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Development and validation of a novel instrument to measure pedestrians' smartphone use: The Smombie Scale

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ABSTRACT

This study aimed to develop and verify the psychometric properties of the Smombie Scale, a new instrument to measure pedestrians' smartphone use. The instrument development process comprised two phases: instrument development and psychometric evaluation. Data were collected from September to October 2020 using the "Invite" panel aggregator. The link to the online questionnaire was sent via smartphone text message to 400 young adults aged 18–39 years and yielded 398 valid responses. We randomly selected 200 participants for the exploratory factor analysis; the remaining 198 participants were selected for confirmatory factor analysis. The Smombie Scale comprises 15 items and four factors: (a) perceived risk; (b) stationary smartphone use, always on the smartphone; (c) pending instant message; and (d) smartphone dependency. Model fit was statistically significant ($\chi^2/df = 2.20$). The analyses indicated a sufficient goodness-of-fit index of 0.93, a comparative goodness-of-fit index of 0.95, a normed fit index and Tucker–Lewis index of 0.91, and a root mean square error of approximation of 0.07. The scale was also found to have sufficient reliability (Cronbach's alpha = 0.83). The newly developed Smombie Scale is valid and reliable in measuring pedestrians' smartphone use among young adults. The Smombie Scale shows evidence of being suitable for evaluating smartphone-distracted pedestrians. Its results can provide data for drafting educational programs to prevent smombie behaviors and deal with potential risks.

1. Introduction

1.1. Background

The smartphone ownership rate is increasing worldwide. Globally, it is highest in South Korea (97%), and about 95% of South Korean adolescents own a smartphone (National Information Society Agency, 2019). With the increased prevalence of smartphones, multitasking on the smartphone while walking has risen, representing a potential safety risk for pedestrians and others on the road (Osborne et al., 2020).

In Korea, 99.2% of the population reports using smartphones while walking, and the rate of smartphone use while crossing the street has increased from 13.2% in 2017 to 14.9% in 2019 (Korean Ministry of Land, 2019). Similarly, research in Melbourne, Australia indicated that 20% of people used smartphones while crossing the street (Horberry et al., 2019). While pedestrians use smartphones to

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accomplish daily tasks, one study of 122 people indicated that pedestrians primarily used their smartphones for non-essential tasks like social media, music, reading, and games. Furthermore, individuals aged 18–30 years exhibited more smartphone-distracted behaviors than members of other age groups while on the sidewalk (Lennon et al., 2017).

Fernández et al. (2020) categorized people's smartphone usage when crossing roads into five types based on visual observation and showed the diversity of potential risk. The first type is invisible smartphone usage, as the phones are kept inside handbags, backpacks, or pockets, indicating pedestrians concentrate on walking. The second type includes making a phone call while crossing crosswalks. When holding a phone against the ear with one hand, individuals have visual space to look around, but their visual and auditory attention concentration levels are significantly distracted. The third type includes wearing headphones or earphones, where auditory stimuli are blocked, and they face difficulty picking up traffic signals, car's klaxon noises, and other pedestrians' actions. The fourth type includes individuals holding smartphones in their hands so that whenever it rings, they are immediately distracted. The fifth type includes "smombies," those looking at or using both hands to manipulate smartphones. In this study, the terms "smartphone-distracted pedestrian" and "smombie" are used interchangeably to refer to individuals who focus on their smartphone or are distracted from their surroundings by phone calls or use of headphones.

The word smombies (or smartphone zombies) refers to individuals who focus on their smartphones while walking (Duke & Montag, 2017), and was coined in Germany in 2015. The concept became renowned in 2016 with the rise of pedestrian crashes associated with Pokémon Go players who were playing games on smartphones while walking around (Duke & Montag, 2017). Smombies tend to exhibit behaviors such as walking slowly, taking shorter steps, and paying less attention to their surroundings, which can lead to traffic safety-related crashes. Additionally, their eyes are fixed on the smartphone screen and their faces are angled downwards; this can lead to the increased risk of traffic injuries (Brodsky & Slor, 2013; Byington & Schwebel, 2013; Nemme & White, 2010; Redelmeier & Tibshirani, 1997; Schwebel et al., 2012).

