Right-looking habit and maladaptation of pedestrians in areas with unfamiliar driving rules

Yun Ye[a], S.C. Wong[a], Fanyu Meng[b,c], Pengpeng Xu[a]
[a] Department of Civil Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China
[b] Academy for Advanced Interdisciplinary Studies, Southern University of Science and Technology, Shenzhen, China
[c] Department of Statistics and Data Science, Southern University of Science and Technology, Shenzhen, China

ABSTRACT

Both left-driving (LD) and right-driving (RD) rules are used around the world. When traveling to places with different driving rules, pedestrians are likely to make mistakes. To investigate the frequency of such mistakes, a case study was conducted with pedestrians in Hong Kong, which follows LD rules, i.e., traffic drives on the left. The study aimed to probe the effects of hometown driving rules and length of stay on pedestrians' right-looking habit and maladaptation to the Hong Kong LD system and determine the mediating effect of the right-looking habit. A face-to-face survey was conducted with 581 respondents at seven locations in Hong Kong. A structural equation model was applied to determine the relationship among hometown driving rules, length of stay, right-looking habit, and maladaptation. The model exhibited good fitness ($\chi^2/degrees\ of\ freedom = 2.154$; $comparative\ fit\ index = 0.989$; $Tucker-Lewis\ Index = 0.980$; and $root\ mean\ square\ error\ of\ approximation = 0.045$). The results revealed that hometown driving rules and length of stay had positive effects on the right-looking habit, and hometown driving rules had a direct negative effect on maladaptation. The right-looking habit partially mediated the effect of hometown driving rules and fully mediated the effect of length of stay on maladaptation to the Hong Kong LD system. It was found that when foreign pedestrians were in areas with unfamiliar driving rules, they tended to practice their hometown looking habits, especially foreign pedestrians who had stayed only for a short time; this behavior differed significantly from that of local pedestrians, and it led to more severe maladaptation. The findings of this study provide empirical evidence of pedestrians' looking habits and maladaptation in areas with unfamiliar driving systems and have significant implications for improving the safety of foreign pedestrians.

Key words: Looking habit, maladaptation, driving rules, questionnaire survey, structural equation modeling

1. Introduction

With the accelerated progress of globalization in the modern era, interconnectivity between different regions is increasing economically, politically, and socially. Increasingly, people are traveling internationally for both business and leisure. According to the United Nations World Tourism Organization (UNWTO), there were approximately 1.4 billion international tourists in 2018, a 6% increase from 2017 (UNWTO, 2018). With such a large volume of international travel, the traffic-related risks faced by foreign visitors have become a major concern. Traffic crashes are the leading cause of injury-related deaths among international visitors, and such visitors are more likely to be involved in traffic crashes than are local residents (Mohammed et al., 2019; Castillo-Manzano et al., 2020). Therefore, the important risk factors for traffic crashes involving international visitors are worth investigating.

One of the common characteristics is that international visitors may arrive from countries with different driving rules, such as a person traveling from a country with right-driving (RD) rules to a country with left-driving (LD) rules. Such persons may find themselves in an unfamiliar driving system when walking in the streets. A recent experimental study conducted in a virtual-reality (VR) environment indicated that foreign travelers might make mistakes in judging the traffic direction and, therefore, be exposed to higher risks of injury or death. This may be caused by the differences between their habitual crossing behaviors and those of the local residents given that people exposed to different driving systems show significant differences in their looking behaviors when crossing roads (Ye et al., 2020).

Although the abovementioned experimental study shed light on the role of habitual behavior in pedestrians' street-crossing decisions in areas with unfamiliar driving rules, it was conducted in a virtual reality (VR) environment. The responses of pedestrians in VR environments must be validated against those in real-world environments. A recent study comparing pedestrian behavior in virtual and real environments reported no significant differences in crossing intention, distance estimation, and risk perception, but significant differences were observed in speed estimation and presence measurement (Bhagavathula et al., 2020). Therefore, it would be useful to further investigate pedestrians' habitual behaviors and maladaptation in a real-world context, as these could be important factors associated with pedestrians in an environment with unfamiliar driving rules.

