TSR TRAFFIC SAFETY RESEARCH
AN INTERDISCIPLINARY JOURNAL

Research article

Investigating pedestrian safety-related behavior in developing countries: Egypt as a case study

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Received: 14 May 2022; Accepted: 30 September 2022; Published: 8 November 2022

Abstract: Understanding pedestrian behavior and road safety culture is essential for improving traffic safety in developing countries. The primary aim of this study was to investigate the validity for applying the Pedestrian Behavior Scale (PBS) in Egypt to explore the pedestrian behaviors in developing countries and to investigate the relationship of these behaviors across demographic variables. A Pedestrian Behavior Questionnaire (PBQ) was conducted in Egypt containing behavioral items and demographic questions with a total of 567 participants. Exploratory factor analysis (EFA) was applied to assess the number of behavioral factors that express the pedestrian behaviors. The analysis showed that the Egyptian pedestrian behaviors consist of four factors, including transgressions (violations and errors), lapses, aggressive behaviors, and positive behaviors. *T*-test and ANOVA were conducted to explore the significant difference across gender, age groups and education level. Furthermore, linear regression analysis was conducted to investigate how the examined variables influence the behavioral factors. The current study showed that the Pedestrian Behavior Scale (PBS) is an effective tool for investigating Egyptian pedestrian's behaviors. This study added a validation for applying the PBS to explore the pedestrian behaviors in developing countries such as Egypt and to understand the variables affecting the pedestrian behaviors. The findings can be used by infrastructure agencies to enhance educational road safety programs and enact appropriate laws, which could reduce the number of pedestrian-related crashes.

Keywords: exploratory factory analysis (EFA), Pedestrians Behavior Scale (PBS), regression analysis

1 Introduction

Traffic crashes are a worldwide public health issue, especially for the vulnerable road users. Approximately, there are 1.35 million fatalities and more than 50 million injuries around the world every year. Children and young adults are found to be more prevalent in these statistics, with traffic crashes being the leading cause of death worldwide. Pedestrian deaths accounted for 40% of traffic deaths in Africa (WHO 2018).

Although the importance of studying pedestrian behavior, attitude, and perception regarding road safety, only a few studies have been conducted in developing countries, and specifically Egypt, on this topic. Egypt is the largest developing country in the Middle East, with a population of over 100 million people growing at a rate of 2.7% per year and over 11 million registered vehicles (CAPMAS 2019). The average number of traffic crashes over the last five years has been 11 800, resulting in more than 4 200 deaths and 14 800 injuries, most of them are vulnerable road users (CAPMAS 2019). Crash investigations showed that human errors are responsible for more than 75% of road crashes (CAPMAS 2019). The investigation of pedestrian behavior could help in the reduction of road fatalities by trying to implement protective precautions and policies customized to this mode of transportation (CAPMAS 2019).

In regions in which Pedestrians Behavior Scale (PBS) has not yet been investigated, the lack of consistency across PBS measures becomes a barrier to use, particularly given that any number of various items or forms could be used. The most suitable items and subsequent factor structure are almost obviously dependent on both the culture and infrastructure of the country under consideration. It is necessary to investigate how frequently reported pedestrian behaviors are in Egypt. As a result, the objective of this study was to build on previous worldwide research of pedestrian behavior questionnaires and validate a questionnaire for an Egyptian pedestrian population and to investigate the pedestrian behaviors across the demographic variables. In this research, a short version of the PBS was used to collect the data. This data analyzed using exploratory factor analysis (EFA), analysis of variances (ANOVA) and linear regression models. Finally, policy recommendations were provided based on the discussion of the results.

2 Background

Various data collection methods have been used by researchers over the last decade to get a better knowledge of pedestrian behaviors. Direct observation and video recording are two common approaches for observing pedestrian behaviors (Alhajyaseen & Iryo-Asano 2017; Hamann *et al.* 2017; Koh *et al.* 2014; Brosseau *et al.* 2013; Papadimitriou 2012). Other approaches for observing pedestrian behaviors include using GPS and similar devices to track and record pedestrian paths (Quistberg *et al.* 2017; Pulugurtha *et al.* 2007), exploring road traffic crashes (Tay *et al.* 2008; Sze & Wong 2007; Lee & Abdel-Aty 2005; Gårder 2004) and evaluating the pedestrian level of service (PLOS) (Gallin 2001; Dixon 1996; Sarkar 1995). Observations and objective data analysis are the basis of these strategies. However, in order to use an appropriate method to control risky behaviors, it is necessary to understand why pedestrians behave that way. For this, questionnaires are necessary.

The driver behavior literature has greatly assisted in the development of tools for investigating pedestrian behaviors. Moyano Díaz (1997) created the Scale of Pedestrian Behaviors, a questionnaire based on the Driver Behavior Questionnaire (Moyano Díaz 1997). This scale classified pedestrian behaviors into the same three categories that were used to investigate driver behaviors: violations, errors, and lapses. To improve explanation of the pedestrian behaviors, Granié *et al.* (2013) constructed and validated the Pedestrian Behavior Scale (PBS), a self-report scale that evaluates injury risk behaviors in pedestrians of all ages. The PBS was developed based on six validated questionnaires: the Moyano Díaz (1997) pedestrian behavior scale (Moyano Díaz 1997), the Driver Behavior Questionnaire (DBQ) (Lawton *et al.* 1997; Reason *et al.* 1990), Aggressive Driver Behaviors Scale and Positive Driver Behaviors Scale (Özkan & Lajunen 2005), the Adolescent Road User Behavior Questionnaire (ARBQ) (Elliott & Baughan 2004), and Granié's road user behavior perception scale (Granié 2008). Table 1 shows the definitions of different types of pedestrian behaviors (Deb *et al.* 2017).

