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Research article

# Pedestrian behavior among Chinese seniors: Insights from factor analysis and structural equation modeling

Zhiwei Liu [a,*], Ziyang Shi [b], Yating Wei [b], Xutong Zhu [b], Jianrong Liu [b]

[a] School of Civil Engineering and Architecture, Wuhan Polytechnic University, Wuhan City, China
[b] School of Civil Engineering and Transportation, South China University of Technology, Guangzhou City, China

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ABSTRACT

Pedestrians contribute significantly to the total number of road fatalities and injuries, with their behavior playing a pivotal role in traffic mishaps. Despite this, a limited body of research has delved into the walking behaviors of Chinese seniors. Given this gap, our study rigorously examines the patterns of seniors' walking behaviors and their influencing factors. We employed exploratory factor analysis to decipher the intrinsic component structures of seniors' walking patterns in China. Subsequently, structural equation modeling was utilized to analyze the impact of demographic attributes and personality characteristics on these behaviors. The findings revealed a four-dimensional structure for senior walking behaviors: transgression, inattention, aggression, and positive behaviors. Introducing personality traits as variables notably enhanced the explanatory power of our model. Specifically, anger, altruism, and normlessness significantly influenced certain dimensions of walking behaviors, while sensation-seeking did not exhibit any notable effect. This study not only highlights the complexity and diversity of elderly walking behaviors but also underscores the importance of tailored interventions to improve walking safety and quality of life for seniors.

## 1. Introduction

### 1.1. Background

More than 1.35 million people are killed in traffic collisions every year, and another 50 million are injured. This makes traffic crashes the eighth leading cause of death globally [1]. Notably, pedestrians, due to their inherent vulnerability and lack of protective gear, face a higher risk of injury compared to vehicle occupants [2]. Pedestrians account for a disproportionate 22 % of all traffic deaths worldwide [3]. In a comprehensive analysis of traffic-related incidents across China in 2022, data obtained from the National Bureau of Statistics of China unveils a significant prevalence of such events. The records delineate a total of 256,409 traffic accidents, culminating in 60,676 fatalities. Within this dataset, a noteworthy subset involves pedestrian-occupants, implicated in 3907 of these accidents and accounting for 1409 deaths ( Available from: https://data.stats.gov.cn ) . This alarming data accentuates the urgent necessity for the implementation of robust traffic safety measures and the formulation of stringent policies aimed at substantially reducing the occurrence of accidents and the consequent loss of life.

* Corresponding author. Science and Education Building 1208, 68 Xuefu South Road, Changqing Garden, Wuhan, 430023, China.
*E-mail addresses:* tonyliuzhiwei@whpu.edu.cn (Z. Liu), 1731153093@qq.com (Z. Shi), 2371077266@qq.com (Y. Wei), 1737814610@qq.com (X. Zhu), ctjrliu@scut.edu.cn (J. Liu).

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Recent empirical research has increasingly focused on the walking behaviors of Chinese seniors, underscoring the pivotal role of physical activity in this demographic group. Cerin et al. reveal that walking is the most prevalent form of physical exercise among older Chinese adults, examining perceived neighborhood attributes and the implications of urban densification on walking behaviors [4,5]. Yu et al. explored correlations between perceived neighborhood walkability and outcomes such as walking time, well-being, and loneliness [6]. Safety is a critical aspect, with studies highlighting the deterring effect of traffic barriers on walking for transportation purposes [7]. Delclòs-Alió et al. investigated how temperature and precipitation impact neighborhood walkability's effectiveness on seniors' walking time [8]. Kwon et al. linked walking levels to reduced morbidity and mortality among older adults [9]. Leung et al. used focus groups to assess quality of life components among elderly Chinese populations, highlighting walking's integral role [10]. Woo et al. extended this scope by examining the influence of cardiovascular risk factors, including physical activity, on overall mortality and morbidity in elderly Chinese individuals [11].

Elderly pedestrians exhibit distinct travel behavior patterns influenced by various factors. Noh and Joh (2012) indicate that elderly individuals primarily rely on walking for different trip purposes [12]. However, more than 90 % demonstrate unsafe traffic behavior, highlighting potential risks [13]. With the aging population, the proportion of middle-aged and elderly pedestrians crossing streets at signalized intersections is increasing, necessitating considerations for their safety in signal timing optimization [14]. Age-related declines pose safety challenges, especially while crossing streets, emphasizing the need for appropriate street-crossing facilities [15]. Muthusamy found that the problem of the elderly population is a wrong assessment of their own motor skills, and at a certain age, similar to children, the cognitive capacity to analyze complex traffic situations [16]. Factors such as physical inconvenience due to aging, decreased reaction speed, and vulnerability to serious trauma and accidents contribute to the risks faced by elderly pedestrians [17]. Studies show that elderly pedestrians can significantly reduce the capacity of signalized intersections, with up to a 30 % reduction in capacity observed in certain scenarios [18]. Socioeconomic status also influences safety crossing decisions, with those from higher socioeconomic levels making better choices [19]. Improving elderly pedestrian safety is crucial, considering their higher risks in traffic accidents due to factors like decreased reaction speed and physical limitations [19]. Elderly pedestrian walking behavior plays a vital role in planning and designing infrastructure like underground stations and crosswalks [20]. However, interventions to reduce road traffic injuries among the elderly have predominantly focused on drivers, with less attention to enhancing elderly pedestrian safety [21]. With the acceleration of China's aging process, the proportion of the elderly population continues to increase. As physical functions gradually decline, the walking behaviors and safety issues of the elderly become increasingly prominent. Studying these behaviors is essential for improving their quality of life and travel safety.

A comprehensive understanding of crash causative factors is pivotal for the formulation of effective preventive strategies. Existing literature underscores that human factors, whether acting independently or synergistically with other elements, predominantly contribute to traffic accidents [22–25]. Unsafe pedestrian behaviors, in particular, have been identified as a leading cause of such collisions [26]. Therefore, to create successful interventions to protect pedestrians and promote safe walking, it is imperative to have a thorough understanding of the elements that lead to aberrant walking behaviors.