Verplanken and Aarts (1999) defined "habits" as "learned sequences of acts that have become automatic responses to specific cues, and are functional in obtaining certain goals or end-states." In modern daily life, the selection of travel modes is a behavior with high repetitiveness, and thus, it is affected by people's habits and is often considered in models of people's travel-mode choices (Verplanken et al., 2008). The role of habit in daily travel-mode choices has been studied as well, and the results indicate that habit reduces the elaborateness of information used when selecting travel modes (Aarts et al., 1997). Pedestrian habits have also been examined in several studies. For example, Schwarz et al. (2015) measured street-crossing habits to enhance the safety of pedestrian navigation systems. Kari (2016) studied the relationship between the strength of pedestrians' habit of utility walking and their perception of a walking environment. However, the role of pedestrian habits in scenarios with unfamiliar driving systems remains to be addressed.

Regarding maladaptation, Gardner (2012) showed that repetition of an action in a particular context enhances context–action associations in memory, and hence, control over the initiation of a behavior to form a habit. This means that the intention-initiated behavior becomes an environmental cues-initiated behavior. After living for a long time in a country, people become familiar with the local driving rules and develop habitual behaviors related to repetitively crossing roads in their daily life. For example, in response to oncoming traffic, for their own safety, pedestrians will look in a specific direction before crossing a street. Hence, a looking habit is created by pedestrians' frequently and satisfactorily pairing the execution of an act (e.g., looking in a specific direction) with the response to a specific cue (e.g., preparing to cross a street) (Hull, 1943; Tolman, 1932). After developing a looking habit and adapting to a familiar driving system, maladaptation may occur when pedestrians are exposed to an unfamiliar driving system. It is thus reasonable to assume that there may be a relationship between pedestrian-crossing habits and pedestrian maladaptation in different driving systems. Research has found that the repetition of a behavior in response to specific cues increases behavioral automaticity (Lally et al., 2010). Therefore, a longer length of stay in a specific driving system increases the frequency of looking around in the context of crossing streets as pedestrians, which may lead to the formation of a specific looking habit.

Pedestrian behaviors are associated with the risk of injury and fatality of pedestrians in street crossings (Wang et al., 2020). In Hungary, risky behaviors of pedestrians caused 44% of the pedestrian-related crashes at pedestrian crossings (Mako and Szakonyi, 2016). Moreover, risky behaviors of pedestrians, including crossing a roadway improperly, lack of attention, and failure to obey traffic signs, accounted for 28%, 15%, and 3% of pedestrian fatalities, respectively, in the U.S. (Bungum et al., 2005). In Hong Kong, in 2018, approximately 18% of pedestrian casualties were caused by pedestrian inattentiveness (Road Safety Council, 2018; Census and Statistics Department, 2020). Generally, there are two types of risky behaviors of pedestrians, namely, intentional offenses (deliberate risky behaviors) and unintentional offenses (unintended risky behaviors). Furthermore, intentional offenses can be classified into violations and aggressive behaviors, and unintentional offenses into errors and lapses (Deb et al., 2017a). Intentional violations were committed by more than 21% of the pedestrians in an observation study (Cinnamon et al., 2011) and were found to contribute to pedestrian–vehicle collisions (Gitelman et al., 2019). In addition, walking-related crashes were found to be related to both errors and violations (Useche et al., 2020; Deb et al., 2017a; Granié et al., 2013). Hence, to improve pedestrian safety, it is essential to understand the street-crossing behaviors of pedestrians.

In real-world contexts, observational surveys have been commonly used in pedestrian street-crossing studies to directly observe pedestrians' behaviors (e.g., walking speed, gap selection, and route choice), structural factors (e.g., road design and traffic-signal design), and environmental factors (e.g., traffic speed, traffic type, and weather). Therefore, the resulting data accurately reflect the actual situations. King et al. (2009) studied illegal crossing behaviors at signalized intersections by conducting an observational survey. Similarly, Xie et al. (2017) focused on jaywalking at signalized crosswalks using video recordings. Social and technological distractions were also studied by observing pedestrians crossing streets, and it was found that these distractions increased crossing time and were associated with a higher risk of pedestrian injury (Thompson et al., 2013). In other studies, the crossing patterns of pedestrians were observed to be different in environments with different pedestrian characteristics and traffic environments (Jain et al., 2014).