Table 1 Definitions of different types of pedestrian behaviors (Deb *et al.* 2017)

Pedestrian behavior	Definition	Example	Reference
Violation	Deliberate deviation from social rules without intention to cause injury or damage.	Not using nearby pedestrian crosswalk to cross	Reason *et al.* (1990)
Error	Deficiency in knowledge of traffic rules and/or in the inferential processes involved in making a decision	Crossing diagonally to save time	Reason *et al.* (1990)
Lapse	Unintentional deviation from practices related to a lack of concentration on the task; forgetfulness.	Forgetting to look around for vehicles before crossing	Reason *et al.* (1990)
Aggressive behavior	A tendency to misinterpret other road users' behavior resulting in the intention to annoy or endanger.	Getting angry with another user and insulting him	Lawton *et al.* (1997)
Positive behavior	Behavior that seeks to avoid violation or error and/or seeks to ensure traffic rule compliance.	Not crossing diagonally or letting other road users go first	Özkan & Lajunen (2005)

Various regions of the world had applied the PBS. Following its early validation by Granié *et al.* (2013), Nordfjærn & Şimşekoğlu (2013) also used it to explore the role of local cultures variables and behavior toward safety on self-reported risky pedestrian behavior among Turkish urban pedestrians. This version of the PBS was also used by Şimşekoğlu (2014) to study the role of attitudes and personality characteristics on Turkish pedestrian behavior. In Esfahan, Iran, 32 items from the PBS were used to deal with the pedestrian behavior (Jalilian *et al.* 2015). In 2016, modified PBS had been verified in Serbia and China (Antić *et al.* 2016; Qu *et al.* 2016). To calculate the frequency of unsafe pedestrian traffic behavior, Antić *et al.* (2016) used the PBS with the entire set of assessed dimensions (Antić *et al.* 2016). They also included information about the use of cellphones while driving. Qu *et al.* (2016) developed a Chinese version of the PBS (CPBS) by using items from the French (Granié *et al.* 2013) and Turkish (Nordfjærn & Şimşekoğlu 2013) pedestrian behavior questionnaires to meet the Chinese context. Deb *et al.* (2017) developed and validated the Pedestrian Behavior Questionnaire (PBQ) for the US population using the original 43 items of the PBS. Deb *et al.* (2017) verified a short questionnaire, which was frequently utilized in the Americas in later years (Deb *et al.* 2018). Ruiz *et al.* (2019) validated the short questionnaire developed by Deb *et al.* (2017) on a Mexican population. The PBS has been applied in various parts of the world, including the United Kingdom, Africa (Kenya), Southeast Asia (Bangladesh and Thailand), and the Western Pacific (China and Vietnam) (Liu *et al.* 2021; Dinh *et al.* 2020a; Dinh *et al.* 2020b; McIlroy *et al.* 2020a; McIlroy *et al.* 2020b; McIlroy *et al.* 2019).

Exploratory factor analysis (EFA) method was used to determine the number of factors to which the different items belonged (O'Hern *et al.* 2020; Hőgye-Nagy 2018). Then each item was listed on the dimension(s) to which it best associates using principle component analysis (PCA). In most studies, PCA is used to validate questionnaires (Esmaili *et al.* 2021; Liu *et al.* 2021; O'Hern *et al.* 2020; Solmazer *et al.* 2020; Nordfjærn & Zavareh 2016; Qu *et al.* 2016; Granié *et al.* 2013; Nordfjærn & Şimşekoğlu 2013). Granié *et al.* (2013) differentiated only four variables for pedestrian behaviors using PCA: transgressions, lapses, aggressive behaviors, and positive behaviors.

This instrument has been used not only to analyze pedestrian behaviors, but also to connect the many characteristics of pedestrian behaviors to a variety of individual attributes. In addition to fundamental socio-demographic data such as gender, age, and education level, several research have connected PBS to extended socio-demographic characteristics such as income and marital status (Esmaili *et al.* 2021). Pedestrian behaviors as measured by the PBS was also associated to many road environment characteristics such as infrastructure, mobility, and historical collision involvement. Pedestrian behaviors has been correlated to levels of satisfaction with infrastructure and the environment (Şimşekoğlu 2014; Nordfjærn & Şimşekoğlu 2013), as well as modes of transportation such as cycling or public transportation (Hőgye-Nagy 2018). Other studies have found that past involvement in crashes, whether as a pedestrian, a driver, or a road user influences pedestrian behaviors (Esmaili *et al.* 2021; Ruiz *et al.* 2019). Pedestrian behaviors are also highly connected to driver behaviors (Şimşekoğlu 2014) and daily driving duration (Esmaili *et al.* 2021; Hőgye-Nagy 2018). Reasons for walking (Hőgye-Nagy 2018; Antić *et al.* 2016) as well as frequency, walking duration, and distance travelled (Esmaili *et al.* 2021; Antić *et al.* 2016) all have a part in pedestrian behaviors. This study would contribute to a good understanding of pedestrian behaviors in Egypt as a developing country, which is an essential and initial step to deal with pedestrian safety based on science and therefore toward a future with fewer pedestrian crashes.