There is growing concern about the safety of road users who are distracted by their smartphones (Osborne et al., 2020). Studies from the USA have demonstrated that 11,101 distracted-walking injuries occurring between 2000 and 2011 were associated with smartphone use, showing a significant annual increase in distraction-induced injury rates (Smith et al., 2013). In South Korea, pedestrians comprised 71.4% of the total number of deaths due to traffic injuries, indicating that they are the population most vulnerable to traffic injuries. Moreover, failure to respond appropriately or promptly due to smartphone use can also lead to physical injury or harm to others (Korean Ministry of Land, 2019).

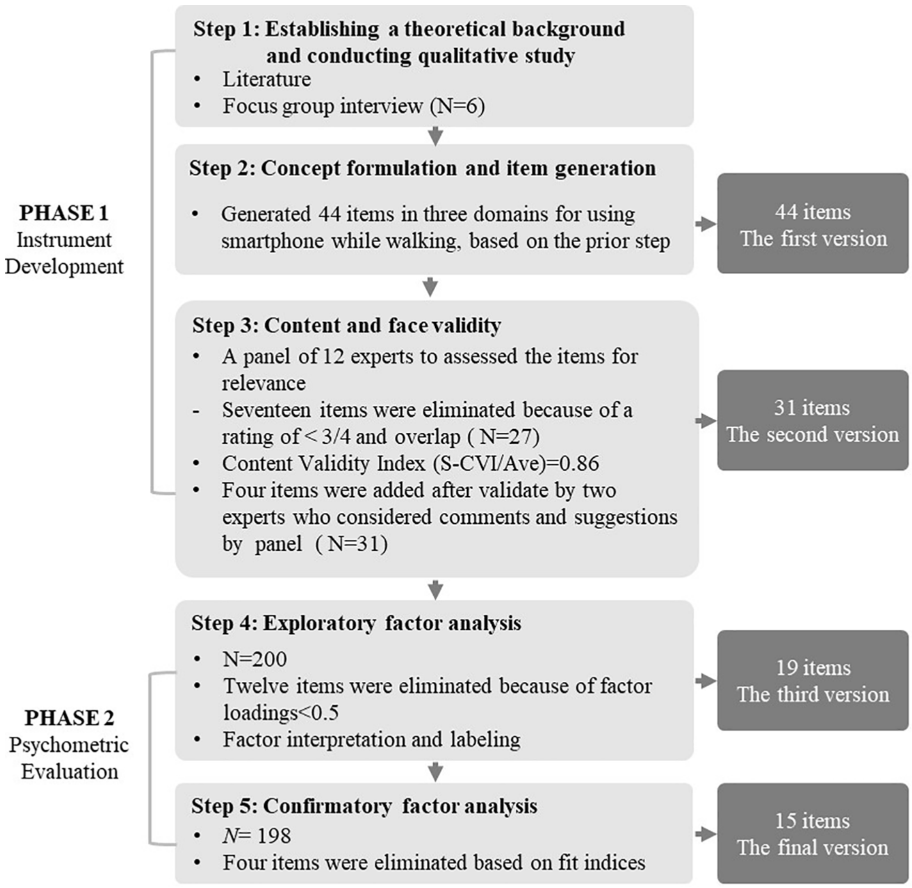

Fig. 1. Process of developing and validating the Smombie Scale.

Recent evidence suggests smartphone distraction among pedestrians decreases their concentration and increases the risk of traffic crashes (Horberry et al., 2019). Moreover, pedestrians' audio-visual response capabilities are significantly slowed while using smartphones. In Japan, an experiment with 24 university students revealed pedestrians using cell phones, especially those playing games on smartphones, displayed significantly lower visual and auditory response rates, resulting in a higher risk of crashes (Haga et al., 2015). Smombie behaviors hinder the stability of walking because visual information from one's surroundings is not properly received (Lim et al., 2017).