Existing literature underscores a consistent correlation between self-reported aberrant behaviors and directly observed risky actions. Lucidi et al.revealed that lapses, errors, and violations committed by senior drivers have a tangible impact on their involvement in crashes and the frequency of citations received [27]. Twisk et al. identified that errors, combined with unsafe play and inadequate protective measures, have a direct link to self-reported accidents among teenagers [28]. Esmaili et al. discovered that pedestrian errors are intrinsically tied to self-reported pedestrian-related collisions [29]. Contemporary research provides evidence that mobile phone-induced distractions significantly amplify crash risks and the rate of pedestrian injuries [30,31]. In conclusion, the inherent risks of pedestrian behaviors critically compromise safety; effective mitigation can lead to a substantial reduction in collisions. To date, many studies have analyzed individuals' walking behaviors with self-report questionnaires.

### *1.2. Factors influencing walking behaviors*

Extensive literature has elucidated various demographic factors linked with aberrant walking behaviors. For instance, correlations have been established between walking behaviors and variables such as gender [32–36], age [25,34–38], the education level [36,38,39], income [40], marital status [40], and dissatisfaction with environmental and transportation infrastructure [37].

Numerous research has looked at how personality affects walking behaviors. Simsekoglu identified that empathy inversely correlates with risky pedestrian behaviors, while conformity exhibits a direct relationship [37]. Qu illuminated that normlessness plays a significant role in determining transgressive and aggressive behaviors, whereas altruism prominently shapes positive behaviors [41]. Zheng et al.analyzed the effect of the Big Five personality factors on walking behaviors [42,43].

As to individuals' attitudes, most studies have found that attitude significantly influences walking behaviors [25,33,36,37,44,45], while Demir found that attitude does not significantly impact violation behavior, lapses, or positive behavior [46].

In addition to personality traits and attitude, researchers have found that social value [47], fatalistic beliefs (general fatalism, internality, divine control, and luck) [25,48,49], subjective norm [46,49], rules compliance ability [50], values (self-transcendence, openness to change, self-enhancement, and conservation) [51], and pedestrian inconvenience [52] may affect walking behaviors. The

impact of various demographic characteristics and personality traits on the walking behaviors of the elderly varies. By analyzing these influencing factors, scientific evidence can be provided to the government and relevant departments to formulate personalized intervention measures, thereby enhancing the walking safety and adherence to traffic rules among the elderly.

### 1.3. The current study

Younger individuals tend to engage in walking predominantly for utilitarian purposes such as work-related activities or social engagements. In contrast, the elderly population is more inclined to walk for health and leisure purposes. This divergence in walking behavior can be attributed to the physiological and functional differences between these age groups. Older adults, constrained by diminished physical capabilities and a reduced capacity to adapt to environmental challenges, exhibit characteristics in their walking patterns such as reduced speeds and lower endurance levels. However, they often demonstrate a heightened sense of safety during walking activities. Existing research on pedestrian behavior primarily focuses on the general population or younger age groups, with limited studies specifically addressing the walking behaviors of the elderly. This study fills this research gap and provides essential reference and foundational data for subsequent related research. This investigation is driven by several key considerations:(1)The aging demographic of China, where over 18.70 % of the population is aged 60 and above, coupled with the prevalence of walking as a primary mode of transportation among this age group. For instance, in Beijing, 60 % of senior citizens' trips are made on foot [53].(2) The observed variation in the structure and scoring of Personality-Based Question (PerBQ) instruments across different countries, indicating that insights from international studies may not be directly applicable to the Chinese context. This discrepancy arises from several factors: cultural differences, language and translation issues and socioeconomic factors. (3)The potential differences in walking behaviors between senior and younger populations, highlighting the need for targeted research on seniors, especially given the current lack of studies focusing on the unique walking patterns of this age group. The purpose of this research is to fill these gaps, providing a nuanced understanding of how demographic and personality variables influence the walking habits of China's elderly population, which is crucial for developing tailored health promotion and urban planning strategies.