3 Data collection

3.1 Pedestrian Behavior Questionnaire (PBQ)

The original Pedestrian Behavior Scale (PBS) items were first translated into Arabic, and the translated version was pilot tested on thirty persons of various genders and ages. Several of these items were removed from the questionnaire to reduce confusion and to ensure that the time required for the questionnaire is appropriate for the participants. Other unclear statements were rephrased to increase suitability and clarity for Egyptians.

Following that, an online questionnaire was created. In order to make the survey more understandable by the respondents, the homepage included a short description of the aim of the questionnaire. To reduce any concern regarding privacy issues, the survey did not require any online registration or providing any personal data. The survey took approximately 15 minutes to complete.

The questionnaire was divided into five sections, and the first two sections of the questionnaire are those concerned with this study. The first section contains social and demographic characteristics items (gender, age and education). The second section is about pedestrian behaviors which was developed from Granié *et al.* (2013)'s Pedestrian Behaviors Scale (PBS); a self-report survey for measuring pedestrian behaviors when using the roadway. It consists of 19 items of pedestrian behaviors, 18 items from the PBS and one item added by the researchers related to one of the most repeated behavior in Egypt ('While crossing the road, I use hand signals to inform the driver of my decision to stop or cross the road') to determine in which category it belonged to. The replies were given on a 5-point Likert scale (from 1 = never to 5 = always).

This questionnaire addresses five categories of behavior: Violations, Errors, Lapses, Positive Behaviors, and Aggressive Behaviors. Lapses are risky behaviors that are unintended concerning inattention and carelessness. Violations are dangerous behaviors that are intentional acts against the law, whereas errors are mistakes and incorrect decisions that lead to unsafe actions that are not illegal. Aggressive behavior is associated with a violent attitude and showing

irritating expressions toward other road users. Positive behaviors represent positive interactions between pedestrians and other road users.

3.2 Sample size

A total of 567 participants over 16 years old responded to the questionnaire and completed the form, that achieves 95% significance level and 5% margin of error (Bartlett *et al.* 2001). The gender ratio in the sample was fairly balanced with 60% males and 40% females. To reflect adolescence, young adulthood, and adult, age was separated into three groups: < 25 years old (55%), 25 to 39 years old (40%), and 40 to 49 years old (4%). Although it was determined that the sample did not fairly represent individuals in the age group from 40 to 49 years old, it was still included in the study for further investigations. Figure 1 shows the demographics of the collected sample in this study and Egyptian population.

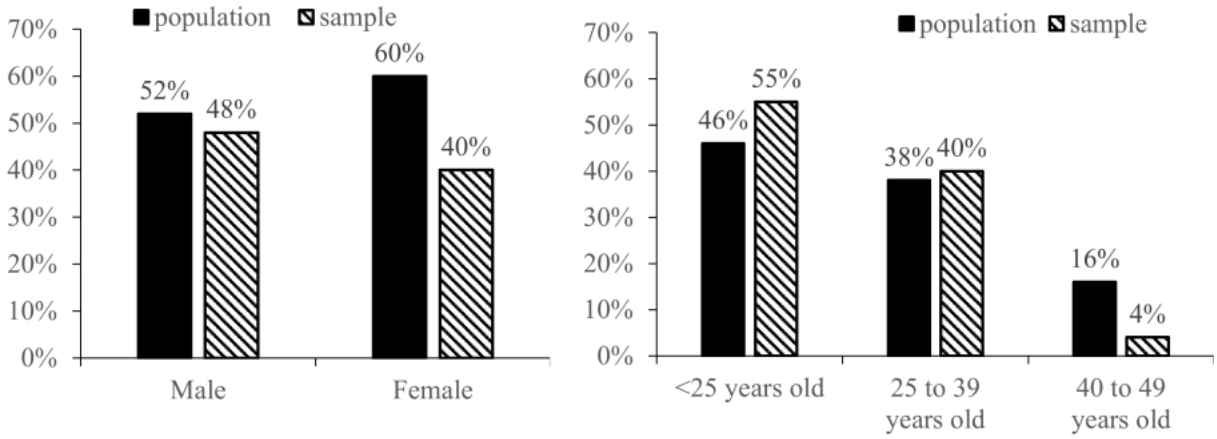

Figure 1 Demographics of sample and Egyptian population

4 Methodology

4.1 Exploratory factor analysis (EFA)

Exploratory factor analysis (EFA) using principal component analysis (PCA) with varimax rotation method was conducted with 19 items to identify the most appropriate factor structure for pedestrian behaviors in Egypt. The Kaiser-Meyer-Olkin (KMO) test determines whether your data is suitable for factor analysis. The statistic is a measure of the proportion of variance among variables that might be common variance. KMO values between 0.8 and 1 indicate the sampling is adequate (O'connor 2000). The Bartlett's test of Sphericity is used to test the null hypothesis that the correlation matrix is an identity matrix. An identity correlation matrix indicates that your variables are unrelated and thus unsuitable for factor analysis. A significant statistical test ($p < 0.05$) shows that the correlation matrix is not an identity matrix (rejection of the null hypothesis).

