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The impact of perceived injury risk and psychosocial factors on walking equity

J.E. Rod [a,b], Mark King [a], Oscar Oviedo-Trespalacios [c,*]

[a] *Queensland University of Technology, Centre for Accident Research and Road Safety-Queensland (CARRS-Q), 130 Victoria Park Rd, Kelvin Grove, 4059, Australia*

[b] *Universidad del Norte, Departamento de Salud Pública, KM 5, via Puerto Colombia, Colombia*

[c] *Delft University of Technology, Faculty of Technology, Policy and Management, Section of Safety and Security Science, Jaffalaan 5, 2628 BX Delft, the Netherlands*

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ABSTRACT

Walking is the cornerstone of active and sustainable transport. However, traffic safety concerns among pedestrians could reduce walking behaviour. Safety concerns are generally measured through risk perceptions. Unfortunately, a lack of theoretical development of risk perceptions in walking behaviour research has limited our capacity to identify groups of pedestrians who are inequitably affected and address their concerns. To address this gap, the present investigation identified various theory-driven risk dimensions (i.e., mechanism of injury, temporal risk dimensions, and information processing). Logistic and hierarchical linear regression analyses were used to investigate the effect of the risk dimensions on walking behaviour while considering psychosocial factors (e.g., attitudes and social norms). The findings suggest that policymakers and practitioners should consider both objective and perceived pedestrian safety to promote sustainable mobility. Older adults require particular attention as they are inequitably affected by objective and subjective risks.

1. Introduction

1.1. Background

Walking is the most basic form of active mobility, contributing to public health and environmental sustainability (Audrey et al., 2014; Kummeneje et al., 2019; Ogilvie et al., 2004). Walking for transport reduces non-communicable disease incidence and mortality (Celis-Morales et al., 2017; Hamer et al., 2008; Panter et al., 2018). For instance, people living in areas of high walkability (vs low) in Canada, have up to 50 % lower likelihood of developing diabetes (Howel et al., 2022). The health benefits of shifting from motorised to active transport outweigh the associated risks of active transportation, e.g., traffic injury and respiratory disease due to air pollution (Mueller et al., 2015). Hence, public health and transport agencies have devoted increasing policy attention to promoting active mobility (Audrey et al., 2014; Kummeneje et al., 2019; Ogilvie et al., 2004), which is a leading intervention for environmental and transport justice (Beiler and Mohammed, 2016; Martens, 2016; Martínez-Buelvas et al., 2022).

* Corresponding author at: Delft University of Technology, Faculty of Technology, Policy and Management, Section of Safety and Security Science, Jaffalaan 5, 2628 BX Delft, The Netherlands.

E-mail addresses: javierz@uninorte.edu.co (J.E. Rod), O.OviedoTrespalacios@tudelft.nl (O. Oviedo-Trespalacios).

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Even though the benefits of walking are widely recognised, in many places, it is not a common form of purposeful (as opposed to incidental) travel. In Australia, 80 % of trips to work or education are made with private motor vehicles (Zapata-Diomedi, et al., 2017). This highlights the opportunity to transition people from motorised to active mobility. However, motivating people to engage in walking requires walking risk management. This implies understanding the relationship between the physical transport infrastructure and pedestrian trauma. Simultaneously, it is essential to understand pedestrians' perceptions as they are a crucial determinant of walking behaviour (Basu, et al., 2021a; Basu, et al., 2021b). However, limited research is devoted to understanding the relationship between risk perception and its potential influence on walking behaviour (Kummeneje et al., 2019).

Perceived risk is a core predictor of behaviour in the psychological literature (Ferrer, Klein, Persoskie, Avishai-Yitshak, & Sheeran, 2016; Sheeran, Harris, & Epton, 2014). There is *meta*-analytical evidence that interventions that heighten risk appraisals have a significant impact on health-protective intentions and behaviours (Sheeran et al., 2014). Indeed, fear of injury has been suggested to be associated with reduced physical activity levels (Huebschmann et al., 2011). Arguably, if policymakers and practitioners do not manage risk perceptions, people could deliberately avoid walking as a protective measure. Another concern is that some groups of pedestrians might feel more vulnerable to risks than others and that such differences could lead to an inequitable effect on walking behaviour. For example, older adults consider reducing outdoor activities due to concerns about potential injuries from a fall (Schepers et al., 2017; Wijlhuizen et al., 2007). These concerns may not have the same salience among younger people. Thus, pedestrian trauma might have a twofold inequitable effect on active mobility: (1) pedestrian trauma has direct serious health consequences for pedestrians, and (2) it can increase risk perceptions of a broader cross-section of the population resulting in an overall decrease in walking. This negative effect could be, inequitably, more pronounced in older populations.

1.2. *Perceived risk and its impact on walking behaviour*

Perceived risk is a complex construct to define due to abundant and inconsistent terminology. e.g. risk perception (Douglas et al., 1982; Fischhoff et al., 1985; Sjoberg, 2000; Slovic, 1987), safety perception (Dollisson et al., 2013; Ni et al., 2017), perceived severity (Wong et al., 2017), perceived susceptibility (Dillard et al., 2012; Ranby et al., 2010), probability judgements and worry (Magnan et al., 2013; Peters et al., 2006). Many authors have suggested the need to strengthen the theoretical basis of risk perception research (Dillard et al., 2012, Leppin et al., 2009; Wilson et al., 2018). Thus, in the present study, we suggest a comprehensive conceptualisation that considers three dimensions of pedestrians perceived risk of trauma: the mechanism of injuries, the temporal dimension of risk, and psychological information processing. We have labelled this conceptualisation as the dimensions of Perceived Risk of Pedestrian Injury (PRPI). The first dimension is the injury mechanism and involves taking into account different types of pedestrian trauma which broadly include pedestrian-vehicle collisions (PVC) and pedestrian falls (Rod et al., 2021a; Rod et al., 2021b Methorst et al., 2017a). The literature suggests that exposure to both types of injury mechanisms leads to significant proportions of fatalities (Schepers et al., 2017) and injuries (Methorst et al., 2017b; Schepers et al., 2017).

The second dimension is temporal. Risk perception research generally focuses on only one temporal aspect of a particular risk event, ignoring other associated subsequent temporal risks (Leppin et al., 2009). The present research sought to include different points in time across the natural history of disease of pedestrian trauma reported by Rod, et al., (2021a). In Fig. 1 it is shown that there are various risks associated with both pedestrian trauma injury mechanisms. From those, it is possible to evaluate PRPI at different points in time such as the event, severe injury outcomes, and death.

The third dimension refers to risk information processing (Smerecnik, et al., 2012). The most common approach has focused on a dual information processing perspective, where cognition and affect/intuition determine the perception of risk. Theoretical examples of this approach are the risk-as-feelings hypothesis (Loewenstein et al., 2001), the affect heuristic (Slovic et al., 2007) and the somatic

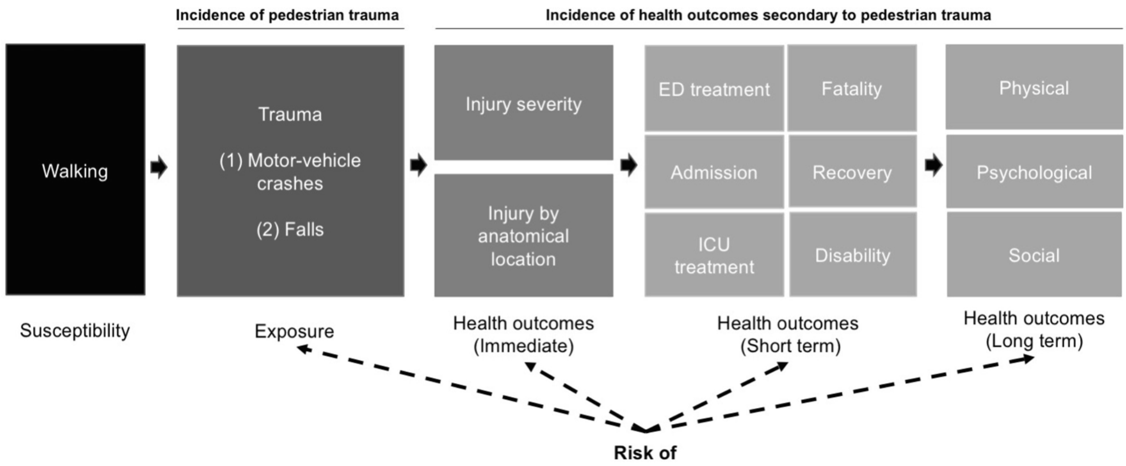

Fig. 1. Natural history of disease for pedestrian trauma. Adapted from (Rod et al., 2021a). In the figure, risk of short-term health outcomes excludes *"recovery",* there we think probability of or chances of is a more accurate term.

marker hypothesis (Bechara and Damasio, 2005). The dual processing approach recommends to researchers the incorporation of worry as a measure of affect/intuition in addition to the cognitive evaluation of probability judgements. A recently proposed alternative approach to information processing is Fuzzy Trace Theory (FTT) (Reyna et al., 2015; Rivers et al., 2008). FTT suggests that intuition should not be considered an equivalent of affect and that humans have a *meta*-cognitive capacity that range from an intuitive or experiential gist, to more systematic, deliberate, verbatim and numerical forms of cognition (Reyna et al., 2015; Rivers et al., 2008). In a similar vein, the tripartite model of risk perception TRIRISK was recently proposed to measure risk perception by utilising the affective, experiential and cognitive dimensions of information processing (Ferrer et al., 2016).