The studies presented thus far provide evidence that the behavior, gait, and physical and cognitive changes of smartphone-distracted pedestrians ("smombies"), increase the risk of traffic injury. However, these approaches have failed to measure smombie-typical risky behavior, intended behavior, perceived risk, or consequences of smombie behavior that could be used to facilitate appropriate smartphone usage and ensure pedestrians' safety. This study designed, developed, and validated a self-report scale for evaluating pedestrians' smartphone use by capturing and characterizing behavior, attitude, and outcomes, namely the consequences of such behavior.

The findings of this study could form the basis for the development and implementation of interventions to prevent smartphone use on the road and cope with risks. It is hoped that this research will contribute to raising healthcare providers' awareness of the risk smartphone use poses to pedestrians.

2. Materials and methods

2.1. Aim

The study aimed to develop and psychometrically test a new instrument, the Smombie Scale, to measure pedestrians' smartphone use.

2.2. Methodology

2.2.1. Study design, sample, and setting

The instrument development process spanned two phases covering five steps. Phase I of instrument development: (a) establishing a theoretical background and focus group interviews from which domains and items could be derived; (b) concept formulation and item generation; (c) testing face and content validity. Phase II of psychometric evaluation: (d) examining structural validity; and (e) model fit analysis (Fig. 1).

2.2.2. Phase I: Instrument development

2.2.2.1. Step 1: Establishing a theoretical background. In the first step of the instrument development process, we examined the literature thoroughly and developed a framework that included the concepts. To refine the framework, focus group interviews with six young adults (four women and two men; aged 18–39 years) were conducted in September 2020 by one trained interviewer using semi-structured questionnaires. These six participants were interns at the research institute where the author of this study is employed.

2.2.2.2. Step 2: Concept formulation and item generation. In step 2, we formulated the concept of pedestrians' smartphone use, and items were generated based on the data from the previous step.

2.2.2.3. Content and face validity. Content and face validities of the instrument were conducted based on the assessment of a panel of 12 experts and a pilot test. The experts were asked to rate each item for relevance (1 = *not relevant*, 2 = *somewhat relevant*, 3 = *quite relevant*, and 4 = *very relevant*). They could provide comments and suggestions on whether the items expressed the potential characteristics of smombies. The cut-off for an acceptable content validity index (CVI) value was set at 0.80, according to previous evidence (Davis, 1992).

2.2.3. Phase II: Psychometric evaluation

2.2.3.1. Participants. The target population was young-adult smartphone users, aged 18–39 years, living in South Korea. The sample was limited to this age group because use of smartphones is more prevalent among this age group than among others. To reach young adults, we paid for advertising using the "Invite" panel aggregator over 10 days from September 24 to October 3, 2020. Participants were targeted based on profiling attributes included in online panels and guarantee detailed and accurate data from panel respondents. The sample size was determined by a previous study that indicated that 200 participants are an appropriate number for factor analysis when there are less than 40 items (Kang, 2013). We collected a sufficient number of participants (400) in a single run for both exploratory factor analysis (EFA) and confirmatory factor analysis (CFA)(Orcan, 2018).

2.2.3.2. Data collection. Participants recruited via the panel received a smartphone text message from "Invite" inviting them to participate in the study by clicking on a link to a screening questionnaire to assess eligibility. We used the age profiling attributes previously provided by users to target participants for the survey. Of the 398 valid questionnaires, we randomly selected data from 200 participants to construct the instrument and conduct EFA; data from the remaining 198 participants were used to validate the instrument and conduct CFA. Randomization was performed using a computerized random-number generator provided by STATA 16.0.

2.3. Preliminary instrument

The preliminary smartphone-distracted pedestrian (Smombie) scale included 31 items: 12 items on behavior, nine on attitude, and 10 on the consequences of smombie behavior. Items were scored on a 5-point Likert scale ranging from 0 (*strongly disagree*) to 4 (*strongly agree*). Higher scores indicate severe smartphone road use. This instrument was originally developed in the Korean language, was translated into English, and then back-translated into Korean.

2.4. Ethical considerations

The study was carried out following the Declaration of Helsinki. The study design was approved by the Institutional Review Board (IRB) in October 2020 (IRB number: 7001988-202010-HR-1008-02) after full-board review.