Factor analysis is part of General Linear Model (GLM), a technique that is used to reduce a large number of variables into fewer numbers of factors. This technique extracts maximum common variance from all variables and puts them into a common score. Several factor analysis methods are available such as: (*1*) principal component analysis, (*2*) common factor analysis, and (*3*) maximum likelihood method. Principle component analysis (PCA) starts extracting the maximum variance and puts them into the first factor. After that, it removes that variance explained by the first factors and then starts extracting maximum variance for the second factor. This process goes to the last factor. Factor loading is basically the correlation coefficient for the variable and factor. Factor loading shows the variance explained by the variable on that

particular factor. By taking the sample size into consideration, Hair *et al.* (2014) suggests that the cut-off value for the items factor loading to be 0.30 for sample size greater than 350, so the items with value of factor loading less than 0.30 was deleted.

The number of factors to keep was calculated through eigenvalue analysis (O'connor 2000). Eigenvalues shows variance explained by that particular factor out of the total variance. When eigenvalue is larger than one, a factor should be considered; when eigenvalue is less than one, then that factor should be discarded. Rotation method affects the eigenvalues or percentage of variance extracted. There are several rotation techniques to choose from: (*1*) no rotation method, (*2*) varimax rotation method, (*3*) quartimax rotation method, (*4*) direct oblimin rotation method, and (*5*) promax rotation method.

Each of these factor analysis approaches and rotation methods could be simply selected in SPSS Software, and the variance explained by those methods can be compared. Among various approaches, principal component analysis (PCA) with varimax rotation was chosen for attaining the highest explained variance for factors.

Cronbach's alpha is a measure of internal consistency, that is, how closely related a set of items are as a factor. It is considered to be a measure of scale reliability. In general, a reliability measure of more than 0.6 is regarded appropriate (Hair *et al.* 2009).

4.2 Regression models

To investigate the variations in behavioral factors across socio-demographic groups, ANOVA and *t*-tests were used. Linear regression models were developed to investigate the relationship between each pedestrian behavior and socio-demographic characteristics. Gender, age groups and education level were entered as independent variables to investigate their effect on pedestrian behaviors as dependent variables.

Some statistics were conducted to interpret the outcomes: (*i*) *p*-value with value below 0.05 indicates that the independent variable is significant, and (*ii*) R^2, ranging from 0 to 1, with higher values indicating better model fit since multi-collinearity issue has a negative impact on statistical significance or interpretation of variables (Hair *et al.* 2014). Variance Inflation Factor (VIF) was calculated to ensure that multi-collinearity issue had no considerable effect. IBM SPSS Statistics 25 was used to analyze the data.

5 Analysis and results

5.1 Descriptive Analysis

Means and standard deviations (σ) for the Pedestrian Behaviors Questionnaire (PBQ) items are presented in Table 2. The most frequently reported behavior was associated with positive behavior and connection with vehicle drivers (thanking the driver who stops for a pedestrian to cross, with a mean score of 4.39 out of 5). The following most often reported conduct was also associated with positive behavior and interacting with other pedestrians, with a mean score of 4.21 out of 5). Followed by error behavior (crossing even though cars are approaching because I think they will stop for me, with a mean of 2.26 out of 5) and violation behavior (crossing while speaking on the phone or listening to music using headphones, with a mean score of 2.23 out of 5). Finally, responders reported fewer lapses and aggressive actions than other behavioral categories.

Table 2 Means and standard deviations of pedestrian behavior items

Behavior item	Item code	Mean	St. dev.
I thank a driver who stops to let me cross	P1	4.39	1.00
When I am accompanied by other pedestrians, I walk in single file on narrow sidewalks so as not to bother the pedestrians I meet	P2	4.21	1.12
I let a car go by, even if I have the right-of-way, if there is no other vehicle behind it.	P3	3.68	1.20
While crossing the road, I use hand signals to inform the driver of my decision to stop or cross the road	P4	3.60	1.35
I cross even if vehicles are coming because I think they will stop for me.	E1	2.26	1.33
I cross while talking on my cell phone or listening to music on my headphones.	V1	2.23	1.25
I cross even though obstacles (parked vehicles, buildings, trees, trash bins, etc.) obstruct visibility.	E2	2.22	1.31
I cross without looking when following other people who are crossing	L1	2.20	1.32
I get angry with another road users (pedestrian, driver, cyclist, etc.), and I yell at them.	A1	2.19	1.28
I avoid using pedestrian bridges or underpasses for convenience, even if one is located nearby.	V2	2.09	1.19
I cross the street even though the pedestrian light is red.	V3	1.94	1.19
I walk on the roadway when I could walk on the sidewalk.	E3	1.90	1.15
I walk in a way that forces other pedestrians to let me through.	A2	1.84	1.13
I have run into a pedestrian or an obstacle while walking because I am not paying attention.	L2	1.81	1.03
I realize that I have crossed several streets and intersections without paying attention to traffic.	L3	1.62	1.04
I cross very slowly to annoy a driver.	A3	1.61	1.01
I forget to look before crossing because I am thinking about something else.	L4	1.56	0.95
I cross without looking because I am talking with someone.	L5	1.49	0.92
I get angry with another road user (pedestrian, driver, cyclist, etc.), and I make a hand gesture.	A4	1.48	0.99

Note: P indicates positive behavior; A indicates aggressive behavior; V indicates violation; E indicates error; L indicates lapses.