Some emerging research provides insights into the association between multidimensional risk perception and walking frequency. For instance, a moderate negative association between pedestrian worry (measuring the dimension of affect) and walking frequency was found by Kummeneje and Rundmo (2019). However, the literature suggests it is important to explore beyond past walking frequency as an outcome measure of pedestrian behaviour and also evaluate surrogate measures of future walking behaviour such as behavioural intentions (Rundmo et al., 2011). Furthermore, to the best of our knowledge, there is no research looking at the potential effects that PRPI could have on walking duration. This is important given that physical activity duration is a crucial metric for achieving physical activity sufficiency and harnessing the health benefits of active mobility. Finally, Kummeneje and Rundmo (2019) explored the perceived risk of pedestrian *"accidents"* by including a question on severity beyond the occurrence of the event. We feel that the term *"accident"* is too broad as it could involve any unfortunate incident related to pedestrian activity. For instance, the infection and severe disease risk from COVID-19 (Rod, et al., 2020) or injuries arising from animal encounters (Heger et al., 2019). Therefore, the present study explicitly focuses on PRPI arising from road trauma, including PVC and pedestrian falls and includes additional temporal (death) and processing dimensions (experiential). In addition, there are age differences in the objective risk associated with pedestrian trauma (Rod et al., 2021b) and in subjective risk perceptions (Bonem, et al., 2015). Thus we also cosidered it important to explore age differences in PRPI.

1.3. *A theory-based approach to pedestrian behaviour*

Everyday travel can be considered a habit (Verplanken et al, 1997). In cases where habits are formed in a particular behavioural context, **past behaviour** is a significant predictor of future behaviour (De Bruijn et al., 2011; Ouellette et al., 1998). Thus, understanding past walking behaviour through walking frequency and duration can give insights into walking habits and future walking behaviour. Predicting human behaviour is complex (Nettle et al., 2013; Sapolsky, 2017), and research on pedestrian behaviour has generally not been informed by an underlying theory (Lennon et al., 2017). The Theory of Planned Behaviour (Ajzen, 1991, 2006) has become one of the main influential theories explaining social (Lee et al., 2016; Oviedo-Trespalacios et al., 2020; Oviedo-Trespalacios et al., 2021) and health behaviours (Cooke et al, 2016; Godin and Kok, 1996) including physical activity (Hagger et al, 2002; Hagger et al., 2018; Martin et al., 2007). According to the TPB, behavioural intentions (BI), defined as plans for engaging in a particular behaviour, are the most essential behavioural determinant. Three psychological constructs influence BI: **attitudes**, positive or negative evaluations of performing the behaviour, **subjective norms**, which reflect the perceived social pressure to execute the behaviour, and **perceived behavioural control**, beliefs related to the capacity to perform the behaviour (Ajzen, 1991, 2006). There is *meta*-analytical evidence supporting intentions as a predictor of behaviour (Hagger et al., 2002; Hagger et al., 2018) and the prediction capacity of the TPB for engaging in physical activity (Hagger et al., 2002). The TPB is a flexible theory with few constructs; this enables the extension of the theory to increase its explanatory capacity. Therefore, we used a comprehensive measure of behavioural intentions by including in one construct three items of **behavioural expectations** (BE), defined as predictions of one's future likely behaviour, three items of **behavioural willingness** (BW), defined as openness to the opportunity to engage in the behaviour and three items of the traditional measure of **behavioural intentions** (BI). The nine items were considered under the umbrella of the construct of behavioural intentions, as suggested by Armitage and Conner (2001) and Fishbein (2008).

1.4. *The current study*

The aims of the present study were to (i) explore the psychological structure and associated age differences of PRPI by considering critical risk dimensions (i.e., mechanism of injury, temporal risk dimensions, and information processing), (ii) investigate the effect of PRPI on pedestrian past walking behaviour (i.e., walking frequency and frequency-duration), and (iii) the potential effect of PRPI and psychosocial factors on future walking intentions. The Theory of Planned Behaviour (TPB) was used to explore psychosocial factors on future walking intentions.

These three aims sought to establish a link between PRPI and actual walking behaviour by building on previous *meta*-analytical evidence that **perceived risk** encourages protective behaviour (Sheeran et al., 2014), empirical evidence that **past behaviour** is a significant predictor of future habitual behaviour (De Bruijn et al., 2011; Hagger et al., 2002 Ouellette et al., 1998), and *meta*-analytical evidence that behavioural **intentions** predict actual behaviour (Hagger et al., 2002; Hagger et al., 2018; Webb, & Sheeran, 2006). To address these aims, a theoretically-informed cross-sectional study was conducted. Participants completed an online questionnaire administered in Australia. The research was approved by the Ethics Review Committee of Queensland University of Technology (approval number 2000000876).

2. Methods

2.1. Cross-sectional online survey sampling plan and administration.

A cross-sectional online survey was administered through an online survey provider. The sampling plan was based on a convenience sampling strategy. This strategy was selected given the novelty of the research question. Early insights from non-probability sampling are needed to justify fund allocation for more resource-intensive probability sampling types of studies (Jager et al., 2017). In addition, multiple strategies were used to recruit participants to obtain a wide range of individuals in terms of experience and age groups. To explore age differences in Perceived Risk of Pedestrian Injury (PRPI) the recruitment process aimed to recruit enough older participants.

Several data collection strategies were used to recruit participants. The first recruitment strategy involved disseminating the survey via institutional emails and social media channels at the Queensland University of Technology (QUT) and the Centre for Accident Research and Road Safety-QUT (CARRS-Q) in Brisbane (Australia). Participants were offered the possibility of entering a prize draw to win a cash gift card as an incentive. The second strategy involved distributing the survey through the School of Psychology & Counselling QUT Psychology Research Management System (SONA), which grants QUT students course credit for participation in research studies. Given that we expected these strategies to provide a higher proportion of younger participants and people living in Queensland, we used an additional method to increase recruitment of older adults. A global online market search firm with experience in academic research was contracted to provide online questionnaire administration in Australia. The emphasis on older adults was deliberate, given the susceptibility of older pedestrians to trauma (Rod et al., 2021a) and demographic differences in the objective risk of non-vehicle pedestrian trauma (Rod et al., 2021b) and subjective risk perceptions (Bonem et al., 2015). The inclusion criteria for the selection of participants were being 18 years or older, currently living in Australia and being able to walk.

2.1.1. Characteristics of survey participants

A total of n = 487 participants completed the survey;13 participants had missing data and were excluded from further analysis, yielding a total sample of n = 474 participants. All participants reside in Australia. Participants were asked to report the highest level of education they had completed and were asked about their current employment status. In addition, they were asked to report their previous experiences regarding the number of times they had a pedestrian fall or were hit by motorised or non-motorised vehicles. For an overview of the sample characteristics, see Table 1.

Table 1
Sample characteristics.

	Sample	
Variables	n	%
Age		
18–59	245	51.7 %
60+	229	48.3 %
Gender		
Female	274	57.8 %
Male	195	41.1 %
Other	5	1.1 %
Education level		
Year 12	118	24.9 %
Bachelor's degree	104	21.9 %
Advanced diploma and diploma	100	21.1 %
Postgraduate degree	78	16.5 %
Year 11 or below	70	14.8 %
No educational attainment	4	0.8 %
Employment status		
Pensioner	153	32.3 %
Full time work	116	24.5 %
Part time work	82	17.3 %
Unemployed	54	11.4 %
Both worker and student	39	8.2 %
Student	30	6.3 %
Pedestrian falls in the past 3 years		
Zero	308	64.9 %
One	63	13.9 %
Two	61	12.9 %
Three	20	4.1 %
Four or more	22	4.2 %
Pedestrian vehicle collisions in the past 3 years (experienced as pedestrians)		
Zero	461	97.2 %
One	11	2.4 %
Two	1	0.2 %
Three	1	0.2 %

2.2. Measurements

The self-reported online survey included the measurement instruments listed below. All items were measured using closed response questions and were slightly modified from previous items and scales that have previously been employed in the relevant literature on perceived risk, walking and pedestrian behaviour and road safety research. The survey was focused on pedestrian injury occurring only on public roads and footpaths. This information was transmitted to participants at the beginning of the survey and every time they finished a particular section of the survey.

2.2.1. Perceived risk of pedestrian trauma

There were 18 items measuring each mechanism of injury (falls and PVC). For each mechanism of injury, six items measured different reference points in time along the temporal dimension (event, severity, fatality). Among these six items, blocks of two items measured the information processing dimension (cognitive, affective, intuitive). These items were adapted from the TRIRISK risk perception framework (Ferrer et al., 2016). The following are examples of the modified TRIRISK items (e.g. 1- H*ow likely is it that you will be involved in/will get* ***[Risk-i]*** *at some point in the future? 2- The way I look after my health means that my odds of* ***[Risk-i]*** *when walking in a public space are*) two affective items (e.g. 1- H*ow worried are you about/about developing* ***[Risk-i]*** *in the future? 2- How fearful are you about getting a severe injury from* ***[Risk-i]*** *while walking in a public space in the future?*) and two the experiential items (e.g. 1-H*ow easy is it for you to imagine yourself /yourself developing* ***[Risk-i]*** *in the future? 2- My first reaction when I hear someone had a severe injury from* ***[Risk-i]*** *while walking in a public space is "that could be me someday")*. The full list of items measuring PRPI is presented in **Appendix A**.