2.5. Data analysis

Data were analyzed using SPSS (version 26.0) and M−plus 8.3. Descriptive statistics were conducted for individual item scores and demographic variables, such as age and sex. The Cronbach's alpha coefficient was used to examine the internal consistency of the overall scale and subscales.

To reduce the number of items and refine the scale, we carried out an EFA with the principal component and varimax rotation based on the following criteria: (a) each factor should explain at least 5% of the total variance; (b) the factor loading of the items should be at least 0.5; (c) an item should not load on two factors with more than 0.40; (d) the items contained in each factor should have adequate internal consistency ($\alpha > 0.70$).

To analyze the fit of the factor structure to the resulting model in the EFA, we performed CFA. Following the recommendations for this analysis (Hu & Bentler, 1999; Tabachnick & Fidell, 2007), we employed various fit indices: root mean square error of approximation (RMSEA), comparative goodness-of-fit index (CFI), and normed fit index (NFI). Moreover, to assess the goodness of fit, we also took into account the goodness-of-fit index (GFI) and the Tucker–Lewis index (TLI). Values of NFI, GFI, and TLI equal to or higher than 0.90 and CFI equal to or higher than 0.93 reflected a good fit. RMSEA values lower than 0.05 reflected an excellent fit, whereas values between 0.05 and 0.08 reflected an adequate fit. Although the chi-square statistic is very sensitive to sample size and overrates the non-fit of a model (Bollen, 1989), this metric was used, and instead, more attention was paid to the aforementioned indices. To assess the reliability of the resulting scale, we assessed internal consistency with Cronbach's alpha. The analyses were carried out for the global scale and each subscale obtained in the factor solution.

3. Results

3.1. Participants

In total, 398 young adults completed the instrument, of which 59.0% were females. Participants were between 18 and 39 years and mean age was 30.6 years ($SD = 4.9$). We collected data in one sitting from 400 participants, out of whom two individuals were excluded because of insufficient responses. We then randomized the 398 participants into two samples, one for EFA and one for CFA. There was no significant difference in sex and age between the two samples (Table 1).

3.2. Theoretical background

The theoretical background was based on the existing literature about smartphone-distracted pedestrians' behavior patterns, attitude, and the physical, psychological, and cognitive consequences of smombie behavior as well as safety risk (Byington & Schwebel, 2013; Fernández et al., 2020; Haga et al., 2015; Neider et al., 2010; Korean Ministry of the Interior and Safety, 2017). The themes were extracted from in-depth interviews and were divided into 9 codes. These codes were further analyzed and categorized by two researchers into three domains.

Table 1
Participant characteristics by age and sex.

Characteristics	Total (*N* = 398)		Sample 1 (*N* = 200)		Sample 2 (*N* = 198)	
	N/mean	%/*SD*	N/mean	%/*SD*	N/mean	%/*SD*
Age	30.6	4.9	30.7	4.9	30.4	5.0
Sex						
Male	163	41.0	83	41.5	80	40.4
Female	235	59.0	117	58.5	118	59.6

3.3. Concept formulation and item generation

The concept of pedestrians' smartphone use was confirmed to have three domains: behavior, attitude, and consequences of smombie behavior. Behavior included following road safety rules and active or passive use of one's smartphone while walking, with sending text messages or looking up information while walking being defined as active behavior, whereas listening to music and watching videos was considered passive behavior. Attitude included the pedestrian's attitude toward road use of smartphones and their degree of smartphone dependency. Consequences of smombie behavior included decreased situational awareness, risk of traffic crashes, physical changes, and changes in gait (Fig. 2). In the initial draft, 44 statements (the first version) related to the characteristics of smartphone-distracted pedestrians were generated across the three domains (Fig. 1).

3.4. Content and face validity

Content validity was assessed by an expert panel that included 12 members: seven university professors with expertise in instrument development, three doctoral candidates, one digital addiction specialist, and one practicing nurse. In the first round, 17 items were eliminated for various reasons, especially statements with ratings of 1 = not relevant, 2 = somewhat relevant, or 3 = quite relevant (versus those rated as 4 = very relevant) and those that received comments regarding overlapping content; thus, 27 items remained. The questionnaire was found to have good estimated content validity and internal consistency (S-CVI/AVE = 0.86). Finally, two authors reviewed the remaining items and identified if there were sufficient remaining items to measure each concept of behavior, motivation, and outcome of smartphone-distracted pedestrians, namely the constructs the instrument was designed to measure. We added four items according to the suggestions of the panel, resulting in a total of 31 preliminary items.