**Table 1**
The results of EFA.

| No. | Items | Mean | Std. dev. | Skewness | Skurtosis | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | I cross the intersection diagonally to save time. | 1.982 | 1.032 | 1.049 | 3.731 | 0.700* | 0.027 | 0.007 | −0.036 |
| 2 | I avoid using pedestrian bridges or underpasses for convenience, even if one is located nearby | 1.666 | 0.911 | 1.598 | 5.674 | 0.816* | 0.012 | 0.035 | −0.015 |
| 3 | I crossed the street even though the pedestrian light was red. | 1.578 | 0.935 | 1.925 | 6.654 | 0.650* | −0.021 | 0.233* | −0.021 |
| 4 | Even if it is not far away, I don't cross the street in a crosswalk. | 1.868 | 1.028 | 1.129 | 3.7 | 0.816* | 0.059 | −0.038 | −0.032 |
| 5 | I cross between vehicles stopped on the roadway in traffic jams. | 2.076 | 1.127 | 0.874 | 2.918 | 0.808* | 0.002 | −0.115* | 0.088* |
| 6 | Even if vehicles are coming, I will cross the road because I think they will stop for me. | 1.745 | 1.075 | 1.374 | 3.897 | 0.715* | −0.029 | 0.123* | −0.033 |
| 7 | Even if the sidewalk is wide, I still take the bicycle lane or motor vehicle lane for convenience. | 1.63 | 0.935 | 1.724 | 5.819 | 0.730* | 0.022 | 0.088 | 0.06 |
| 8 | I ran across the street without looking, for I was in a hurry. | 1.566 | 0.948 | 1.893 | 6.185 | 0.568* | 0.01 | 0.322* | 0.031 |
| 9 | I forget to look before crossing the street because I am thinking of something else. | 1.695 | 0.946 | 1.642 | 5.728 | −0.029 | 0.929* | 0.016 | −0.02 |
| 10 | I forget to look before crossing the street because I am talking to someone. | 1.78 | 1.015 | 1.531 | 5.06 | 0.005 | 0.896* | −0.001 | 0.028 |
| 11 | I realize that I have passed several streets and intersections without paying attention to the traffic. | 1.669 | 0.979 | 1.776 | 6.002 | −0.036 | 0.918* | −0.015 | 0.002 |
| 12 | I forget to look before crossing the street because I want to join the people on the opposite sidewalk. | 1.707 | 0.995 | 1.652 | 5.482 | 0.101* | 0.761* | 0.036 | −0.002 |
| 13 | Talking on the phone while crossing the street, without checking the road conditions carefully | 1.73 | 0.996 | 1.597 | 5.324 | 0.046 | 0.893* | 0 | −0.004 |
| 14 | I am angry with the behavior of other people on the road and shout at them. | 1.604 | 0.988 | 1.847 | 5.997 | 0.027 | 0.047 | 0.831* | −0.004 |
| 15 | I cross the road so slowly that I annoy the driver. | 1.654 | 0.941 | 1.713 | 5.954 | 0.051 | 0.078* | 0.772* | 0.023 |
| 16 | I get angry with another road user and make a hand gesture. | 1.411 | 0.934 | 2.529 | 8.75 | −0.032 | −0.001 | 0.987* | 0.006 |
| 17 | I become angry at a driver and hit their car. | 1.381 | 0.895 | 2.725 | 10.04 | 0.039 | −0.03 | 0.952* | −0.018 |
| 18 | I thank a driver who stops to let me cross. | 3.029 | 1.465 | −0.129 | 1.628 | 0.05 | 0.015 | −0.018 | 0.938* |
| 19 | When I'm with other pedestrians, I walk in single file on narrow sidewalks to avoid bothering them. | 3.235 | 1.371 | −0.352 | 1.845 | 0.009 | −0.013 | −0.029 | 0.940* |
| 20 | I walk on the left-hand side of the pavement so as not to bother the pedestrians I meet. | 3.742 | 1.393 | −0.842 | 2.357 | 0.027 | 0.016 | −0.02 | 0.917* |
| 21 | I let a car go by, even if I have the right-of-way if there is no other vehicle behind it. | 3.44 | 1.35 | −0.511 | 2.062 | −0.110* | −0.011 | 0.113* | 0.918* |

## 2. Method

### 2.1. Conceptual framework

This research examined the effects of demographic characteristics and personality on seniors' walking behaviors, including aberrant walking behaviors and positive walking behaviors, using the structural equation modeling (SEM). This study is structured around a three-section questionnaire: demographic information (8 items), pedestrian behavior questions(PBQ) (21 items), and personality traits assessment (20 items). The PBQ for this study was developed based on references (see Table 1.) [25,34–36,45,54]. We have chosen to retain only those items in our questionnaire that pertain to the walking characteristics of the elderly. If extremely similar items are found across different versions of the questionnaire, they will be consolidated. This approach ensures a focused and efficient assessment, specifically tailored to the relevant aspects of geriatric mobility. The questionnaire encompassed 21 items related to walking behaviors in four categories—transgression (including violations and errors), inattentions, aggressions, and positive behaviors. The personality traits assessment focused on altruism, sensation-seeking, anger, and normlessness. Among these, the