2.2.2. Pedestrian behaviour location

The present study considered walking behaviour occurring on public roads and footpaths. The first reason for selecting public roads and footpaths is that active mobility is likely to have a higher representation in this environment than on private roads. Second, there is

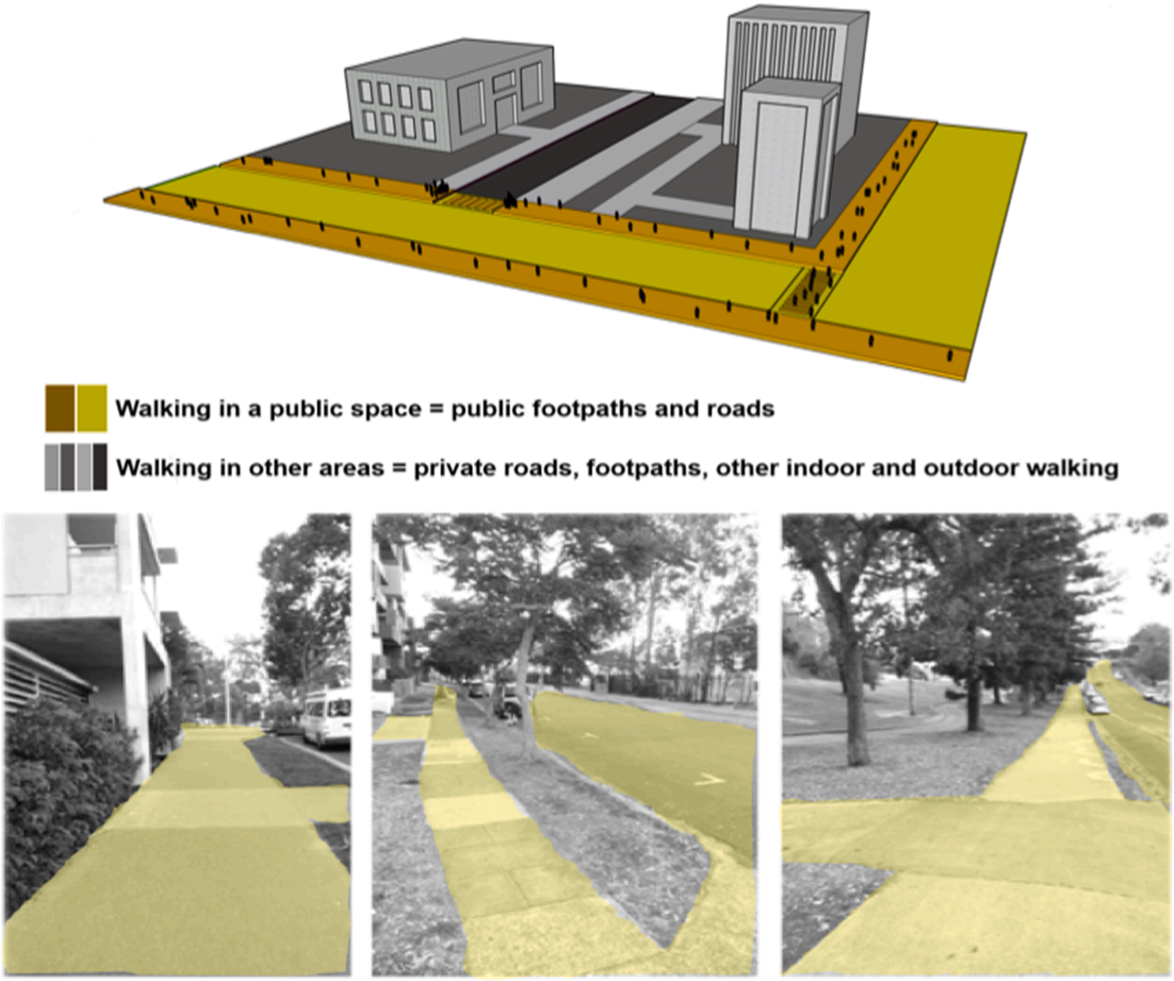

Fig. 2. Walking in the public space.

less heterogeneity regarding the road infrastructure and rules on public roads (Department of Transport and Main Roads Queensland, 2021) relative to private roads, given that they are the responsability of the government́. Consequently, public footpaths might offer a more consistent psychological experience of the environment than private footpaths. For a graphical representation of what is meant by walking in the public space, see Fig. 2**.** Participants were directed multiple times to look at Fig. 2 **in the online survey,** so that they were constantly reminded that the study was focused on public roads and footpaths.

2.2.3. Pedestrian behaviour outcome measures

2.2.3.1. Past walking behaviour – Walking frequency per week. Responses to this question required the participant to provide the number of days they walk per week after reading the following paragraph. *Think about the time you spent walking in public spaces in the last week. This includes any outdoor walking occurring in places that are not private buildings (*e.g. *within a University), driveways or footpaths/sidewalks for recreation, sport, exercise, or leisure.* The responses were dichotomised to "three times a week or less" (≤3/week = considered as low walking frequency) and "four times a week or more" (≥4/week = considered as high walking frequency); this approach has been used in the literature to closely approximate the number of recommended weekly sessions to meet physical activity sufficiency (King et al., 2015).

2.2.3.2. Past walking behaviour – Walking duration-frequency. An additional pedestrian walking behaviour question requested participants to provide a combined measure of walking frequency and duration on a seven-point Likert scale ranging from (1) strongly disagree to (7) strongly agree. Participants were presented with the following statements. *1-I have walked at least 30 min a day, 5 days a week. 2- When I think about the moments I have walked, I remember having engaged in walking at least 30 min a day, 5 days a week.* This approach has been used in the literature to closely approximate the number of recommended weekly sessions to meet physical activity sufficiency (King et al., 2015).

2.2.3.3. Future walking behaviour as walking intentions (intentions, expectations and willingness). Walking intentions were measured by nine items, three for each construct related to intentions (BI, BW, BE). For instance, BI was measured by presenting participants with the following statements (1- *I intend to walk at least 30 min a day, 5 days of the next week. 2- My goal is to walk at least 30 min a day, 5 days of the next week, 3- I plan to walk at least 30 min a day, 5 days of the next week*) and indicate their level of agreement on a seven-point Likert scale ranging from (1) *strongly disagree* to (7) *strongly agree*. BW was measured by the following questions (1- *If you need to go somewhere, how willing will you be to walk so that you can achieve at least 30 min of walking 5 days of the next week?, 2- If you want to have fun in the next week, how willing will you be to walk so that you can achieve at least 30 min of walking 5 days a week?,3- If you want to do some exercise in the next week, how willing will you be to walk so that you can achieve at least 30 min of walking 5 days a week?*) and indicating their level of agreement on a seven-point Likert scale ranging from (1) *not at all willing* to (7) *very willing*. Finally, BE was measured by the following questions/statements (1-*How probable is that you will walk at least 30 min a day, 5 days of the next week?, 2- How likely is that you will walk at least 30 min a day, 5 days of the next week?, 3-I will walk at least 30 min a day, 5 days of the next week*) and indicating their level of agreement on a seven-point Likert scale ranging from (1) *extremely improbable* to (7) *extremely probable*.

2.2.4. Theory of Planned behaviour constructs

Four items were used to evaluate attitudes towards walking by presenting the following statements, "*For me walking at least 30 min a day, 5 days of the next week for transport, leisure or exercise will be" (very unenjoyable, safe, wise, satisfying)* (1) to *very (enjoyable, safe, wise, satisfying)* (7) on a seven-point Likert scale. Four items evaluated subjective norms (*Most people who are important to me would approve of me to walk at least 30 min a day, 5 days of the next week, most people whose opinions I value would approve of me to walk at least 30 min a day, 5 days of the next week, most people important to me would think that I should to walk at least 30 min a day, 5 days of the next week, most health professionals that look after me think that I should walk at least 30 min a day, 5 days of the next week), and were measured on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). Lastly, three items were used to evaluate perceived behavioural control (It is mostly up to me whether or not I walk at least 30 min a day, 5 days of the next week, Walking at least 30 min a day, 5 days of the next week would be easy for me to do, I have complete control over whether or not I walk at least 30 min a day, 5 days of the next week) on a seven-point Likert scale ranging from strongly disagree (1) to strongly agree (7). A similar approach to the TPB has been used in previous research looking at the influence of psychosocial factors on road safety* (Lennon et al., 2017; 2015 Oviedo-Trespalacios et al., 2020; Oviedo-Trespalacios et al., 2021; Pomery et al., 2009).

2.3. Data analysis

Descriptive statistics were used for data exploration. Considering that the TRIRISK framework has been proposed as a sound theoretical perspective for measuring risk perceptions, its current empirical evidence is limited to the perceived risk of chronic diseases (Ferrer et al., 2016). Thus, its usefulness in evaluating other types of perceived risks is unknown. In addition, the employed perceived risk questionnaire was designed to capture the three dimensions of PRPI. Therefore, an Exploratory Factor Analysis (EFA) was performed. EFA is a widely used technique in exploring the presence of theoretical constructs of self-reported data and determining which of the employed items constitute a particular construct (Norris and Lecavalier, 2010; Watkins, 2018). This data analysis technique requires a series of procedures that are susceptible to researchers' judgment. In an attempt to reduce bias, we followed the recommendations for conducting and reporting EFA in transportation research (Ledesma et al, 2021).