5.2 Exploratory factor analysis (EFA)

Principal component analysis (PCA) was applied to investigate the factorial structure of the Egyptian pedestrian behavior questionnaire. The results revealed justifiable factor loading values for items that the data best fit into four factors (transgressions; violations and errors, lapses, aggressive behaviors, and positive behaviors), with a total variance of 50.01%. Kaiser- Meyer-Olkin test for sampling adequacy was 0.88, and the Bartlett test was significant ($p < 0.0001$), indicating that the data were appropriate for principal component analysis.

Lapses, the first factor, explained 15.71% of the variation and were determined by five questions concerning inattention and carelessness. Items in this component were risky behaviors that were unintended. The second element, transgression (as stated by Granié *et al.* (2013)), explained 13.46 % of the variation and included six items relating to errors (3 items) and violations (3 items). All items placed into this factor are hazardous behaviors, which are either

intentional acts against the legal rules (violations) or mistaken, and incorrect decisions that lead to unsafe actions that are not opposed to the legal rules (errors) (Granié *et al.* 2013). The third component, aggressive behavior, accounted for 11.90% of the variation. All four items loading into this component are connected to clashing attitude and showing irritating expressions toward other road users. Positive behavior, the fourth factor, represented 8.94% of the variation. This factor was measured through four elements that represent pedestrians' positive interactions with other road users.

Table 3 Principle component analysis results

Behavior item (how often do you …)	Item code	Lapses	Trans-gressions	Aggressive behaviors	Positive behaviors
I cross without looking because I am talking with someone.	L5	0.694			
I forget to look before crossing because I am thinking about something else.	L4	0.693			
I realize that I have crossed several streets and intersections without paying attention to traffic.	L3	0.665			
I have run into a pedestrian or an obstacle while walking because I am not paying attention.	L2	0.647			
I cross without looking when following other people who are crossing.	L1	0.613			
I avoid using pedestrian bridges or underpasses for convenience, even if one is located nearby.	V2		0.709		
I cross the street even though the pedestrian light is red.	V3		0.709		
I cross while talking on my cell phone or listening to music on my headphones.	V1		0.608		
I walk on the roadway when I could walk on the sidewalk.	E3		0.572		
I cross even if vehicles are coming because I think they will stop for me.	E1		0.548		
I cross even though obstacles (parked vehicles, buildings, trees, trash bins, etc.) obstruct visibility.	E2		0.484		
I get angry with another road users (pedestrian, driver, cyclist, etc.), and I yell at them.	A1			0.728	
I get angry with another road user (pedestrian, driver, cyclist, etc.), and I make a hand gesture.	A4			0.709	
I walk in a way that forces other pedestrians to let me through.	A2			0.624	
I cross very slowly to annoy a driver.	A3			0.437	
While crossing the road, I use hand signals to inform the driver of my decision to stop or cross the road.	P4				0.675
I let a car go by, even if I have the right-of-way, if there is no other vehicle behind it.	P3				0.659
I thank a driver who stops to let me cross.	P1				0.652
When I am accompanied by other pedestrians, I walk in single file on narrow sidewalks so as not to bother the pedestrians I meet.	P2				0.539
% of variance explained		15.71%	13.46%	11.90%	8.94%
Cronbach's alpha		0.80	0.75	0.63	0.52

To assess internal reliability, Cronbach's alpha scores were measured for Lapses (0.80), Transgressions (0.75), Aggressive Behaviors (0.63), and Positive Behaviors (0.52). The usual cut-off number is 0.7 (Tavakol & Dennick 2011; Nunnally 1978). Apart from aggressive and positive behavior, the results indicated an adequate level of internal consistency. Some researchers regard alpha values between 0.6 and 0.7 to be acceptable (Robertson & Evans 2020; Taber 2017; Qu *et al.* 2016; van Griethuijsen *et al.* 2014). According to (Nunnally 1978), a result between 0.50 and 0.60 is appropriate in the initial stages of study. It's possible that an alpha value of less than 0.6 for the positive behavior scale is owing to a lack of questions or weak item interrelatedness. As a result, the positive subscale was kept in subsequent analyses, and the outcomes should be properly reviewed. These 19 items are a short edition of the pedestrian behavioral questionnaire suitable for Egypt and can be used as a dependable framework for assessing Egyptian pedestrian behaviors. Factor loading of each item and Cronbach's alpha coefficient for each factor are presented in Table 3.

5.3 Determinants of pedestrian behaviors

The investigation of mean responses revealed that aggressive behaviors and transgressions had a significant difference across gender. Males reported more transgressions and aggressive behaviors than females.

ANOVA was performed to determine whether how behavior differed between age groups. Positive behaviors, aggressive behaviors, transgressions, and lapses all showed a significant age impact. The Bonferroni post hoc test showed that older pedestrians (those over the age of 40) reported more positive behaviors than those under the age of 40. Adolescents (those under the age of 25) exhibited higher aggressive behavior than those above the age of 25. Adults (over 40) committed fewer transgressions than pedestrians under 40. Teenagers (under the age of 25) reported greater lapses than those over the age of 25.