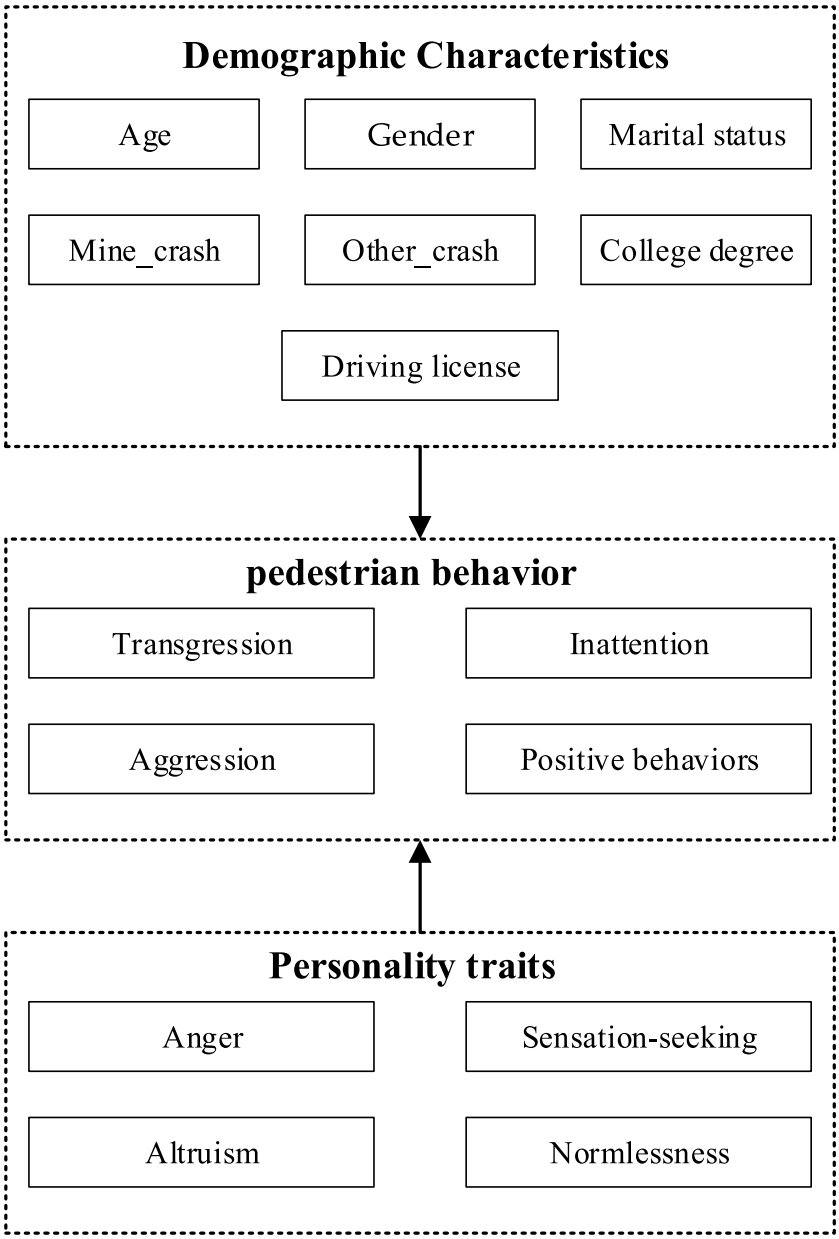


**Fig. 1.** Conceptual Framework of the Relationship Between Seniors' pedestrian behavior, Demographic Characteristics, and Personality Traits.

measurement of altruism, sensation-seeking, and anger in this study utilized specific items provided by the International Personality Item Pool (IPIP) (http://ipip.ori.org). The IPIP is a recognized psychological assessment resource, offering an array of standardized test items for the evaluation of various personality traits. These items have been meticulously designed and extensively validated, ensuring precise measurement of the personality dimensions under investigation. There are five items on the altruism scale; a sample item is, "I enjoy helping others" [55]. There are five items on the sensation-seeking scale; a sample item is, "I like to do frightening things" [56]. There are five items on the anger scale; a sample item is, "I get angry easily" [57]. The normlessness scale was adopted [58], and is made up of five items; a sample item is, "As long as you do not directly violate laws and rules, you can avoid them". Interviewees were asked to answer all items on a five-point Likert scale, from 1 = strongly agree to 5 = strongly disagree. The complete survey is attached in Supplementary material.

Based on the theoretical and empirical background discussed above, 8 hypotheses were formed.

**Hypothesis 1**. (H1). There is an association between age and pedestrian behavior.

**Hypothesis 2**. (H2). There is an association between gender and pedestrian behavior.

**Hypothesis 3**. (H3). There is an association between marital status and pedestrian behavior.

**Hypothesis 4**. (H4). There is an association between mine_crash and pedestrian behavior.

**Hypothesis 5**. (H5). There is an association between other_crash and pedestrian behavior.

**Hypothesis 6**. (H6). There is an association between having a college degree and pedestrian behavior.

**Hypothesis 7**. (H7). There is an association between having a driving license and pedestrian behavior.

**Hypothesis 8**. (H8). There is an association between pedestrian behavior and personality.

The relationship between pedestrian behavior and demographic characteristics as well as personality traits is illustrated in Fig. 1.

### 2.2. Statistical analysis methods

Exploratory Factor Analysis (EFA) and Structural Equation Modeling (SEM) are two statistical methods widely employed in research to understand and model complex relationships among observed and latent variables [59].

Exploratory Factor Analysis (EFA) is a technique used to identify underlying structures in a set of observed variables. It aims to uncover latent factors that explain the patterns of correlations within a set of observed variables. EFA starts with a hypothesis that any observed variable is directly associated with any factor. The analysis then proceeds by extracting factors based on their ability to account for the variances and covariances among the observed variables. The factors are extracted either through methods like principal component analysis or common factor analysis. The output of EFA provides factor loadings, indicating the strength and direction of the relationship between each variable and the underlying factors. This method is particularly useful when the research is exploratory in nature, and there is no a priori theory to specify which variables are related to which factors.

Structural Equation Modeling (SEM), on the other hand, is a more comprehensive statistical technique that encompasses multiple regression analysis, path analysis, and factor analysis. It is used to test and estimate causal relationships using a combination of statistical data and qualitative causal assumptions [60]. SEM involves constructing a model based on a theoretical framework, specifying causal relationships among variables, and then testing the model using empirical data. It allows for the examination of both direct and indirect effects among observed and latent variables. In SEM, observed variables are indicators of latent variables, which represent constructs that are not directly measured. The model is evaluated based on how well it fits the data, using fit indices like the Chi-square test, Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), and Tucker-Lewis Index (TLI).

Both EFA and SEM are powerful tools for understanding the underlying structures of complex data sets and for testing theoretical models in various scientific disciplines. They are particularly prevalent in social sciences, psychology, marketing, and other fields where understanding the relationships among variables is crucial.

### 2.3. Participants

The survey was approved by the research ethics committee of the authors' institution. This survey was conducted across core districts of Guangzhou City in Guangdong Province, namely Tianhe District, Yuexiu District, and Haizhu District, during the period from April 2022 to May 2022. All questionnaires were collected in public places (seniors' activity centers, markets, parks, etc.). The survey targeted a representative sample of the elderly population, considering factors like age, gender, and socio-economic status. Data was collected through a structured questionnaire designed to capture socio-economic attributes (such as income, education, occupation, family structure), personality traits, and walking behavior. The study employed specific criteria for participant inclusion and exclusion to ensure a representative sample. For inclusion, participants were required to be aged 55 or above, residing in the area of study, and physically capable of independent travel. Exclusion criteria involved individuals with cognitive impairments or severe physical disabilities that significantly limit their ability to walk, and those not residing within the study's geographical scope during the data collection period. To mitigate location bias, self-selection bias, and health bias, we employed stratified random sampling to ensure diversity in terms of age, gender, socio-economic status, and geographical location.