Table 2
EFA sample.

PRPI dimensions			Items	Factor loadings
Mechanism	Temporal	Processing		
				Factor 1 loadings
Vehicle collisions	Event, severity & death	Aff	1- How worried are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.82
			2- How worried are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.82
			3- How fearful are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.82
			4- How fearful are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.81
			5-How worried are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.79
		Exp	6- How easy is it for you to imagine yourself getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.78
		Aff	7- How fearful are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.78
		Exp	8- How easy is it for you to imagine yourself getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.76
		Exp	9- My first reaction when I hear of someone that someone was hit by any vehicle (motorised or human powered) while walking in a public space is “that could be me someday”	0.76
			10-How easy is it for you to imagine yourself dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.76
			11- My first reaction when I hear someone died from getting hit by any vehicle (motorised or human powered) while walking in the public space is “that could be me someday”	0.75
			12- My first reaction when I hear someone had a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space is “that could be me someday”	0.74
		Cog	13- How likely is it that you will get hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.53
				Factor 2 loadings
	Event & severity	Aff	1- How worried are you about falling while walking in a public space in the future?	0.85
			2- How fearful are you about falling while walking in a public space in the future?	0.83
Fall			3- How worried are you about getting a severe injury from falling while walking in a public space in the future?	0.81
			4- How fearful are you about getting a severe injury from falling while walking in a public space in the future?	0.77
		Cog	5- The way I look after my health means that my odds of falling when walking in a public space are	0.69
			6- The way I look after my health means that my odds of getting a severe injury from falling when walking in a public space are	0.69
		Exp	7- How easy is it for you to imagine yourself getting a severe injury from falling while walking in a public space in the future?	0.67
		Cog	8- How likely is it that you will get a severe injury from a fall when walking in a public space in the future?	0.63
		Exp	9- How easy is it for you to imagine yourself falling while walking in a public space in the future?	0.61
		Cog	10- How likely is it that you will fall when walking in a public space in the future?	0.56
				Factor 3 loadings
	Death	Aff	1- How fearful are you about dying from falling while walking in a public space in the future?	0.80
Fall			2- How worried are you about dying from falling while walking in a public space in the future?	0.77
		Exp	3- How easy is it for you to imagine yourself dying from falling while walking in a public space in the future?	0.64
		Cog	4- The way I look after my health means that my odds of dying from falling when walking in a public space are	0.56
			5- How likely is it that you will die from falling when walking in a public space in the future?	0.56
				Factor 4 loadings
	Event, severity & death	Cog	1- The way I look after my health means that my odds of dying from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.64
Vehicle collisions			2- The way I look after my health means that my odds of getting a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.60

(*continued on next page*)

Table 2 (*continued*)

PRPI dimensions			Items	Factor loadings
Mechanism	Temporal	Processing		
			3- How likely is it that you will get a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.59
			4- How likely is it that you will die from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.55
				Factor 5 loadings
Fall	Event, severity & death	Exp	1- My first reaction when I hear someone had a severe injury from a fall while walking in a public space is "that could be me someday"	0.65
			2- My first reaction when I hear that someone has fallen while walking in a public space is "that could be me someday"	0.53
			3- My first reaction when I hear someone died from falling while walking in the public space is "that could be me someday"	0.53

Following the statistical analysis guidelines, we found that the study sample size of 474 meets both the minimal recommendations of 200 participants and the n/variables ratio of 10 (current study = 13.2) (Ledesma et al., 2021). Moreover, the exploration of the data for skewness and correlations suggested that most coefficients of asymmetry were below one and that most perceived risk inter-variable correlations were around 0.5 (Ferrando and Lorenzo-Seva, 2014). Given that the data showed moderately correlated variables, had variables with more than five categories, and few skewed distributions, we considered product-moment correlation matrix estimated by SPSS to offer a reasonable approximation of the linear relationship between variables and the extracted factors. In addition, early work evaluating different types of risk perception scales, including ordinal and interval type questions for data collection, supported that there were high correlations (>0.6) between 11, 12-point continuous numerical scales and seven-point Likert scales like the one used in the present study (Diefenbach et al., 1993). In addition, the Bartlett test of sphericity and the Kaiser-Meyer-Olking (KMO) sampling adequacy measure were conducted to test factorability.

The unweighted least squared (ULS) factor extraction method was selected, given that the data did not meet the assumption of multivariate normality as suggested by Coughlin (2013). We used a multiple-criteria approach to select the total number of factors to be extracted and prioritised a parsimonious model with high theoretical interpretability. First, the scree-plot was used to scan the potential number of factors. Then the Kaiser criterion (Eigenvalues > 1), the total amount of explained variance and the theoretical interpretability based on the PRPI three dimensions were used to determine the number of factors to be extracted. Rotation methods in factor analysis should be consistent with research objectives (Bewick et al., 2005; Gaskin et al., 2014; LaValley, 2008). Varimax rotation was used, given that we expected the perceived risk of vehicle collisions to be uncorrelated with the perceived risk of pedestrian falls (Ledesma et al., 2021). However, items measuring the temporal dimension and the same information processing constructs were expected to be correlated. The injury mechanism was given priority as it was the dimensional construct measured by all the items that measured the other two dimensions. The full rotated pattern loading matrix can be found in **Appendix A** for other researchers to evaluate. Given the high number of measured variables for the same overall concept of PRPI, expected correlations among two of the PRPI dimension, and the pursuit of a parsimonious solution, we removed items with factor loadings < 0.5 in the presented tables in the paper. In addition, cross-loading of items in factors was expected as all the items measure the overall concept of PRPI. Items with cross-loadings were not removed from the EFA tables. However, to visually explore the latent structure of the measured variables, they were presented in the tables as only loading within the factor with the least number of loading items (favouring theoretical interpretability). The EFA was conducted first at the overall sample level, and then the sample was divided by age into those < 60 and 60 + to explore differences in the extracted factors. Then, using the sample extracted factor solution and scores, mean differences using the Mann-Whitney *U* test and logistic regressions were used to evaluate the effect of the extracted factors on dichotomous outcomes. Bivariate correlations and hierarchical multiple regressions were used for continuous variables. Alpha was set at $\alpha = 0.05$ and p-values were reported at 2 decimal points. The analyses were conducted using SPSS IMB statistics version 25.0.0.

3. Results

3.1. The dimensions of perceived risk of pedestrian injury (PRPI) and association with individual differences

To explore the dimensions of PRPI, we conducted an Exploratory Factor Analysis (EFA) and found a total of five factors (KMO-sampling test = 0.951 & Bartlett's test of sphericity = p < 0.01). Factor one represented the perceived risk of vulnerability to pedestrian-vehicle collisions (PVC) event, severity and death (54 % of explained variance). Factor two represented the perceived risk of vulnerability to pedestrian falls event and severity (11 % of explained variance). Factor three represented the perceived risk of vulnerability to pedestrian falls death (5 % of explained variance). Factor four represented the perceived probability of PVC event, severity and death (4 % of explained variance), and factor five represented the intuition of pedestrian falls event, severity and death (3 % of explained variance) (see Table 2). The first three factors seem to capture the negative affect associated with the potential for physical injury. In comparison, the remaining two factors are more related to the estimation of the occurrence of pedestrian trauma at the cognitive and experiential dimensions of risk information processing. When exploring age differences between adults aged < 60 and adults aged 60+, it was found that those aged < 60 had four out of the five factors of the overall sample, yet factors remained

Table 3
Correlation between PRPI, TPB variables, age & past walking behaviour.

		PRPI					TPB				Age	Past walking behaviour	
	Mean (SD)	1	2	3	4	5	6	7	8	9	10	11	12
1-Factor 1: PVCa	3.2 (0.97)	1	0.03	−0.08	0.14**	0.12**	0.10*	−0.64	0.04	−0.08	−0.29**	0.08	0.02
2-Factor 2: Pfa	2.8 (0.96)		1	0.04	0.07	0.12**	−0.22**	−0.26**	−0.21**	−0.29**	0.16**	−0.21**	−0.20**
3-Factor 3: PFb	3.9 (0.95)			1	−0.04	−0.027	−0.02	−0.05	−0.13**	−0.04	0.04	−0.01	−0.16**
4-Factor 4: PCVb	4.3 (0.91)				1	0.013	−0.15**	−0.12**	−0.17**	−0.12**	−0.05	−0.13**	−0.04
5-Factor 5: PFc	4.1 (0.93)					1	−0.03	0.01	−0.01	0.01	0.30**	−0.01	−0.07
6-Walking intentions	4.9 (1.85)						1	0.70**	0.63**	0.68**	−0.01	0.82**	0.68**
7-Walking attitudes	5.2 (1.52)							1	0.60**	0.61**	0.01	0.58**	0.52**
8-Walking subjective norms	5.7 (1.3)								1	0.59**	0.03	0.50**	0.46**
9-Walking perceived behavioural control	5.6 (1.3)									1	0.02	0.57**	0.46**
10-Age	52 (19)										1	−0.15**	−0.11**
11-Walking frequency-duration	4.6 (2.2)											1	0.63**
12.Walking frequency	4.0 (2.3)											1	

Factor 1: PVCa –Vulnerability to pedestrian vehicle collisions – Event, severity, death – Affective, experiential cognitive.
Factor 2: Pfa –Vulnerability to pedestrian falls – Event, severity – Affective, experiential cognitive.
Factor 3: Pfb – Vulnerability to pedestrian falls – Death – Affective, experiential cognitive.
Factor 4: PVCb – Probability of pedestrian vehicle collisions – Severity, death – Cognitive.
Factor 5: PFc – Intuition of pedestrian falls – Event, severity, death – Experiential.
+For interpretability of the mean of the extracted factors, they were converted using a linear transformation so that all values are positive using the following formula = (1 + abs (minimum value of X) + X.
Correlation values are based on the raw extracted factors.
$p < 0.05$*, $p < 0.01$**, there were no values of $p < 0.001$***.

similar to the factorial structure of the overall sample for those aged 60 +. In addition, adults aged 60 + have a more consistent rank order in the strength of the factor loading that referred to a particular information processing dimension. This means that items relating to similar information processing strategies load closer to each other.