Table 4 ANOVA and *t*-test results

	Positive behaviors	**Aggressive behaviors**	**Transgressions**	**Lapses**
Gender (*t*-test)	$t = 0.950$	$\mathbf{t = 5.079}$	$\mathbf{t = 1.899}$	$t = 1.522$
	$p = 0.343$	$\mathbf{p = 0.000}$	$\mathbf{p = 0.058}$	$p = 0.129$
Male	$m = 3.99$	$m = 1.90$	$m = 2.16$	$m = 1.77$
Female	$m = 3.93$	$m = 1.58$	$m = 2.03$	$m = 1.67$
Age groups (ANOVA)	$\mathbf{F = 3.950}$	$\mathbf{F = 3.356}$	$\mathbf{F = 6.807}$	$\mathbf{F = 6.863}$
	$\mathbf{p = 0.020}$	$\mathbf{p = 0.036}$	$\mathbf{p = 0.001}$	$\mathbf{p = 0.001}$
< 25 Years	$m = 3.95$	$\mathbf{m = 1.85}$	$m = 2.12$	$\mathbf{m = 1.82}$
25 to 39 Years	$m = 3.94$	$m = 1.69$	$m = 2.17$	$m = 1.68$
≥ 40 Years	$\mathbf{m = 4.27}$	$m = 1.70$	$\mathbf{m = 1.68}$	$m = 1.38$
Education (*t*-test)	$\mathbf{t = 2.058}$	$t = 1.080$	$\mathbf{t = 2.302}$	$\mathbf{t = 3.585}$
	$\mathbf{p = 0.040}$	$p = 0.281$	$\mathbf{p = 0.022}$	$\mathbf{p = 0.000}$
University education	$m = 3.93$	$m = 1.79$	$m = 2.15$	$m = 1.79$
Postgraduate education	$m = 4.07$	$m = 1.71$	$m = 1.98$	$m = 1.56$
Awareness Campaigns (*t*-test)	$t = 0.293$	$t = 0.269$	$t = 1.376$	$t = 0.172$
	$p = 0.770$	$p = 0.788$	$p = 0.169$	$p = 0.863$
Yes	$m = 3.95$	$m = 1.76$	$m = 2.20$	$m = 1.72$
No	$m = 3.97$	$m = 1.78$	$m = 2.08$	$m = 1.74$

Note: *m* is mean of the Pedestrian Behavior; *t* is *t*-value related to *t*-test; *F* is *F*-value related to ANOVA test.

Positive behaviors, violations, and lapses all had a significant education impact. People with post-graduate education reported more positive behaviors than those with only a university level. Pedestrians with only a university degree performed more violations than the second group, as well as more repeated lapses.

Across all behaviors, the analysis of mean responses revealed no significant differences about whether or not participating in awareness campaigns, knowing that the proportion of people who received an awareness campaign is 20%. *T*-test and ANOVA results are shown in Table 4.

The linear regression analysis exploring parameters related with pedestrian behavior are presented in Table 5. Age and education both predicted positive behavior scores. Positive behaviors are associated with older age and better education. The identified aggressive behavior has been significantly associated with gender, with males presenting more aggressive behaviors than females. Lower education is found to be significantly associated with higher transgressions. Finally, the reported lapses were associated with being younger and having a relatively low level of education.

Table 5 Linear regression models

Positive behaviors	**R^2 = 0.014; F = 2.687, p = 0.046**			
	***B* (90% CI)**	***β***	***p***	**VIF**
Gender (Ref: male)	-0.084	-0.054	0.207	1.055
Age Group (Ref: under 25 years)	0.089	0.075	**0.083**	1.074
Education (Ref: University degree)	0.128	0.073	**0.079**	1.023
Aggressive behaviors	**R^2 = 0.046; F = 9.102, p = 0.000**			
	***B* (90% CI)**	***β***	***p***	**VIF**
Gender (Ref: male)	-0.303	-0.194	**0.000**	1.055
Age Group (Ref: under 25 years)	-0.057	-0.48	0.263	1.074
Education (Ref: University degree)	-0.077	-0.045	0.284	1.023
Transgressions	**R^2 = 0.017; F = 3.207, p = 0.023**			
	***B* (90% CI)**	***β***	***p***	**VIF**
Gender (Ref: male)	-0.117	-0.069	0.107	1.055
Age Group (Ref: under 25 years)	-0.065	-0.051	0.243	1.074
Education (Ref: University degree)	-0.158	-0.084	**0.047**	1.023
Lapses	**R^2 = 0.031; F = 7.007, p = 0.000**			
	***B* (90% CI)**	***β***	***p***	**VIF**
Gender (Ref: male)	-0.062	-0.039	0.365	1.055
Age Group (Ref: under 25 years)	-0.155	-0.125	**0.004**	1.074
Education (Ref: University degree)	-0.207	-0.115	**0.006**	1.023

6 Discussion

6.1 Questionnaire validity

One of the main purposes of this study was to evaluate the reliability and factorial structure of a subset of questions chosen based on expert recommendations. Following the exclusion of questions that do not fit the culture of Egyptians and may create confusion in understanding the questions, a pilot study was conducted to select from the PBS long form (47 items) developed by Granié *et al.* (2013) as a self-report method for assessing risky behaviors among Egyptian pedestrians.

According to the exploratory factor analysis (EFA), principal component analysis based on eigenvalue greater than one with orthogonal varimax rotation was carried out. The Egyptian version of this questionnaire had the best fitting in four pedestrian behavior factors. These were transgressions, lapses, positive behaviors and aggressive behaviors, explained through 19 items.