Considering the current retirement age for women in China is 55, the age of respondents was limited to 55 years and above. Of the initial 400 senior participants aged 55 years or older, the final sample comprised 341 respondents after exclusion due to missing responses. The sample size meets the requirements for Structural Equation Modeling (SEM) [61,62]. The mean age was 67.8 (with SD = 7.29). 55.1 % of respondents were male (n = 153). 83.3 % of respondents were married (n = 284). 33.1 % of respondents had a college degree (n = 113). 55.7 % of respondents had a driving license (n = 190). 8.2 % of respondents still needed to work (n = 28). 13.2 % of respondents reported having been involved in a collision while walking in the preceding five years (n = 24). 43.1 % of respondents reported having witnessed a pedestrian being struck by a car in the last five years (n = 147).

## 3. Results

### 3.1. EFA result

As delineated in the Appendix, the categorization of unsafe walking behaviors varies across studies. Some studies have segmented aberrant walking behaviors into three distinct classes, while others have identified four. In this study, we conducted an EFA to determine the dimensions of the walking behaviors of seniors. The eigenvalues for the sample correlation matrix were, in order: 9.202, 3.557, 2.647, 1.350, 0.579, 0.561, 0.393, 0.345. Four factors with eigenvalues greater than 1 were discovered through EFA (see Table 1). Therefore, factor 1 consisted of transgression (including violations and errors), which contained eight items (Item 1 - Item 8); factor 2 consisted of inattentions, which contained five items (Item 9 - Item 13); factor 3 consisted of aggressions, which contained four items (Item 14 - Item 17); and factor 4 consisted of positive behaviors, which contained four items (Item 18 - Item 21).

### 3.2. Confirmatory factor analysis (CFA)

Before examining the causal links or correlations between variables, the validity and reliability of the measurement model (which determines the extent to which the indicators reflect latent constructs) should be investigated [63,64]. CFA was conducted on the latent constructs' indicators, and the results are summarized in Tables 2 and 3.

Table 2 shows that the standardized factor loadings are significant and more than 0.6, indicating that the latent constructs' indicators are acceptable [65]. Composite reliability (CR) measures the variation that is shared by a latent construct's indicators, and a value of CR that is more than 0.7 is regarded as satisfactory [66,67]. The average variance extracted (AVE) is a metric for the proportion of variation that a construct captures compared to the proportion of variance resulting from measurement error; a value greater than 0.5 is considered acceptable [66,68]. The CR and AVE values meet the required norms, as indicated in Table 2, which demonstrates that the latent variables' convergent validity is acceptable.

Discriminant validity (DV) determines whether or not the model's constructs are substantially associated with one another. The square root of the average value of each construct should be smaller than the correlations between them [63]. In Table 3, diagonal elements are the square root of the AVE, while off-diagonal elements are the correlation coefficients between the constructs. In Table 3, the diagonal element is always larger than the other elements in the same row and column, indicating that the constructs' discriminant validity holds.

### 3.3. Hierarchical regression analysis

Hierarchical regression analysis and Structural Equation Modeling (SEM) serve complementary purposes in our study. Hierarchical regression analysis is used to explore the incremental contribution of different sets of predictors (demographic characteristics, personality traits) on pedestrian behaviors by entering variables in blocks to assess changes in the explained variance ($R^2$) and identify significant predictors. SEM, on the other hand, tests the overall theoretical framework, examining relationships among observed and latent variables while accounting for measurement errors. It includes confirmatory factor analysis (CFA) for validating measurement models and path analysis for testing hypothesized relationships. Hierarchical regression provides preliminary insights into individual predictor contributions, whereas SEM offers a comprehensive approach to simultaneously test measurement models and structural relationships.

Hierarchical multiple regression analysis was used to analyze the influences of demographic characteristics and personality traits on seniors' walking behaviors. In step 1, only demographic characteristics were considered. In step 2, demographic characteristics and

**Table 2**
Convergent validity of the latent constructs.

| Latent Variables | Standardized Factor Loadings | CR | AVE |
|---|---|---|---|
| Transgression | 0.699–0.833 | 0.928 | 0.620 |
| Inattention | 0.828–0.918 | 0.951 | 0.795 |
| Aggression | 0.849–0.963 | 0.952 | 0.834 |
| Positive behaviors | 0.907–0.944 | 0.961 | 0.860 |
| Anger | 0.887–0.950 | 0.960 | 0.829 |
| Sensation-seeking | 0.743–0.905 | 0.927 | 0.718 |
| Altruism | 0.642–0.885 | 0.885 | 0.609 |
| Normlessness | 0.815–0.877 | 0.927 | 0.717 |

**Table 3**
Discriminatory validity of the latent constructs.

| Latent Variables | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1 Transgression | 0.787 | | | | | | | |
| 2 Inattention | 0.518 | 0.892 | | | | | | |
| 3 Aggression | 0.741 | 0.395 | 0.913 | | | | | |
| 4 Positive behaviors | 0.111 | 0.073 | 0.042 | 0.927 | | | | |
| 5 Anger | 0.482 | 0.304 | 0.649 | 0.068 | 0.91 | | | |
| 6 Sensation-seeking | 0.549 | 0.335 | 0.499 | 0.167 | 0.382 | 0.847 | | |
| 7 Altruism | 0.111 | −0.015 | −0.035 | 0.389 | 0.061 | 0.189 | 0.78 | |
| 8 Normlessness | 0.75 | 0.444 | 0.595 | 0.066 | 0.384 | 0.657 | 0.035 | 0.847 |

Note: Values along diagonal (in bold) are the square value of the constructs. Values below diagonal are the correlations between two constructs.

**Table 4**
Fit indexes of the models.

| Fit index | Criterion | Step 1 | Step 2 |
|---|---|---|---|
| $\chi^2$/df | 1~3 | 2.29 | 2.36 |
| CFI | >0.9 | 0.925 | 0.913 |
| TLI | >0.9 | 0.912 | 0.902 |
| RMSEA | <0.08 | 0.074 | 0.061 |
| SRMR | <0.08 | 0.127 | 0.054 |

Note: CFI - comparative fitting index; TLI - Tucker-Lewis index; RMSEA - root mean square error of approximation; SRMR - standardized root mean square residual; df - degrees of freedom.

personality traits were considered. The model fit index is shown in Table 4. All of the indicators fell within acceptable ranges [69–71], indicating that these two models are suitable for analyzing walking behaviors.