Adults aged < 60 years had a higher mean rank (factor one: 277 vs 195, $p < 0.01$) perceived risk of vulnerability to PVC than adults aged 60 +. In contrast, adults aged 60 + years had a higher mean rank (factor two: 259 vs 217, $p < 0.01$) perceived risk of vulnerability to pedestrian falls event and severity that those < 60 years. They also reported a higher mean rank perceived risk of intuition of pedestrian falls (factor five: 266 vs 210, $p < 0.01$). Furthermore, females had a higher mean rank (factor two: 275 vs 198, $p < 0.01$) perceived risk of vulnerability to pedestrian falls event and severity than males. Participants with low walking frequency (≤3/week) had a higher mean rank perceived risk of vulnerability to pedestrian falls event and severity (factor two: 270 vs 215, $p < 0.01$) and vulnerability to pedestrian falls death (factor three: 260 vs 222, p = < 0.01) than those with high walking frequency (≥4/week). Spearman correlations between age and extracted factors and walking frequency-duration found only statistically significant weak negative correlation between vulnerability to pedestrian falls event and severity (factor two: − 0.209, $p < 0.01$) and very weak correlations for the perceived risk probability to PVC (factor four: − 0.109, $p < 0.01$) and age (−0.176, $p < 0.01$). Spearman correlations between PRPI variables and TPB variables can be found in Table 3**.** There is shown that, the perceived risk of vulnerability to PVC (factor one) had a positive weakly statistically significant correlation with walking intentions. In contrast, the perceived risk of vulnerability to pedestrian falls event and severity (factor two) and the perceived risk probability of PVC (factor four) have statistically significant negative weak correlation with all the TPB variables (walking intentions, walking attitudes, subjective norms and perceived behavioural control).

3.2. Past walking behaviour – Walking frequency and frequency-duration

The results of the logistic regression model of low walking frequency (≤3/week) suggested that the perceived risk of vulnerability to pedestrian falls event and severity (factor two: OR 1.49, 95 %CI 1.21 to 1.83, $p < 0.01$) and the perceived risk of vulnerability to pedestrian falls death (factor three: OR 1.40, 95 %CI 1.14 to 1.71, $p < 0.01$) were associated with low walking frequency independent of age, gender, and other PRPI factors (see Table 4). Furthermore, hierarchical multiple regression was used to explore the effect of PRPI on walking frequency-duration in step one. Later, age and gender were entered into the model in step two. The findings of step 1 suggest that there is a significant regression equation ($F (5,463) = 11.39$, $p < 0.01$) with an R^2 of 0.010. The perceived risk of vulnerability to PVC events, severity and death (factor one) was positively associated with walking frequency-duration ($p = 0.02$). In contrast, the perceived risk probability of PVC event, severity and death (factor four) ($p < 0.01$) and vulnerability to pedestrian falls event and severity (factor two) ($p < 0.01$) were negatively associated with walking frequency-duration. The findings of step 2 suggest that there is a significant regression equation ($F (7,461) = 9.20$, $p < 0.01$) with an R^2 of 0.11.) with only the perceived risk probability of PVC (factor four) ($p < 0.01$) and vulnerability to pedestrian falls event and severity (factor two) ($p < 0.01$) remaining negatively associated with walking frequency-duration. Age was also negatively associated with walking frequency-duration ($p = 0.02$), while gender did not have a statistically significant effect on walking-frequency duration. There was a minimal improvement of the R^2 (R^2

Table 4
Logistic regression model of low walking frequency in the public space (≤3/week).

Parameters				95 % Confidence Interval		
Variable	B	Std. Error	OR	Lower	Upper	p-value
(Intercept)	−0.21	0.18	0.81	0.57	0.57	0.23
Aged < 60	−0.43	0.21	0.65	0.43	0.99	0.05
Aged 60+ (Ref)	0		1			
Male	−0.03	0.20	0.97	0.65	1.46	0.89
Female (Ref)	0		1			
Factor 1: PVCa	−0.03	0.11	0.97	0.79	1.20	0.79
Factor 2: Pfa	0.40	0.11	1.49	1.21	1.83	<0.01
Factor 3: Pfb	0.33	0.11	1.40	1.14	1.71	<0.01
Factor 4: PVCb	0.01	0.11	1.01	0.82	1.25	0.93
Factor 5: PFc	0.10	0.11	1.11	0.90	1.37	0.34

Factor 1: PVCa –Vulnerability to pedestrian vehicle collisions – Event, severity, death – Affective, experiential cognitive.
Factor 2: Pfa –Vulnerability to pedestrian falls – Event, severity – Affective, experiential cognitive.
Factor 3: Pfb – Vulnerability to pedestrian falls – Death – Affective, experiential cognitive.
Factor 4: PVCb – Probability of pedestrian vehicle collisions – Severity, death – Cognitive.
Factor 5: PFc – Intuition of pedestrian falls – Event, severity, death – Experiential.
Assumptions:
1- Linearity of the log odds was evaluated using the Box-Tidwell transformation, cheeking significance across variables after performing logistic regression and by visually exploring continuous variables vs log odds of continuous variables on a scatterplot and inspecting for linearity.
2- Outliers: No extreme outliers were reported by performing casewise list analysis.
3- Multicollinearity: The highest correlation coefficients among continuous variables were < 0.8.
4- Independence: There are not repeated measures in this dataset.
Model misfit:
There is low probability of model misfit based on the Omnibus test X = 36.148, $p < 0.01$ and the Hosmer and Lemeshow test X = 7.68, $p = 0.47$.

^{change} = 0.01).

3.3. Future walking behaviour – Walking intentions

Hierarchical multiple regression was conducted to test the effect of PRPI on walking intentions in step one. A significant equation regression was found ($F (5,463) = 13.23$, $p < 0.01$) with an R^2 of 0.12. When including the TPB variables in the model in step two to adjust for the relationship between PRPI and walking intentions, the perceived risk of vulnerability to PVC event, severity and death (factor one) and the perceived risk of vulnerability of death from pedestrian falls (factor three) were positively associated with walking intentions. All the TPB variables had a statistically significant positive effect on walking intentions. A significant equation regression was found ($F (8,460) = 122.57$, $p < 0.01$) with an R^2 of 0.59. When age and gender were entered into the model in step three, it was found that they did not significantly influence walking intentions. See Table 5 for an overview of the results of the hierarchical multiple linear regression.

4. Discussion

4.1. Summary

The main finding is that different dimensions of PRPI interact differently with different aspects of walking behaviour. The perceived risk of vulnerability to pedestrian fall events, severity (factor two) and death (factor three), are the only factors of PRPI that are negatively associated with past walking frequency. The perceived probability of pedestrian-vehicle collisions (PVC) (factor four) and

Table 5
Hierarchical multiple linear regression walking intentions.

