.41	2	0.960	79	218	136	58	11
V9	I cross even though the light is still green for vehicles	2.26	2	0.919	104	216	135	41	6
V10	I take passageways forbidden to pedestrians to save time	1.33	1	0.643	368	112	15	3	4
V11	I deliberately walk on the roadway when I could walk on the side-walk or on the shoulder	1.25	1	0.565	404	76	18	3	1
<i>Lapses</i>									
L1	I cross without looking, following other people who are crossing	1.47	1	0.768	330	123	34	13	2
L2	I lose my way because I get lost in my thoughts	1.63	1	0.901	290	138	49	18	7
L3	I realise that I do not remember the route I have just taken	1.59	1	0.886	311	116	49	23	3
L4	I hit a pedestrian or an obstacle because I am not paying attention	1.36	1	0.608	352	126	20	3	1
L5	I forget to look before crossing because I am thinking about something else	1.39	1	0.661	351	115	29	7	0
L6	I cross without looking because I am talking with someone	1.42	1	0.626	324	147	28	3	0

(continued on next page)

Table 5. Continued

Item	Average	Mode	SD	Absolute frequencies				
				1	2	3	4	5
L7 I forget to look before crossing because I want to join someone on the side-walk on the other side	1.18	1	0.478	428	59	14		1
L8 I realise that I have crossed several streets and intersections without paying attention to traffic	1.42	1	0.678	339	120	39	3	1
<i>Aggressive behaviours</i>								
A1 I walk in a way that forces other pedestrians to let me through	1.51	1	0.731	300	159	32	9	2
A2 I get angry with another user (pedestrian, driver, cyclist, etc.) and I yell at him/her	1.35	1	0.654	364	110	20	6	2
A3 I cross very slowly to annoy a driver	1.13	1	0.469	454	35	8	4	1
A4 I get angry with another user (pedestrian, driver, cyclist, etc.) and I make a hand gesture	1.29	1	0.672	401	67	25	6	3
A5 I get angry with another user and insult him/her	1.20	1	0.506	422	63	15	1	1
A6 I get angry with a driver and hit his vehicle	1.06	1	0.265	474	25	3		

Appendix 2

Table 6. Rotated matrix, result from CFA

Item	Factor			
	1	2	3	4
V4 I cross diagonally to save time	0.794			
E2 I start to cross on a pedestrian crossing, and I finish crossing diagonally to save time	0.747			
V6 I cross the street even though the pedestrian light is red	0.747			
E3 I cross between vehicles stopped on the roadway in traffic jams	0.725			
V8 I cross outside the pedestrian crossing even if there is one less than 50 m away	0.719			
V9 I cross even though the light is still green for vehicles	0.715			
E1 I cross the street between parked cars	0.715			
E4 I look at the traffic light and start crossing as soon as it turns red	0.548			
E6 I walk on the roadway to be next to my friends on the side-walk or to overtake someone who is walking slower than I am	0.480			
V7 I start walking across the street, but I have to run the rest of the way to avoid oncoming vehicles	0.438			
V10 I take passageways forbidden to pedestrians to save time	0.414			
L5 I forget to look before crossing because I am thinking about something else		0.802		
L7 I forget to look before crossing because I want to join someone on the side-walk on the other side		0.738		
E9 I run across the street without looking because I am in a hurry		0.737		
L8 I realise that I have crossed several streets and intersections without paying attention to traffic		0.716		
L6 I cross without looking because I am talking with someone		0.713		
L1 I cross without looking, following other people who are crossing		0.671		
L2 I lose my way because I get lost in my thoughts		0.621		
L3 I realise that I do not remember the route I have just taken		0.552		
L4 I hit a pedestrian or an obstacle because I am not paying attention		0.491		
V11 I deliberately walk on the roadway when I could walk on the side-walk or on the shoulder		0.436		
A2 I get angry with another user (pedestrian, driver, cyclist, etc.) and I yell at him/her			0.761	
A5 I get angry with another user and insult him/her			0.752	
A4 I get angry with another user (pedestrian, driver, cyclist, etc.) and I make a hand gesture			0.749	
A3 I cross very slowly to annoy a driver			0.529	
A6 I get angry with a driver and hit his vehicle			0.526	
P3 I walk on the right-hand side of the side-walk so as not to bother the pedestrians I meet				0.627
P4 I let a car go by, even if I have the right-of-way, if there is no other vehicle behind it				0.592
P5 When I am accompanied by other pedestrians, I walk in single file on narrow side-walks so as not to bother the pedestrians I meet				0.540
P1 I stop to let the pedestrians I meet by				0.503
P2 I thank a driver who stops to let me cross				0.429

Appendix 3

Table 7. Average and SD of composed variables by gender and age

Age	Gender	Transgression		Violation		Error		Lapse		Aggressive behaviour		Positive behaviour		N
		Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	
15–24	Female	25.89	6.64	13.26	3.81	12.63	3.52	11.52	3.78	5.71	1.49	16.76	2.95	161
	Male	28.88	8.20	14.92	4.33	13.95	4.31	12.06	4.22	6.00	1.66	16.83	2.94	65
	Total	26.75	7.23	13.74	4.03	13.01	3.80	11.68	3.91	5.79	1.55	16.78	2.94	226
25–34	Female	27.04	7.78	14.08	4.46	12.97	3.65	11.97	4.72	5.99	1.97	16.87	2.75	91
	Male	28.67	6.18	14.70	3.14	13.96	3.65	11.59	3.83	6.46	2.31	16.41	2.92	54
	Total	27.65	7.24	14.31	4.02	13.34	3.67	11.83	4.40	6.17	2.11	16.70	2.82	145
35–44	Female	24.79	5.62	12.53	3.39	12.26	2.78	11.53	3.82	5.97	1.80	17.68	2.20	34
	Male	27.47	5.66	14.39	3.40	13.08	2.77	10.67	2.60	7.03	2.63	16.17	2.62	36
	Total	26.17	5.76	13.49	3.50	12.69	2.78	11.09	3.25	6.51	2.31	16.90	2.53	70
45–54	Female	23.36	6.10	12.00	3.56	11.36	3.11	11.36	4.26	5.91	1.72	17.18	3.22	22
	Male	25.67	7.65	13.11	4.01	12.56	3.91	9.89	2.83	6.50	1.98	17.50	2.79	18
	Total	24.40	6.85	12.50	3.76	11.90	3.50	10.70	3.72	6.18	1.84	17.33	3.00	40
55–64	Female	24.71	10.97	12.43	5.71	12.29	5.68	9.14	1.21	6.43	1.99	18.00	2.16	7
	Male	21.70	5.60	10.90	3.11	10.80	3.33	9.30	1.64	5.70	1.06	16.70	3.83	10
	Total	22.94	8.07	11.53	4.27	11.41	4.35	9.24	1.44	6.00	1.50	17.24	3.23	17
Not declared	Female	25.00	2.00	12.67	2.52	12.33	0.58	10.33	2.52	6.00	1.73	14.00	2.65	3
	Male	19.00		10.00		9.00		8.00		5.00		20.00		1
	Total	23.50	3.42	12.00	2.45	11.50	1.73	9.75	2.36	5.75	1.50	15.50	3.70	4
Total	Female	25.89	6.96	13.31	4.01	12.59	3.50	11.58	4.07	5.85	1.70	16.92	2.84	318
	Male	27.78	7.16	14.33	3.83	13.45	3.82	11.27	3.66	6.36	2.10	16.65	2.91	184
	Total	26.59	7.09	13.68	3.97	12.90	3.64	11.46	3.92	6.04	1.87	16.82	2.87	502

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