The influence of demographic characteristics and personality traits on seniors' walking behaviors is shown in Table 5.The table delineates the impact of demographic attributes and personality traits on the walking behaviors of seniors. In Step 1, several demographic factors were observed to have a significant influence on transgression, including age ($\beta = 0.028$, $p < 0.01$), marital status ($\beta = -0.391$, $p < 0.01$), mine_crash ($\beta = 0.364$, $p < 0.01$), other_crash ($\beta = 0.134$, $p < 0.10$), and having a college degree ($\beta = -0.294$, $p < 0.01$). In Step 2, after incorporating personality traits, age ($\beta = 0.010$, $p < 0.01$), mine_crash ($\beta = 0.163$, $p < 0.10$), college degree ($\beta = -0.212$, $p < 0.01$), anger ($\beta = 0.138$, $p < 0.01$), and normlessness ($\beta = 0.426$, $p < 0.01$) emerged as significant predictors. It's noteworthy that the model's explanatory power for transgression amplified, moving from 28.0 % in Step 1–67.2 % in Step 2.

In Step 1, age (0.031, $p < 0.01$), marital status (−0.539, $p < 0.01$), and mine_crash (0.479, $p < 0.01$) were found to significantly affect inattention. These factors account for 17.4 % of the variance in inattention. In Step 2, age (0.019, $p < 0.05$), mine_crash (0.351, $p < 0.05$), anger (0.108, $p < 0.05$), and normlessness (0.312, $p < 0.01$) were found to significantly affect inattention. After considering personality traits, the model's explanatory power for transgression increased from 17.4 % to 28.0 %.

In Step 1, age (0.041, $p < 0.01$), marital status (−0.593, $p < 0.01$), mine_crash (0.234, $p < 0.10$), and college degree (−0.179, $p < 0.10$) were found to significantly affect aggression. 26.0 % of the variance in aggression was explained in Step 1. In Step 2, age (0.019,

**Table 5**
Predictions of influences of various factors on seniors' walking behaviors.

| | Transgression | | Inattention | | Aggression | | Positive behaviors | |
|---|---|---|---|---|---|---|---|---|
| | Step 1 | Step 2 | Step 1 | Step 2 | Step 1 | Step 2 | Step 1 | Step 2 |
| Demographic characteristics | | | | | | | | |
| Age | 0.028[c] | 0.010[b] | 0.031[c] | 0.019[b] | 0.041[c] | 0.019[c] | 0.024[b] | 0.015 |
| Gender (ref: male) | 0.041 | −0.091 | −0.009 | −0.11 | 0.028 | −0.043 | −0.034 | 0.018 |
| Marital status (ref: unmarried) | −0.391[c] | 0.013 | −0.539[c] | −0.226 | −0.593[c] | −0.086 | 0.314[a] | 0.123 |
| Mine_crash (ref: no) | 0.364[c] | 0.163[a] | 0.479[c] | 0.351[b] | 0.234[a] | 0.072 | −0.108 | −0.231 |
| Other_crash (ref: no) | 0.134[a] | −0.021 | −0.004 | −0.1 | 0.065 | −0.074 | 0.438[c] | 0.327[b] |
| Having a college degree (ref: no) | −0.294[c] | −0.212[c] | −0.015 | 0.036 | −0.179[a] | −0.147[a] | −0.071 | −0.008 |
| Having a driving license (ref: no) | 0.060 | 0.064 | 0.066 | 0.07 | 0.101 | 0.104 | −0.101 | −0.086 |
| Personality traits | | | | | | | | |
| Anger | | 0.138[c] | | 0.108[b] | | 0.397[c] | | 0.01 |
| Sensation-seeking | | 0.010 | | −0.019 | | 0.067 | | 0.119 |
| Altruism | | 0.035 | | −0.027 | | −0.088[b] | | 0.434[c] |
| Normlessness | | 0.426[c] | | 0.312[c] | | 0.287[c] | | −0.036 |
| $R^2$ | 0.280 | 0.672 | 0.174 | 0.280 | 0.260 | 0.624 | 0.051 | 0.180 |

Note.
[a] $p < 0.1$.
[b] $p < 0.05$.
[c] $p < 0.01$.

$p < 0.01$), college degree (−0.147, $p < 0.10$), anger (0.397, $p < 0.01$), altruism (−0.088, $p < 0.05$), and normlessness (0.287, $p < 0.01$) were found to significantly affect inattention. After considering personality traits, the model's explanatory power for transgression increased from 26.0 % to 62.4 %.

In Step 1, age (0.024, $p < 0.05$), marital status (0.314, $p < 0.10$), and other_crash (0.438, $p < 0.01$) were found to significantly affect positive behaviors. 5.1 % of the variance in positive behaviors was explained in Step 1. In Step 2, other_crash (0.327, $p < 0.05$) and altruism (0.434, $p < 0.01$) significantly affected positive behaviors. Step 2 further clarifies the variance of 12.9 %.

## 4. Discussions

The primary objective of this research was to elucidate the structure of walking behaviors among Chinese seniors and to investigate the influence of demographic factors and personality traits on these behaviors.

### *4.1. The effect of demographic characteristics*

Age exhibited a positive relationship with transgression, inattention, aggression, and positive behaviors. Influenced by the cultural background and economic conditions of their time, respondents of an older age may exhibit lower levels of education, contributing to this observed phenomenon. This finding appears to diverge from many earlier studies which have suggested that an increase in age correlates with a decline in aberrant walking behaviors [72-74]]. It's essential to note that such prior studies did not exclusively focus on the walking behaviors of the elderly. Consequently, there is a pressing need for further research tailored to older adults' walking behaviors to validate whether our findings have broader applicability within the Chinese context.