Parameters				95 % Confidence Interval		
Steps	B	Std. Error	SB	Lower	Upper	p
Step 1. PRPI factors 2 &4						
Factor 1: PVCa	0.28	0.08	0.15	0.12	0.44	<0.01
Factor 2: Pfa	−0.51	0.08	−0.27	−0.68	−0.35	<0.01
Factor 3: Pfb	0.39	0.09	0.02	−0.12	0.21	0.65
Factor 4: PVCb	−0.35	0.09	−0.17	−0.52	−0.17	<0.01
Factor 5: PFc	−0.50	0.09	−0.03	−0.22	0.12	0.57
R^2: 0.116, $R^{2change}$ *(p)*: 0.10 (<0.01)						
Step 2. PRPI factors 2 &4 + TPBv						
Factor 1: PVCa	0.34	0.57	0.18	0.14	0.27	<0.01
Factor 2: Pfa	0.00	0.06	0.01	−0.12	0.13	0.98
Factor 3: Pfb	0.12	0.06	0.06	0.09	0.24	0.04
Factor 4: PVCb	−0.07	0.06	0.04	−0.20	0.30	0.25
Factor 5: PFc	−0.09	0.06	−0.04	−0.20	0.03	0.14
Walking attitudes	0.55	0.05	0.45	0.44	0.65	<0.01
Walking subjective norms	0.20	0.06	0.15	0.09	0.33	<0.01
Walking perceived behavioural control	0.36	0.06	0.26	0.25	0.47	<0.01
R^2: 0.599, $R^{2change}$*(p)*: 0.48 (<0.01)						
Step 3. PRPI factors 2 &4 + TPBv + Age						
Factor 1: PVCa	0.30	0.06	0.16	0.18	0.42	<0.01
Factor 2: Pfa	0.02	0.06	0.08	−0.07	−0.17	0.81
Factor 3: Pfb	0.12	0.06	0.06	0.01	0.23	0.04
Factor 4: PVCb	−0.08	0.06	−0.04	−0.20	0.05	0.14
Factor 5: PFc	−0.04	0.06	−0.02	−0.16	0.08	0.52
Walking attitudes	0.54	0.05	0.44	0.43	0.64	<0.01
Walking subjective norms	0.21	0.06	0.15	0.10	0.33	<0.01
Walking perceived behavioural control	0.38	0.06	0.27	0.27	0.49	<0.01
Age	−0.06	0.00	−0.62	−0.01	−0.00	0.07
Gender	0.16	0.12	0.04	−0.06	0.04	0.16
R^2: 0.603, $R^{2change}$*(p)*: 0.04 (<0.04)						

Factor 1: PVCa –Vulnerability to pedestrian vehicle collisions – Event, severity, death – Affective, experiential cognitive.
Factor 2: Pfa –Vulnerability to pedestrian falls – Event, severity – Affective, experiential cognitive.
Factor 3: Pfb – Vulnerability to pedestrian falls – Death – Affective, experiential cognitive.
Factor 4: PVCb – Probability of pedestrian vehicle collisions – Severity, death – Cognitive.
Factor 5: PFc – Intuition of pedestrian falls – Event, severity, death – Experiential.
Assumptions:
1- Linearity was checked by visually inspecting scatterplots of variables and bivariate correlations (present for factors 1,2 & 4), see Table 3.
2- Durbin-Watson of 1.97, suggesting no autocorrelation.
3- Collinearity statistics: All tolerance values > 0.1, all VIF values < 10.
4- Normality of the residuals was inspected by a P—P plot of the regression standardized residuals (RSR).
5- Homoscedasticity was checked by inspecting a scatterplot between the RSR and RSR predicted value.

the perceived risk of vulnerability to pedestrian fall events and severity (factor two) are negatively associated with walking frequency-duration. Furthermore, the analysis also indicated that the perceived risk of vulnerability to pedestrian-vehicle collisions (PVC) (factor one) is positively associated with walking intentions, while pedestrian fall event and severity (factor two) and the perceived probability of PVC (factor four) were negatively correlated with walking intentions and the TPB variables. Although PRPI negatively influenced intentions, psychosocial factors are a more important determinant of intentions. However, given that PRPI was negatively correlated with the TPB variables, it suggests the possibility of improving walking attitudes, social norms, and perceived behavioural control by reducing PRPI, this could ultimately have a positive impact on walking intentions. These findings confirm previous research suggesting that perception of safety influences pedestrians' decision-making and walking decisions (Basu, et al., 2021b, Kummeneje et al., 2019). Researchers and practitioners should consider the theory-driven multidimensional aspects of perceived risk as each dimension (injury mechanism, temporal and information processing) could interact differently with walking behaviour. The present research demonstrates that considering risk as a unidimensional construct could miss some of its effects on behaviour and other psychological constructs such as attitudes (Basu et al., 2022; Nguyen-Phuoc et al., 2021).

4.2. Exploratory analysis of PRPI

PRPI was confirmed to be a multidimensional construct. The factors related to the mechanism of injury (PVC or pedestrian fall) are the most significant ones. The Fuzzy Trace Theory (FTT) suggests that adult's risk information processing might rely more on gist-like representations. This could explain the higher relevance of the mechanism of injury than a cognitive evaluation of the risk at each of the temporal dimensions (Reyna et al., 2015; Rivers et al., 2008). Traditional views suggest that perceived risks are formed based on the perception of (i) controllability-knowledge and (ii) severity of consequences (Fischhoff, et al, 1978;Slovic, 1987). When people think about risk, they are more likely to give a high rating to risks that are perceived as more uncontrollable and severe (Fischhoff et al., 1978; Slovic, 1987). The finding that PVC explained most of the variance of PRPI in the EFA could be a consequence of the low controllability pedestrians have over motorists' behaviour. In addition, a PVC often has more severe consequences than falls, making PVCs more psychologically relevant than pedestrian falls. Historically, there have been periods in countries such as the United States where motor vehicle crashes exceeded the combined deaths from infectious and non-communicable diseases (Methorst, et al., 2017a). The objective and psychological (subjective) primacy of PVC diverts attention from falls, which are the leading mechanism of injury among pedestrians (Methorst, et al., 2017a, Rod et al, 2021c, Rod, 2022). Transport justice requires jurisdictions to recalibrate this belief and work towards reducing the objective and perceived risk of pedestrian falls. Falls also lead to severe injuries, and we found the perceived risk of pedestrian falls consistently affects all dimensions of walking behaviour independently of age and gender.

We also assessed how older pedestrians evaluate risk. A key finding was that adults aged 60 + had a statistically significant lower perceived risk of PVC and higher perceived risk of pedestrian falls. Adults aged 60 + years, lower perceived risk of PVC could be related to lower exposure to PVC risks. In Australia, adults age 60 + live more frequently outside of the greater city area, have a reduced number of commuting trips, tend to perform trips in off-peak hours, and most of their trips are closer to home relative to younger adults (Australian Bureau of Statistics, 2015; Department of Main Roads, 2011). In contrast, pedestrian fatalities due to vehicle collisions tend to be concentrated in major cities across Australia (Bureau of Infraestructure Transport and Regional Economics of the Australian Government, 2013). In urban areas with a high concentration of older adults, pedestrian-friendly infrastructure designed to reduce the perceived and objective risk of falls can help to increase walking when car-free areas are not feasible. For instance, smoothing sloping and uneven terrain, increasing sidewalk width, use of impact absorbing surfaces in footpaths, increasing traffic signals, availability of benches or pedestrian handrails and increasing the numbers of trees that provide shade. Importantly, if reducing the objective and perceived risk of falls is not considered when eliminating crash risks by implementing car and vehicle-free areas, older people and females might still avoid walking due to the perceived risk of falls. Certainly, this has some equity implications as not all groups of the population might benefit from intended interventions to increase walking. Of particular importance is the provision of parks, given that walking is the preferred physical activity of older people (Amireault et al., 2018; Chong et al., 2014; Sun et al., 2013).

The exploratory factor analysis of age differences shows that adults aged 60 + more consistently rely on affective and experiential information processing than adults aged < 60. This can be explained by the decline of cognitive information processing associated with ageing, where older individuals tend to process less information and make qualitatively judgments guided by affect (Helm and Reyna, 2018; Mikels et al., 2015; Peters et al., 2008; Reyna et al., 2015; Rivers et al., 2008). This information is relevant for transportation agencies that aim at increasing active mobility through community programs and behaviour change interventions, given that different populations will be more responsive to particular information formats (numerical vs affective/experiential). Poorly framed messages could inequitably impact walking behaviour among older adults. Here we suggest focusing on messages that aim at persuading participants to walk in a verbal format instead of focusing on numerical information (Steinhardt, 2020). In addition, messages directed to older people could focus on the verbal communication of the positive effects of safety measures that keep them safe while walking, and on the benefits of active mobility (Mikels, & Stuhlmacher, 2020; Steinhardt, 2020).

4.3. Past walking behaviour- walking frequency and frequency-duration

The multivariate analyses found that a higher perceived risk of pedestrian falls was associated with low walking frequency and walking frequency-duration. This supports the findings of Kummeneje & Rundmo, 2019, where increased worry (used as a surrogate measure of affective risk information processing) about pedestrian safety was moderately associated with lower walking frequency. Additional research coming from clinical practice supports that fear of injury due to falls in older adults is associated with outdoor mobility and physical activity restriction (Arfken et al., 1994; Fletcher and Hirdes, 2004; Howland et al., 1998; Murphy et al., 2002;

Wijlhuizen et al., 2007). However, the perceived risk of pedestrian falls seems to be negatively associated with walking behaviour independently of age and gender. This means PRPI is not only relevant to older adults. These findings highlight the importance of considering falls when planning for equitable road infrastructure. Unfortunately, road safety evaluation frameworks are generally focused on crash risk. A literature review of the road safety factors used in evaluations only identified crash risks as a relevant road safety factor (Beiler, & Mohammed, 2016). Including pedestrian falls is necessary, as our findings suggest that falls are not only important due to injury risks but also because they can increase the perceived risk of injury and negatively impact walking behaviour. Some pedestrian falls might be unavoidable, yet some might be preventable; falls are often a neglected road safety outcome among transport authorities (Rod et al., 2021b). Notwithstanding, strategies that seek to encourage active mobility (car-free areas, slowing motor vehicles, segregated bike lanes, and discouraging the use of the private car), which are psychologically anchored on vehicles as the source of the risk (Keall et al., 2022), are still needed. This is supported by our finding in the EFA showing that PVC is given a higher psychological weight than pedestrian falls in the PRPI.