To evaluate face validity, three young adults assessed the 31 items on the questionnaire in terms of ease of response, comprehension, reading level, and precision. The time required for completion was also assessed. The pilot study results revealed that the questionnaire had adequate structure and an acceptable number of items. Response time for each questionnaire was 5–7 min.

3.5. Exploratory factor analysis—factor interpretation and labeling

Using the constructed sample, we performed a factor analysis of the 31 items from the three domains: behavior, attitude, and consequences of smombie behavior. This led to the creation of a scale with four factors comprising 19 items, which explained 64.07% of the overall observed variance. The Kaiser-Meyer-Oklin (KMO) sample adequacy measurement value had high adequacy (KMO = 0.856) (Kaiser, 1974). Table 2 shows all values obtained from the EFA. Correlations between the factors were in the interval of 0.47–0.68, with the highest between firmness and flexibility. All of the path coefficients were significant at the $p < 0.01$ level.

The first factor, "perceived risk," included nine items derived primarily from consequences of smombie behavior, mainly regarding delayed responses in vision and hearing, pain, missed pedestrian-directed signage, and change of gait; it explained 27.12% of the variance, with an estimated alpha of 0.84. The second factor, "stationary smartphone use, always on the smartphone," included four items derived from behavioral measurements of smombies (i.e., while waiting for the bus, subway, crosswalk, and walking outside) and explained 13.99% of the variance, with an estimated alpha of 0.82. The third factor, "pending instant message," included three items derived from the attitude measurements of smombies and actual behavior, namely habits of responding to instant messages

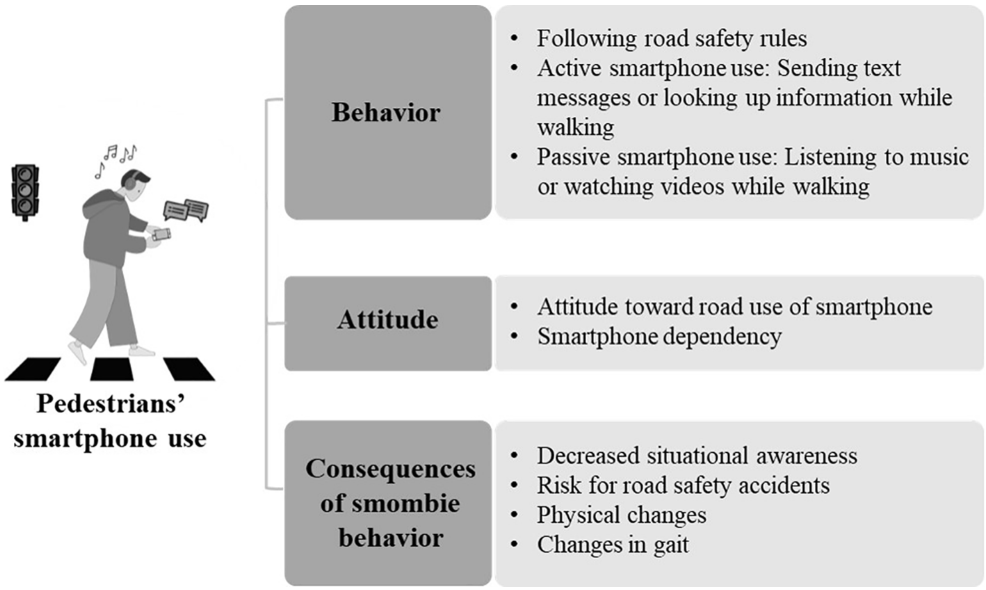

Fig. 2. The conceptualization of pedestrians' smartphone use.

Table 2
The EFA factor loading results for four-factor solution ($N = 200$).