Gender did not significantly influence transgression, inattention, aggression, and positive actions. This result is inconsistent with some previous studies which found that male seniors scored higher than female seniors on transgression [32,33,47]. These studies found that male seniors scored higher than female seniors on transgression. Previous studies have not reached a consistent conclusion on whether gender affects positive behaviors, and in this study, gender was found to have no significant impact.

Marital status had a significant impact on transgression, inattention, aggression, and positive behaviors when personality traits were not considered. This observation aligns with the findings presented in Ref. [40]. Married seniors exhibited fewer deviant walking practices and a higher propensity for positive walking behaviors than their unmarried counterparts.

Traffic Collision Experience: Seniors who had been involved in a traffic collision while walking in the previous five years were more likely to engage in transgression and inattention than those who had not. This can be attributed to psychological impacts such as increased anxiety, behavioral changes including defensive walking, and exacerbated cognitive decline post-trauma. These factors highlight the need for targeted interventions to address the psychological and cognitive aftermath of traffic collisions in seniors, aiming to improve their walking safety and overall well-being. Interestingly, witnessing a pedestrian-car accident in the same timeframe was associated with increased engagement in positive walking behaviors among seniors. This phenomenon may be attributed to the heightened emphasis on safety among the elderly. After witnessing accidents, they might adopt proactive walking strategies, such as choosing safer routes or adhering more strictly to traffic rules, to reduce their own risk of accidents. Additionally, witnessing such incidents could serve as a reminder to pay more attention to changes in their walking environment, leading to increased alertness and caution. Therefore, this finding underscores the importance of enhancing traffic safety awareness and walking safety strategies among the elderly.

Education Level: Whether or not seniors had a college degree significantly affected their engagement in transgression and aggression. Seniors with a college degree engaged in less transgression and aggression, which aligns with previous studies [36,39].

In China, the demographic characteristics of seniors are influenced by historical and social factors unique to the country's development. The older generation experienced significant socio-economic changes, from pre-reform to the post-reform era, affecting their educational attainment and economic conditions. The rapid urbanization and modernization of China have also impacted the mobility and safety of elderly pedestrians, making it crucial to consider these contextual factors when interpreting the findings. The increased emphasis on community and family ties in Chinese culture may explain why marital status plays a significant role in walking behaviors, as married seniors might receive more support and guidance from their families. Moreover, China's rapid economic development and urbanization have led to an increase in traffic density, highlighting the importance of traffic safety awareness for the elderly.

### *4.2. The effect of personality traits*

Numerous studies have historically posited a significant correlation between anger and aberrant driving behaviors [41,75–78], while one study by Ref. [79] argued that anger has no significant impact on prosocial driving and aggressive driving. In the current research, our findings indicate that anger exerts a medium influence on transgression (0.127) and inattention (0.108). Moreover, a pronounced impact was observed on aggression with a value of 0.397. Nevertheless, no substantial effect was discerned with respect to positive walking behaviors. Anger is an intense emotion that can activate an individual's defensive or aggressive mechanisms. During walking or other physical activities, the state of anger may directly intensify aggressive behaviors, such as increasing walking speed or disregarding the actions of others. In contrast, positive walking behaviors, like maintaining a steady pace and adhering to traffic rules, typically require more advanced emotional regulation and self-control. These abilities might be compromised in a state of anger. In the context of Chinese society, the emotion of **anger** may be intensified by social pressures and intergenerational differences, leading to higher levels of aggressive behaviors among elderly pedestrians. However, due to the traditional cultural values of self-control and

modesty, the impact of anger on positive walking behaviors might be mitigated.

The influence of sensation-seeking on travel behaviors remains a debated topic in existing literature. Some studies have claimed that sensation-seeking significantly affects aberrant behavior [27,75,79–81], while some studies did not agree [41,76]. In the context of the current investigation, sensation-seeking did not exhibit a significant impact on aberrant behaviors such as transgression, inattention, and aggression, nor did it affect positive behaviors. Walking is a relatively mild and routine activity, which may not be sufficient to arouse the interest or response of individuals with high sensation-seeking tendencies. Such individuals typically seek higher levels of stimulation or adventure, experiences that ordinary walking may not provide. **Sensation-seeking** may not be common among the elderly in China, as this demographic tends to prefer safe and stable activities over adventurous and high-stimulation behaviors, which explains the lack of significant impact on walking behaviors.

Previous studies on whether altruism significantly affects aberrant behaviors are inconsistent [77,79,80]. found that altruism significantly influences aberrant behaviors. Qu, Zhang [41] found that altruism negatively affects lapse, but has no significant impact on transgression and aggressive behaviors [75]. found that altruism negatively affects ordinary violations, but has no significant effect on aggressive violations [27]. found that altruism significantly affects violations, but does not significantly affect lapses and errors [78]. found that altruism significantly influences aggressive driving and drunk driving, but does not significantly influence negative cognitive/emotional driving and risky driving [82]. revealed that their altruistic tendencies bear no direct correlation to violations, lapses, or errors. In our analysis, altruism demonstrated a marginal negative impact (−0.088) on aggression without significant repercussions on transgression or inattention.

Several studies have consistently highlighted the positive influence of altruism on favorable travel behaviors [41,79]. In this study, a significant influence of altruism on seniors' positive walking behaviors was observed, with a coefficient of 0.434. **Altruism** holds an important place in Chinese traditional culture, and this value may encourage elderly individuals to exhibit more positive behaviors while walking, such as helping others and adhering to social norms.