4.4. Future walking behaviour – Walking intentions.

To the best of our knowledge, this is the first theory-driven study evaluating the effect of PRPI on walking intentions as a surrogate measure of future walking behaviour when controlling for psychosocial factors. We showed that PRPI explained 12 % of the variance in walking intentions. However, when the TPB and demographic variables were included, the negative PRPI impact of factors two and four disappeared. Interstingly, PRPI factor one and three were positively associated with walking intentions, which suggest that some PRPI dimensions do not encourage lowering walking intentions. This further highlights the importance of measuring perceived risk multi-dimensionally.

Psychosocial factors had the highest weight in influencing walking intentions. However, it is important to consider that PRPI was independently associated with lower walking behaviour and was negatively correlated with walking attitudes, subjective norms, and perceived behavioural control. Hence, the effect of PRPI on walking intentions could occur indirectly by negatively impacting psychosocial factors. This finding is supported by previous transport-related studies suggesting risk perceptions can influence attitudes (Ma et al., 2010; Nguyen-Phuoc et al., 2020; Yao and Wu, 2012). Behaviour change practitioners should consider that focusing on psychosocial factors will likely increase walking intentions. However, measuring and recalibrating perceived risk is also important as perceived risk affects psychosocial factors, and it is independently associated with different forms of walking behaviour. These findings suggest that reducing perceived risk through positively charged wording of educational materials (Mikels, & Stuhlmacher, 2020; Steinhardt, 2020) might favour positive walking attitudes, social norms and perceived behavioural control.

One of the challenges of behaviour change is maintaining the interventions long enough to create habitual behaviours. Assisted-living facilities and continuing-care retirement communities are in a perfect position to implement sustained interventions that evaluate PRPI and incorporate risk recalibration into current physical activity interventions. In addition, these agencies are in a unique position to intervene the psychosocial context as older adults interact with a considerable number of peers in these facilities. Any behaviour change strategy to increase walking in older people should run in parallel with programs that evaluate the objective risk of falls (Rod et al., 2021b). In the case of the general population, subjective and objective fall risk evaluations could be implemented by organisations that promote walking groups (Hanson and Jones, 2015).

4.5. Emerging challenges for transportation equity and justice

The need for climate action and sustainability will likely result in policies such as car-lite areas that attract active commuters and reduce fuel-based mobility. Arguably, this will benefit vulnerable road users as they have a lower crash risk in such areas (Elvik & Goel, 2019). However, there can be unintended consequences from these policies as higher pedestrian densities might disproportionally increase older people objective and perceived risk of falls. Previous research has suggested that people avoid walking in areas with high densities, likely due to a higher risk of falls and trampling (Basu, et al., 2021b; Hughes, 2003; Schepers, et al., 2017). Our findings highlight the importance of estimating *"equitably optimal densities"* that protect the most vulnerable road users from objective risks that could harm them, and perceived risks that inequitably prevent them from engaging in active mobility and social participation (Rod, 2022). The consideration of *"equitably optimal densities"* also applies to the design of evacuation infrastructure for pedestrians during natural or man-made disasters. Possibly, pedestrians with a higher perceived risk of falls could refuse to evacuate unsafe areas due to the objective risk of falls and trampling during rapid crowd movements (Haghani, 2020; Jiang et al., 2019; Shi et al., 2016).

The present study sample is from Australia, a high-income country with high standards of infrastructure and a tradition of positive road safety outcomes (Green et al., 2022). Even with this high standard of infrastructure and road safety performance, PRPI can negatively influence walking behaviour directly or through associations with psychosocial factors. The net negative effect of PRPI on active mobility could be different in low- and middle-income countries.

4.6. Strengths, limitations and future research

The present study findings should be considered in light of some methodological limitations. Using the Kaiser criterion in EFA could cause over-factoring and subsequent little theoretical interpretability (Fabrigar et al., 1999). In this study, over-factoring could have helped capture the TRIRISK dimensions, which is supported by evidence from psychological and neuroscience research (Bechara and Damasio, 2005; Ferrer et al., 2016; Kahneman and Klein, 2009; Loewenstein et al., 2001; Reyna et al., 2015; Rivers et al., 2008; Slovic et al., 2007). The validity of our results is arguably limited to the studied sample from Australia. However, a recent review of the pedestrian route choice literature identified at least six publications providing evidence of perceived risk as a reason for avoiding walking (Basu et al, 2021b), in addition, Kummeneje and Rundmo, 2019 presented similar findings in Norway and Wijlhuizen et al., 2007 in the Netherlands. Other international transport and public health research also highlights the effect of perceived risk on psychosocial factors (Basu et al., 2022; Ma et al., 2010; Nguyen-Phuoc et al., 2020, 2021; Yao and Wu, 2012) and how these factors are important determinants of physical activity (Hagger et al, 2002; Hagger et al., 2018; Martin et al., 2007). We think it is reasonable to use this emerging body of evidence to inform policy and practice while further research is conducted.

An additional limitation relates to the lack of measurement of walking intensity. However, both walking frequency and duration are factors that contribute to physical activity sufficiency (King, et al., 2015) independently of intensity (Paluch et al., 2022). Future investigations should measure walking intensity. In addition, the present research has not focused on exploring other factors beyond demographics that could impact perceived risk. Therefore, future research should aim at studying how infrastructure (Basu et al., 2021b, 2022), air pollution (Cortes-Ramirez et al., 2021), chronic disease (Vaezipour et al., 2022), temporal transportation patterns such as pedestrian density (Helbing, Johansson, & Al-Abideen, 2007), the weather (Driscoll, et al., 2008; Saanen et al, 2007) and how different cultures (Alonso et al., 2021; Oviedo-Trespalacios et al., 2021) affect perceived risk across different groups of individuals, e.g., age, race, disability, etc. Especially relevant is the validation of the employed psychosocial constructs in non-western samples (Oviedo-Trespalacios, et al 2021). Future research should also consider not only balancing the sample in terms of age and gender but also gaining similar sample weights regarding the previous experience of pedestrian trauma to evaluate its impact on PRPI.

Despite these limitations, we performed a theoretically sound EFA of PRPI by measuring multiple theoretical dimensions. Furthermore, we employed two different types of regression analyses to understand a multidimensional outcome measure of walking behaviour. Previous research on fear of injury from falls is not specific to locations such as public roads and footpaths (Fletcher and Hirdes, 2004; Rantakokko et al., 2009). Similarly, activities of daily living such as walking (Murphy et al., 2002) or physical activity (walking and cycling) have been measured irrespective of the purpose and location where they occurred (Hornyak et al., 2013; Wijlhuizen et al., 2007). In the present research, we focused on public roads and footpaths. Nonetheless, private roads could also be an important barrier for walking among some communities.

5. Conclusion

In the present research, we demonstrated that pedestrians perceive risk of injury multi-dimensionally. By carefully considering these dimensions, public education messages can be tailored to different groups of the population. Ultimately, this can help to increase active mobility of older people and other disadvantaged groups. To sum up, behaviour change interventions aiming at increasing walking could use perceived risk to pedestrian injury PRPI and psychosocial factors combined to tackle different walking dimensions, such as walking intentions, walking frequency and duration.

Any change in the transportation systems entails the creation of winners and losers (Sunio, 2021). Without carefully considering the subjective risks associated with pedestrian injury, policies directed at transitioning to active mobility could erode some transportation justice progress by decreasing walking behaviour in vulnerable populations, such as older people and women. People use the transport system not only for travel; older adults, women, and children also use the public transport system to engage in physical activity, recreation and social participation (Banister, 2008; King et al., 2021). The road towards transport and environmental equity requires acknowledging that even well intended interventions could negatively impact vulnerable populations.

CRediT authorship contribution statement

J.E. Rod: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft. **Mark King:** Investigation, Methodology, Supervision, Validation, Funding acquisition, Writing – review & editing. **Oscar Oviedo-Trespalacios:** Investigation, Methodology, Supervision, Validation, Funding acquisition, Writing – review & editing.

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.

Data availability

Data will be made available on request.

Appendix A

EFA Full Rotated Matrix.