Item No.	Statement	Eigen value	Factor loading	Cronbach'sα	Variance explained (%)
Factor 1: Perceived risk		5.122		0.87	27.12
(C29)	When using my smartphone while walking outside (sidewalk, street), I have had, or almost had a traffic crash.		0.848		
(C25)	When using my smartphone while walking outside (sidewalk, street), I have been unable to hear a bicycle or car horn.		0.840		
(C26)	When using my smartphone while walking outside (sidewalk, street), I have bumped into another person.		0.809		
(C27)	When using my smartphone, I have missed the crosswalk signal.		0.780		
(C28)	When using my smartphone, I have missed the bus or subway.		0.780		
(C24)	When using my smartphone while walking outside (sidewalk, street), I have been unable to hear someone speaking to me.		0.677		
*(C12)	When I am walking outside (sidewalk, street), I walk slowly because I am using my smartphone.		0.612		
*(C13)	When I am walking outside (sidewalk, street), I stop using my smartphone.		0.612		
*(B16)	When I am walking outside (sidewalk, street), I play games on my smartphone.		0.563		
Factor 2: Stationary smartphone use		2.659		0.83	13.99
(B21)	I use my smartphone while waiting for the bus.		0.867		
(B22)	I use my smartphone while waiting for the subway.		0.848		
(B23)	I use the smartphone while waiting for the crosswalk signal to change.		0.796		
*(B20)	I walk while looking at my smartphone when I am outside (sidewalk, street).		0.598		
Factor 3: Pending instant message		2.271		0.77	11.95
(A5)	When I am walking outside (sidewalk, street), I feel the need to respond to instant messages or texts immediately.		0.824		
(B14)	When I am walking outside (sidewalk, street), I respond to instant messages or texts immediately.		0.789		
(A6)	I feel at ease when I respond to texts immediately.		0.774		
Factor 4: Smartphone dependency		2.092		0.77	11.0
(A8)	I feel an urge to use my smartphone.		0.807		
(A9)	I find it difficult to limit the amount of time I spend on my smartphone.		0.806		
(A7)	I find it difficult to focus on other tasks when my smartphone is on my hands.		0.672		
				overall variance	64.07

EFA, exploratory factor analysis. Kaiser-Meyer-Oklin = 0.856, Bartlett's test of sphericity $\chi^2 = 1856.998$, p=<.001, EFA with principal component and varimax rotation.
B, behavior; M, motivation; C, consequences of smombie behaviour.
*C12, C13, C16, and B20 were removed after the confirmatory factor analysis (CFA; Table 5).

regardless of situation or place; it explained 11.59% of the variance, with an estimated alpha of 0.77. The fourth factor, "smartphone dependency," included three items derived from the motivation measurements of smombies (i.e., feel an urge to use their smartphone, difficulty in limiting smartphone usage, and being distracted easily) and explained 11.01% of the variance, with an estimated alpha of 0.76. Correlations between the factors were significant (Table 3).

Table 3
Correlations between factors according to the EFA results.

	1	2	3	4
1. Perceived risk	1.000			
2. Stationary smartphone use	0.136	1.000		
3. Pending instant message	0.302**	0.262**	1.000	
4. Smartphone dependency	0.346**	0.377**	0.402**	1.000

EFA, exploratory factor analysis.
*$p < .05$; **$p < .01$ (two-tailed).

3.6. Confirmatory factor analysis–model fit analysis

The EFA revealed that the Smombie Scale should include four factors and 19 items. Subsequently, we used the CFA to validate the fit of the factor model. To ensure construct validity, four items (items 12, 13, and 16 from the perceived risk factor, and item 20 from the stationary smartphone use factor) with a factor loading value of less than 0.5 were removed so that the average variance extracted (AVE) for use in the discriminant validity analysis between latent factors was ≥0.5 (Fornell & Larcker, 1981). Therefore, the final version of the Smombie Scale comprised 15 items. The estimated Cronbach's alpha for the entire instrument was 0.829 (Table 4).