Cronbach's alpha results showed high internal reliability (> 0.6), but not for the positive behavior (0.52). Interestingly, low internal consistency for the positive behavior factor had been found in previous studies (Hőgye-Nagy 2018; Deb *et al.* 2017; Granié *et al.* 2013). This inconsistency suggests that a modification of the positive behavior scale is necessary. The researchers anticipate that additional positive behavior items will need to be included and validated. Most of the questions in the positive behavior scale express pedestrians' positive behavior toward other road-users. Inclusion of pedestrians' positive behavior toward traffic rules at crosswalks may improve the internal consistency of that subscale as well as enhance the internal reliability. Bearing in mind that this is the first use of this tool in Egypt, it had been found that most of the findings verified the applicability of this PBQ for the Egyptian population, with only minor revisions required.

6.2 Culture and pedestrian behaviors

The four-factor structure of this study which combines violations and errors in transgressions suggests that Egyptians do not distinguish between unsafe behaviors that are not against the law and risky behaviors that are against the law and committed intentionally, which was a similar pattern described in prior studies in France (Granié *et al.* 2013) and China (Qu *et al.* 2016). This could be due to the lack of enforceable rules and penalties for risky pedestrian behaviors in Egypt. Yıldırım (2007) in Turkey also discovered a four-factor model in their sample, but with the combination of the lapses and errors, which showed that their Turkish sample could not distinguish between them, both of which had an unintended origin (Yıldırım 2007).

Different social, cultural, and physical environments cause different behaviors (Esmaili *et al.* 2021; McIlroy *et al.* 2019). Given the poor quality of the infrastructure, the absence of enforceable laws and penalties for dangerous pedestrian behavior in Egypt, this could be an explanation for the formation of the four-factor model with the formation of the transgression scale.

Furthermore, in many places of Egypt, facilities of pedestrians are poorly planned and insufficient, which is likely to encourage traffic violations. As a result, Egyptian pedestrians may be unaware of the negative implications of their actions or may feel they have no choice except to conduct into unsafe activity. This is essential to investigate because pedestrians who often break the law may display these patterns in all situations (Lawton *et al.* 1997), but dangerous behaviors caused by errors and lapses are not anticipated in all conditions (Antić *et al.* 2016). This finding leads to a better knowledge of Egyptian pedestrian behavior and explains how infrastructure, in combination with the lack of law enforcement, may impact Egyptian pedestrian behavior.

Similar to other research (Esmaili *et al.* 2021; Deb *et al.* 2017; Antić *et al.* 2016; Granié *et al.* 2013), positive behaviors had the higher means, whereas aggressive behaviors and lapses had the lowest. This shows that Egyptian pedestrians in most of the time attempt positive behavior. On the other hand, certain risky behaviors are frequent and increase the chance of crashes. One of the most common of these transgressions is 'I cross while talking on my cell phone or listening to music on my headphones'. These comprehensions are important for road safety agencies and authorities in policy implications for enhancing pedestrian safety.

6.3 Pedestrian behaviors across demographic variables

The results showed that in Egypt, males reported a higher level of engagement in all types of behaviors than females. The comparison by gender showed that males reported more transgressions and aggressive behaviors than females. This gender difference is consistent with worldwide findings (McIlroy *et al.* 2019; Deb *et al.* 2017; Antić *et al.* 2016; Granié *et al.* 2013). Similarly, significant behavior different patterns through gender have been discovered in other types of transportation. For example, among drivers (Simon & Corbett 1996), motorcyclists, and bicyclists (Hezaveh *et al.* 2018; Useche *et al.* 2018). Thus, this might be due to a gender difference in which females are more careful, conservative, and obedient road users than men. Furthermore, similar to Granié *et al.* (2013), males in the current research also reported more aggressive behavior than females. This result may also be attributed to cultural and sociological concerns in Egypt, since females may interact less, particularly when arguing with strangers on the street.

The results showed that all pedestrian behaviors varied by age. Pedestrians under the age of 40 reported higher violations, which is consistent with prior research (Deb *et al.* 2017; Papadimitriou *et al.* 2016; Granié 2008). This finding may be attributed to the increased energy, youthful spirit, and lack of experience that might lead younger pedestrians to display more risk-taking and less cautious behaviors. In line with Deb *et al.* (2017) findings, younger pedestrians (< 25 years) reported more frequent lapses compared to other aged pedestrians. Young people in Egypt are under a lot of stress as a result of the country's economic issues. This psychological conflict, along with relatively low patience and regulations on attitude compared with older people, can lead to distraction and lack of concentration. Also the same result occurred with the aggressive behavior. A large number of positive behaviors were reported in people older than 40 years in comparison with younger participants, which is similar to the study of Antić *et al.* (2016). This outcome might be clarified because older persons having better interactions with others around them as a result of their experience and their different reasons for walking.

The results reveal that all pedestrian behaviors, except aggression, differed across education level. Pedestrians with a university education recorded more transgressions and lapses in attitude than those with a postgraduate education. People with a postgraduate education reported more positive acts than those with a lower education.

The current study also looked into the links between participating in awareness campaigns and behaviors. The results revealed that there is no significant difference in the behavior of pedestrians who are attend or not in the awareness programs in Egypt. This shows that traffic safety awareness efforts in Egypt need a review of their content and to create new strategies in order to be more effective. This finding may help officials design more traffic safety awareness initiatives and take care to be more successful in the community. Therefore, transportation researchers continue to face challenges in increasing pedestrian safety awareness.