Appendix A. Sample Rotated Factor Matrix

Items	Factor				
	1	2	3	4	5
1- How likely is it that you will fall when walking in a public space in the future?	0.13	0.56	0.15	0.21	0.08
2- The way I look after my health means that my odds of falling when walking in a public space are	0.15	0.69	0.22	0.31	0.05
3- How worried are you about falling while walking in a public space in the future?	0.29	0.85	0.17	0.06	0.03
4- How fearful are you about falling while walking in a public space in the future?	0.31	0.83	0.27	0.07	0.00
5- How easy is it for you to imagine yourself falling while walking in a public space in the future?	0.32	0.61	0.17	0.10	0.13
6- My first reaction when I hear that someone has fallen while walking in a public space is "that could be me someday"	0.19	0.56	0.11	−0.01	0.53
7- How likely is it that you will get a severe injury from a fall when walking in a public space in a future?	0.08	0.63	0.17	0.43	0.18
8- The way I look after my health means that my odds of getting a severe injury from falling when walking in a public space are	0.13	0.69	0.24	0.40	0.13
9- How worried are you about getting a severe injury from falling while walking in a public space in the future?	0.31	0.81	0.27	0.10	0.13
10- How fearful are you about getting a severe injury from falling while walking in a public space in the future?	0.32	0.77	0.32	0.10	0.12
11- How easy is it for you to imagine yourself getting a severe injury from falling while walking in a public space in the future?	0.32	0.67	0.22	0.17	0.25
12- My first reaction when I hear someone had a severe injury from a fall while walking in a public space is "that could be me someday"	0.20	0.58	0.17	0.08	0.65
13- How likely is it that you will die from falling when walking in a public space in the future?	0.15	0.35	0.56	0.33	0.07
14- The way I look after my health means that my odds of dying from falling when walking in a public space are	0.19	0.41	0.56	0.45	0.09
15- How worried are you about dying from falling while walking in a public space in the future?	0.33	0.43	0.77	0.07	0.05
16- How fearful are you about dying from falling while walking in a public space in the future?	0.30	0.42	0.80	0.08	0.08
17- How easy is it for you to imagine yourself dying from falling while walking in a public space in the future?	0.34	0.31	0.64	0.13	0.17
18- My first reaction when I hear someone died from falling while walking in the public space is "that could be me someday"	0.31	0.29	0.52	0.11	0.53
19- How likely is it that you will get hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.53	0.24	0.16	0.37	0.06
20- The way I look after my health means that my odds of getting hit by any vehicle (motorised or human powered) in the public space are	0.48	0.28	0.30	0.46	0.02
21- How worried are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.82	0.29	0.19	0.09	0.04
22– How fearful are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.81	0.30	0.28	0.08	0.00
23– How easy is it for you to imagine yourself getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.76	0.14	0.20	0.11	0.13
My first reaction when I hear of someone that someone was hit by any vehicle (motorised or human powered) while walking in a public space is "that could be me 24- someday"	0.76	0.06	0.06	0.07	0.48
25- How likely is it that you will get a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.55	0.23	0.04	0.59	0.05
26- The way I look after my health means that my odds of getting a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.51	0.30	0.15	0.60	0.09
27- How worried are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.82	0.30	0.15	0.19	0.03
28- How fearful are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.82	0.34	0.18	0.18	0.02
29- How easy is it for you to imagine yourself getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.78	0.22	0.11	0.23	0.16
30- My first reaction when I hear someone had a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space is "that could be me someday"	0.74	0.13	0.07	0.17	0.50
31- How likely is it that you will die from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.56	0.22	0.17	0.55	0.05
32– The way I look after my health means that my odds of dying from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.52	0.23	0.20	0.64	0.04
33– How worried are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.79	0.26	0.22	0.20	0.05
34- How fearful are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.78	0.29	0.28	0.21	0.03
35- How easy is it for you to imagine yourself dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.76	0.20	0.27	0.26	0.12
36- My first reaction when I hear someone died from getting hit by any vehicle (motorised or human powered) while walking in the public space is "that could be me someday"	0.75	0.12	0.12	0.19	0.46

Appendix B

Age differences in PRPI.

Appendix Ba. EFA 60+ PRPI dimensions			Items	Factor loadings
Mechanism	Temporal	Processing		
				Factor 1 loadings
Vehicle collision	Event, severity & death	Aff	1- How worried are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.83
			2- How fearful are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.82
			3- How worried are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.81
			4- How fearful are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.80
			5- How fearful are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.80
			6- How worried are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.78
		Exp	7- How easy is it for you to imagine yourself dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.77
			8- How easy is it for you to imagine yourself getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.78
			9- How easy is it for you to imagine yourself getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.75
		Cog	10- How likely is it that you will get hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.50
				Factor 2 loadings
Fall	Event & severity	Aff	1- How worried are you about falling while walking in a public space in the future?	0.86
			2- How fearful are you about falling while walking in a public space in the future?	0.84
			3- How worried are you about getting a severe injury from falling while walking in a public space in the future?	0.79
			4- How fearful are you about getting a severe injury from falling while walking in a public space in the future?	0.78
		Exp	5- How easy is it for you to imagine yourself getting a severe injury from falling while walking in a public space in the future?	0.70
			6- How easy is it for you to imagine yourself falling while walking in a public space in the future?	0.70
		Cog	7- The way I look after my health means that my odds of getting a severe injury from falling when walking in a public space are	0.69
			8- The way I look after my health means that my odds of falling when walking in a public space are	0.68
			9- How likely is it that you will fall when walking in a public space in the future?	0.60
			10- How likely is it that you will get a severe injury from a fall when walking in a public space in a future?	0.51
				Factor 3 loadings
Fall	Death	Aff	1- How worried are you about dying from falling while walking in a public space in the future?	0.80
			2- How fearful are you about dying from falling while walking in a public space in the future?	0.78
		Cog	3- How likely is it that you will die from falling when walking in a public space in the future?	0.59
		Exp	4- How easy is it for you to imagine yourself dying from falling while walking in a public space in the future?	0.57
		Cog	5- The way I look after my health means that my odds of dying from falling when walking in a public space are	0.56
				Factor 4 loadings
Vehicle collision	Event, severity & death	Cog	1- The way I look after my health means that my odds of getting a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.63
			2- How likely is it that you will get a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.62
			3- The way I look after my health means that my odds of dying from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.62
			4- How likely is it that you will die from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.59
			5-The way I look after my health means that my odds of getting hit by any vehicle (motorised or human powered) in the public space are	0.53

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Appendix Ba. EFA 60+ PRPI dimensions			Items	Factor loadings
Mechanism	Temporal	Processing		
				Factor 5 loadings
Vehicle collision & fall	Event, severity & death	Exp	1- My first reaction when I hear someone had a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space is "that could be me someday"	0.64
			2- My first reaction when I hear someone died from falling while walking in the public space is "that could be me someday"	0.62
			3- My first reaction when I hear someone died from getting hit by any vehicle (motorised or human powered) while walking in the public space is "that could be me someday"	0.60
			4- My first reaction when I hear of someone that someone was hit by any vehicle (motorised or human powered) while walking in a public space is "that could be me someday"	0.60
			5- My first reaction when I hear someone had a severe injury from a fall while walking in a public space is "that could be me someday"	0.67
			6- My first reaction when I hear that someone has fallen while walking in a public space is "that could be me someday"	0.57

Appendix Bb. EFA < 60 PRPI dimensions			Items	Factor loadings
Mechanism	Temporal	Processing		
				Factor 1 loadings
Vehicle collision	Event, severity & death	Exp	1- My first reaction when I hear of someone that someone was hit by any vehicle (motorised or human powered) while walking in a public space is "that could be me someday"	0.84
			2- My first reaction when I hear someone died from getting hit by any vehicle (motorised or human powered) while walking in the public space is "that could be me someday"	0.81
			3- My first reaction when I hear someone had a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space is "that could be me someday"	0.81
		Aff	4- How worried are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.77
			5- How worried are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.77
			6- How fearful are you about getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.75
		Exp	7- How easy is it for you to imagine yourself getting a severe injury from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.75
		Aff	8- How worried are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.75
			9- How fearful are you about getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.75
			10- How fearful are you about dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.71
		Exp	11 How easy is it for you to imagine yourself dying from getting hit by any vehicle (motorised or human powered) while walking in a public space in the future?	0.68
			12- How easy is it for you to imagine yourself getting hit by any vehicle (motorised or human powered) while walking in the public space in the future?	0.68
				Factor 2 loadings
Fall	Event & severity	Aff	1- How worried are you about getting a severe injury from falling while walking in a public space in the future?	0.81
			2- How fearful are you about falling while walking in a public space in the future?	0.80
			3- How worried are you about falling while walking in a public space in the future?	0.80
			4- How fearful are you about getting a severe injury from falling while walking in a public space in the future?	0.75
		Cog	5- The way I look after my health means that my odds of falling when walking in a public space are	0.69
			6- The way I look after my health means that my odds of getting a severe injury from falling when walking in a public space are	0.67
			7- How likely is it that you will get a severe injury from a fall when walking in a public space in a future?	0.64
		Exp	8- My first reaction when I hear someone had a severe injury from a fall while walking in a public space is "that could be me someday"	0.63
				0.56

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(*continued*)

Appendix Bb. EFA < 60 PRPI dimensions			Items	Factor loadings
Mechanism	Temporal	Processing		
			9- My first reaction when I hear that someone has fallen while walking in a public space is “that could be me someday”	
			10- How easy is it for you to imagine yourself getting a severe injury from falling while walking in a public space in the future?	0.59
				Factor 3 loadings
Vehicle collision	Event, severity & death	Cog	1- The way I look after my health means that my odds of dying from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.71
			2- The way I look after my health means that my odds of getting a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space are	0.64
			3- How likely is it that you will get a severe injury from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.64
			4- How likely is it that you will die from getting hit by any vehicle (motorised or human powered) when walking in a public space in the future?	0.58
				Factor 4 loadings
Fall	Death	Aff	1- How worried are you about dying from falling while walking in a public space in the future?	0.71
			2- How fearful are you about dying from falling while walking in a public space in the future?	0.78
		Exp	3- How easy is it for you to imagine yourself dying from falling while walking in a public space in the future?	0.73
			4- My first reaction when I hear someone died from falling while walking in the public space is “that could be me someday”	0.58
		Cog	5- How likely is it that you will die from falling when walking in a public space in the future?	0.53
			6- The way I look after my health means that my odds of dying from falling when walking in a public space are	0.53

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