The model fit of the final version was better than that of the version with 19 items (Table 5). The relative chi-square was significant ($\chi^2/df = 2.20$). The analyses indicated a GFI of 0.93, a CFI of 0.95, an NFI and TLI of 0.91, and lastly, an RMSEA of 0.078. Accounting for the reference criteria, we concluded that the model presents a good fit. Correlations between the factors were between 0.44 and 0.54, with the highest between firmness and flexibility (Supplementary Table 1). The final version of the scale is presented in Supplementary Table 2.

4. Discussion

The Smombie Scale is a diagnostic tool developed for measuring smartphone use while walking. It consists of four factors and 15 items. To increase the estimated validity of the tool's contents during the development process, we had it verified by experts and conducted a focus group interview to gather insight from study participants. The tool's estimated compositional feasibility was also verified through EFA. Based on the 19 items of four factors derived from the EFA, CFA was performed with new participants to obtain cross-validity. The research team eliminated four items that tested less than 0.5 in factor loading during the CFA, and the remaining 15 items were deemed useful for the scale (Hair et al., 2010).

Measurement tools for evaluating human behavioral characteristics should have reliable and valid metric properties, in addition to being valid in terms of external compliance (Kim, 1999). The Smombie Scale tested for high internal consistency and compositional feasibility, providing evidence for its reliability as a measurement tool.

Factor 1, "perceived risk," consists of six items of smartphone usage characteristics while walking, including sensory dullness and physical risk. Among the three attributes used as a framework for this study, sensory dullness and physical risk were integrated into one factor, while physical consequences such as muscle pain or neck stiffness and gait change were excluded. Key factors, which include slowing of visual and auditory response rates (Haga et al., 2015; Lim et al., 2017) and increased risk of traffic crashes (Brodsky & Slor, 2013; Nemme & White, 2010; Redelmeier & Tibshirani, 1997; Schwebel et al., 2012; Korean Road Traffic Authority, 2019), were reflected in the results of this study. Therefore, this study provided a rationale for the need to consider safety risks when exploring the characteristics of smartphone-distracted pedestrians.

Factor 2, "stationary smartphone use," combined three items that inquired about smartphone use while waiting at a bus stop, waiting for a subway, and waiting for a walk signal at a crosswalk. This refers to the characteristics of smartphone use when an individual is stationary but may be required to walk on short notice. Social networking services are generally used to relieve boredom or loneliness, and because they tend to promote addiction by "hooking" users through a constant release of dopamine, they make it difficult for people to take their eyes off their smartphones, even if their buses or trains arrive or when the walk signal turns green (Bandaru et al., 2020). Boredom from waiting can lead to frequent or excessive smartphone use (Elhai et al., 2018), which can jeopardize pedestrians' safety. Therefore, when measuring smartphone use characteristics while walking, it is necessary to include stationary and transportation use as a factor.

Factor 3, "pending instant message," combines one behavior item—immediate response to instant messages or texts while walking—with two attitude items on feeling the need to check one's phone when receiving a message. Such difficulty disregarding one's

Table 4
The CFA results ($N = 198$)

Factors	Items No.	B	SE	t	p	CR	AVE	Cronbach's α
Perceived risk	24	0.543	0.055	9.837	<0.000	0.875	0.544	0.89
	25	0.696	0.042	16.662	<0.000			
	26	0.681	0.045	15.083	<0.000			
	27	0.867	0.026	33.229	<0.000			
	28	0.822	0.033	24.833	<0.000			
	29	0.772	0.036	21.33	<0.000			
Stationary smartphone use	21	0.971	0.003	333.355	<0.000	0.879	0.710	0.84
	22	0.807	0.027	30.14	<0.000			
	23	0.732	0.035	20.96	<0.000			
Pending instant message	5	0.786	0.047	16.852	<0.000	0.767	0.525	0.77
	6	0.743	0.048	15.423	<0.000			
	14	0.636	0.054	11.71	<0.000			
Smartphone dependency	7	0.757	0.06	12.637	<0.000	0.771	0.53	0.77
	8	0.680	0.06	11.376	<0.000			
	9	0.744	0.057	13.162	<0.000			

CFA, confirmatory factor analysis; CR, construct reliability; AVE, average variance extracted.
Removed items: No. 12, 13, and 16 from factor of perceived risk, and No. 20 from factor of stationary smartphone use.