A linear regression model has been created that includes the three variables to study their effect together on the behavior of pedestrians. The results showed that the variables that had a significant effect in the *t*-test and ANOVA remained with significant effect in the regression models

for all behavior except for transgressions and aggressive behaviors. It has been found that in aggressive behavior model, gender continued as the only one with a significant effect and Education for transgressions behavior.

7 Conclusions

This research provides a basic framework for investigating pedestrian behaviors in Egypt according to four categories: Transgressions, lapses, aggressive behaviors and positive behaviors. The four-factor structure of this study which combines violations and errors in transgressions suggests that Egyptians do not differentiate between intentional risky behaviors against the legislative rules compared to mistakes and incorrect decisions that lead to unsafe behaviors. The absence of enforceable laws and penalties for dangerous pedestrian behaviors in Egypt could be an explanation for the formation of the transgression scale which combined both of errors and violations. Each of these four different subscales had been evaluated and confirmed to be valid, except for positive behaviors, which requires further assessment. It is recommended to investigate the validity of the long version of the pedestrian behavior scale (PBS), so with more number of items in each factor, the internal reliability may be improved.

In general, aggressive behaviors and lapses had the lowest means, whereas positive behaviors had the highest scores. This shows that most of the time, Egyptian pedestrians make an effort to be positive. Males reported high scores in all types of behaviors than females. This conclusion could also be explained by cultural and sociological factors in Egypt, as females are less likely to interact with strangers on the street. Younger pedestrians reported higher violations, lapses and aggressive behaviors compared with older pedestrians who reported more positive behaviors. This finding may be attributed to the increased energy, low patience and lack of experience that might lead younger pedestrians to display more risk-taking and less cautious behaviors.

Considering the poorly designed infrastructure, the shortage of regulations and fines for pedestrian behaviors, the poorly planned and inappropriate pedestrian facilities, traffic violations and unsafe behaviors are expected to increase. Therefore, Frequent risky behaviors must be investigated by road safety agencies and authorities in terms of policy implications for improving pedestrian safety.

The outcomes of this research have opened the possibility of using the four different behavior elements in pedestrian safety studies. PBQ can be utilized in pedestrian behavior research in many situations, such as changes in pedestrian actions as a result of changes in traffic infrastructure or the introduction of autonomous vehicles on the road. In addition to its effectiveness in safety studies, PBQ might be used to raise pedestrian awareness and encourage them to change their risky behaviors. This tool may be used as a tool for pedestrian self-assessment in educational and training places. This instrument could assist pedestrians in becoming more informed of traffic regulations and changing their unsafe behaviors.

CRediT contribution statement

Abduallah Bayomi: Conceptualization, Data collection, Formal analysis, Methodology, Resources, Writing—original draft. **Mohamed Shawky**: Conceptualization, Data curation, Investigation, Methodology, Resources, Writing—review & editing. **Mohamed Okail**: Conceptualization, Data curation, Investigation, Resources. **Ahmed Osama**: Conceptualization, Data curation, Investigation, Methodology, Resources, Writing—review & editing.

Declaration of competing interests

No competing interests are reported by the authors.

Acknowledgement

An early version of this paper was presented at the 8th Road Safety & Simulation International Conference, held in Athens, Greece, on 8–10 June 2022.

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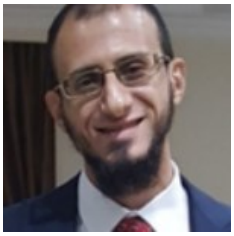

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Questionnaire

1st section: Demographic characteristics

Gender

Age

Education Level

2nd section: Pedestrian behaviors, 5-point Likert scale (from 1 = never to 5 = always**)**

Positive behaviors

P1: I thank a driver who stops to let me cross.

P2: When I am accompanied by other pedestrians, I walk in single file on narrow sidewalks so as not to bother the pedestrians I meet.

P3: I let a car go by, even if I have the right-of-way, if there is no other vehicle behind it.

P4: While crossing the road, I use hand signals to inform the driver of my decision to stop or cross the road.

Aggressive behaviors

A1: I get angry with another road users (pedestrian, driver, cyclist, etc.), and I yell at them.

A2: I walk in a way that forces other pedestrians to let me through.

A3: I cross very slowly to annoy a driver.

A4: I get angry with another road user (pedestrian, driver, cyclist, etc.), and I make a hand gesture.

Errors

E1: I cross even if vehicles are coming because I think they will stop for me.

E2: I cross even though obstacles (parked vehicles, buildings, trees, trash bins, etc.) obstruct visibility.

E3: I walk on the roadway when I could walk on the sidewalk.

Violations

V1: I cross while talking on my cell phone or listening to music on my headphones.

V2: I avoid using pedestrian bridges or underpasses for convenience, even if one is located nearby.

V3: I cross the street even though the pedestrian light is red.

Lapses

L1: I cross without looking when following other people who are crossing

L2: I have run into a pedestrian or an obstacle while walking because I am not paying attention.

L3: I realize that I have crossed several streets and intersections without paying attention to traffic.

L4: I forget to look before crossing because I am thinking about something else.

L5: I cross without looking because I am talking with someone.