The relationship between normlessness and aberrant behaviors remains contentious. Numerous studies have asserted that normlessness significantly affects all dimensions of aberrant behaviors: see Refs. [41,75–77,80]. However, some studies did not agree [27, 82]. Our study indicates that normlessness profoundly affects aberrant walking behaviors in seniors, specifically transgression (0.445), inattention (0.312), and aggression (0.282). However, it does not significantly influence their positive walking behaviors. The influence of **normlessness** may be more pronounced in China, especially during the rapid urbanization process. The fast-paced social changes and shifts in norms may lead to higher instances of aberrant walking behaviors among the elderly.

## 5. Conclusion

This study rigorously investigates the structure of walking behaviors in Chinese seniors, examining the interplay of demographic characteristics and personality traits. Through Exploratory Factor Analysis (EFA) of walking behavior measures, we identified four distinct behavioral dimensions: transgression, inattention, aggression, and positive behaviors. The robustness of these dimensions was confirmed by Confirmatory Factor Analysis (CFA), demonstrating high validity and reliability, in alignment with prior studies such [32,37]. Further, employing Structural Equation Modeling (SEM), the study delved into the influence of sociodemographic and personality factors on these walking behaviors. Incorporating personality traits significantly enhanced the model's explanatory power for the identified dimensions, with notable increments in variance explanation: transgression (38.9 %), inattention (10.6 %), aggression (36.2 %), and positive behaviors (13.1 %).

This study aims to elucidate the structure of walking behaviors exhibited by Chinese seniors and to investigate the influence of demographic characteristics and personality traits on these behaviors. These insights are crucial for developing targeted interventions aimed at reducing the number of traffic accidents involving elderly pedestrians. By understanding the factors that contribute to unsafe walking behaviors, policymakers and urban planners can design more effective safety measures, ultimately enhancing the safety and quality of life for senior pedestrians.

### *5.1. Implications*

First, the study finds a positive correlation between age and transgression, inattention, aggression, and positive behaviors, which contradicts previous research suggesting that age increase correlates with a decrease in aberrant walking behaviors. This finding highlights the need for further research to validate these results in a broader elderly population.

Second, gender was found to have no significant impact on transgression, inattention, aggression, and positive behaviors, which is inconsistent with some previous studies. This inconsistency indicates a need for more research to explore the influence of gender on elderly walking behaviors.

Marital status significantly impacts transgression, inattention, aggression, and positive behaviors, with married seniors exhibiting fewer deviant behaviors and a higher propensity for positive walking behaviors compared to their unmarried counterparts. Additionally, seniors who had experienced or witnessed a traffic accident in the past five years exhibited different walking behaviors, underscoring the importance of enhancing traffic safety awareness and walking safety strategies for the elderly.

Regarding personality traits, anger has a medium influence on transgression and inattention, a significant impact on aggression, but no significant effect on positive walking behaviors. Sensation-seeking did not significantly affect aberrant or positive walking behaviors, possibly because walking is a routine activity that does not stimulate high sensation-seeking individuals. Altruism has a significant positive impact on positive walking behaviors but a marginal impact on aggression and no significant impact on transgression or inattention. Normlessness significantly affects transgression, inattention, and aggression but does not influence positive

walking behaviors.

Improvement measures are proposed based on research conclusions:

Targeted Education Programs: Implement traffic safety education specifically for elderly individuals, particularly those who have experienced or witnessed traffic accidents, to enhance their self-protection awareness and abilities.

Emotional Support and Management: Provide psychological support and emotional management training for elderly individuals prone to anger to help them better control their emotions and reduce aggressive behaviors.

Community Support and Activities: Enrich community activities to increase social support for the elderly, reducing deviant behaviors and promoting positive walking behaviors.

Personalized Safety Strategies: Develop personalized safety strategies based on the personality traits of the elderly. For instance, offer more challenging alternative activities for high sensation-seeking individuals to reduce risky walking behaviors.

Improve Walking Environments: Enhance safety facilities such as pedestrian crossings, traffic lights, and barriers in areas frequently visited by the elderly to ensure their walking safety. Ensure that pedestrian bridges and underpasses are equipped with elevators to accommodate elderly individuals who have difficulty using stairs. Install wider and clearly marked crosswalks with extended signal timings to give elderly pedestrians more time to cross safely.

Educational Interventions: Provide training on traffic rules and safety awareness for elderly groups with lower education levels to help them better understand and adhere to traffic regulations.

### *5.2. Limitations*

This study acknowledges several limitations. This study overlooks the impact of walking time, walking frequency, different cultural contexts, and COVID-19 on the walking behavior of the elderly. Future research could delve deeper into these aspects to address these shortcomings. Walking behaviors in seniors were evaluated using self-report measures rather than through observations or other forms of objective measurement. Given that social desirability may lead to bias in self-reported behaviors [83], such a method may reduce the study's reliability. Studies indicate that participants from China are more prone than those from other countries to mask their actions and depict themselves as virtue-seeking [84,85]. As a result, the use of several measuring methods is critical. Further studies can combine video-recorded pedestrian behaviors with an examination of personality traits to determine whether personality traits play the same functions as were found in this study. The study for this study was conducted in Guangzhou City, a highly developed city. The findings of this research may not generalize to less populous Chinese cities or rural regions. Furthermore, the explanation rates for Inattention and Positive behaviors are relatively low, at 28 % and 18 %, respectively. These values indicate that while our models explain a significant portion of the variance in these behaviors, there remains a substantial amount of variance unexplained. This could be due to several factors not included in our models, such as environmental influences, individual differences, or unmeasured psychological variables. We will consider additional variables and potential interactions to improve the explanatory power of the models in future research.

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## Informed consent statement

Informed consent was obtained from all subjects involved in the study.

## Data availability statement

The data presented in this study are available on request from the corresponding author due to the need to protect individual privacy.

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## CRediT authorship contribution statement

**Zhiwei Liu:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology. **Ziyang Shi:** Resources, Investigation, Data curation. **Yating Wei:** Resources, Investigation, Data curation. **Xutong Zhu:** Resources, Investigation, Data curation. **Jianrong Liu:** Validation, Conceptualization.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e37034.

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