Table 5
Summary of the model fit indices for all CFA models ($N = 198$).

Model	χ^2	*df*	CFI	GFI	TLI	RMSEA
Null model (19 items)	608.884	146	0.862	0.846	0.839	0.090
Modified model (15 items)	288.983	84	0.930	0.905	0.910	0.078

Note: Null model = The original 4-factor model; Modified model = Four items were deleted from the original model; χ^2 = Chi-square test (i.e., minimum fit function).
CFA, confirmatory factor analysis; CFI, comparative fit index; GFI, goodness-of-fit index; TLI, Tucker–Lewis index; RMSEA, root mean square error of approximation.

smartphone notifications even while on the road has been recently coined "nomophobia" (Enock et al., 2014). Nomophobia is common in people who are more prone to anxiety, thus experiencing a sort of nervousness that creates the need to fill a void. Because such individuals are constantly concerned with their smartphone notifications, they are almost always distressed and tend to be more easily susceptible to panic attacks and social anxiety (Enock et al., 2014). Similarly, recent evidence suggests that fear of missing out is one of the main reasons for social media addiction (Bandaru et al., 2020).

Factor 4, "smartphone dependency," borrows from the conceptual framework on smartphone dependency aforementioned in this study (National Information Society Agency, 2019) and combines two items on interference with daily life and tolerance with one item on impulsive desire. Characteristics attributed to smartphone use while walking include control, concentration, and impulse.

Sixteen of the 31 preliminary items were eliminated, most of which were questions about pedestrians' smartphone behavior (e.g., When I am walking outside [sidewalk, street], I play games/listen to music/text or look up information on my smartphone) or road safety behavior (e.g., I check my surroundings when I hear a car or bicycle horn; When I am crossing the road, I check both ways before crossing). Participants leaned more toward items that assessed their attitude toward smartphone use while walking and their perception of potential risks than their behaviors. Therefore, the measurement tool derived from the results of this study can be used to describe individuals' perception of risk when using their smartphones while walking.

This is the first study to develop identification tools for early evaluation of smartphone-distracted pedestrians, and its results can be used as foundational data for drafting educational programs on how to prevent smombie behaviors and address potential risks. Because it is based on a conceptual framework derived from the unique characteristics and behavioral patterns found in Korean culture, this tool may be very useful owing to its high reliability and validity. Future research should further test the scale's reliability and validity in diverse participants regarding age to reveal its strengths and weaknesses and the possible need for additional refinement.

The findings from this study make several contributions to the current literature. First, this study uses a complex, multidisciplinary approach to analyze and integrate the characteristics of smartphone-distracted pedestrians. A measurement tool aimed toward identifying smombies among young adults was developed, providing a strong foundation for further research on this subject. Second, the Smombie Scale is a reliable self-report measure. Self-reported testing has the advantages of being practical, efficient, and convenient. Because it is simple and relatively intuitive, it can be used for diagnostic purposes to understand an individual's current state. The 15 items on the Smombie Scale were rated on a five-point scale, and the estimated time required to complete the questionnaire is approximately three minutes; therefore, we expect it to be a simple and accessible measurement tool.

4.1. Limitations

The current study has several limitations. Data were collected only from young adults in South Korea, and the analyzed responses may have differed if children or older adults had answered the questionnaire. Therefore, the Smombie Scale developed in this study cannot be generalized to different populations and should be applied to only Korean young adults. Additionally, participants were recruited by convenience sampling from online respondent pools. Pooled volunteers from the "Invite" panel aggregator were highly motivated toward online surveys and might not be representative of young adults in all regards. Therefore, the results could not be generalized to young adults.

5. Conclusion

The newly developed Smombie Scale is estimated to be valid and reliable in measuring pedestrian smartphone use among young adults. This scale can help evaluate problematic smartphone use by road users and its results can be used to raise awareness about the risk of distraction-induced injuries and address those risks, as well as provide a strong foundation for further research on this subject.

CRediT authorship contribution statement

Sunhee Park: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing - review & editing. **Beomsoo Kim:** Conceptualization, Validation, 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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.trf.2021.09.004.

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