Although observational surveys can capture pedestrian street-crossing behaviors in detail, they do not allow for detailed analysis of the human factors that cannot be easily observed, such as occupation, nationality, attitudes, and perceptions. Most observational surveys conducted thus far have only collected demographic factors that can be estimated by observation, such as age and sex, and even these are subjective judgments and are, thus, inherently uncertain (Rothman et al., 2016; Xie et al., 2017; Zheng et al., 2020). Therefore, to analyze the street-crossing behaviors of pedestrians in relation to unobserved human factors, a questionnaire survey approach was introduced. Based on the framework of the driver behavior questionnaire (DBQ) (Reason et al., 1990; Özkan and Lajunen, 2005; Lawton et al., 1997), Granié et al. (2013) developed the pedestrian behavior scale (PBS), which has been widely used in many pedestrian behavior studies. Thereafter, many versions of the PBS have been developed and used in different countries. Deb et al. (2017a) validated a pedestrian behavior questionnaire for the U.S. population to evaluate the street-crossing behaviors of pedestrians. Qu et al. (2016) used a Chinese version of the PBS to measure pedestrian behavior in China. A study even validated the PBS across six countries with different cultures and economics, namely Bangladesh, China, Kenya, Thailand, the U.K., and Vietnam (McIlroy et al., 2019). Most recently, the walking behavior questionnaire (WBQ) was developed to include both risky and positive walking behaviors, which further introduced items related to social and technological trends to address new behaviors that might expose pedestrians to risk (Useche et al., 2020). In one study, field observations were combined with questionnaire surveys to introduce human factors into pedestrian behavior models (Papadimitriou et al., 2016).

To study specific pedestrian street-crossing behaviors, an experimental approach is needed because it would allow researchers to design scenarios by themselves. For example, a field experiment was conducted to evaluate the effect of a pedestrian's stare on an oncoming driver's stopping behavior, and it was found that staring increased the number of drivers who stopped (Guéguen et al., 2015). Moreover, virtual-reality-based experiments have been conducted because they are safer and more controllable (Simpson et al., 2003; Zito et al., 2015; Deb et al., 2017b; Sobhani et al., 2018; Ye et al., 2020). However, additional studies are needed to validate the transferability of the virtual-reality experimental results to real-life scenarios (Schneider and Bengler, 2020). Given these advantages and limitations of various pedestrian street-crossing research approaches, a questionnaire survey is used in this study to enable us to measure unobserved human factors in an inexpensive and safe manner.

For data analysis, structural equation modeling (SEM) has been widely used in many studies on pedestrian safety because this approach can manage multiple relationships between latent variables and observed variables. For example, in a comparative study of pedestrians from Iran and Pakistan, the relationships between latent variables, including attitudes toward pedestrian safety and pedestrian risk behavior, and other observed variables were mapped using SEM to examine the differences between the two countries (Nordfjærn and Zavareh, 2016). Dinh et al. (2020) used SEM to measure the relationships between fatalistic beliefs, attitudes toward traffic safety, and pedestrian behavior, and found that fatalistic beliefs were associated with traffic safety attitudes. In our study, latent concepts (e.g., looking habit and maladaptation) are included, and therefore, SEM is applied to model the relationships between the observed and latent variables.

Although many studies on pedestrian street-crossing behavior have been conducted, few studies have examined pedestrian habits and behaviors in areas with unfamiliar driving rules. To better dissect this problem, we conducted a case study in Hong Kong, which has LD rules, in which we administered a face-to-face questionnaire to measure pedestrians' looking habits and maladaptation.

The remainder of this paper is organized as follows. Section 2 proposes the hypotheses and theoretical framework of this study. Section 3 introduces the methods used in this study, namely data collection, measures of variables, and the statistical analysis approach. The results of this study are presented in Section 4 and discussed in Section 5. Section 6 presents our concluding remarks.

2. Hypotheses and theoretical framework

2.1 Hometown driving system

Around 65% of the world's population lives in countries adopting the RD system, whereas the remaining 35% follows the LD system (World Population Review, 2020). In the U.K. (LD), 95% of nonlocal injured pedestrians are from countries that follow the RD system (Baldwin et al., 2008). Moreover, in Australia (LD system), the fatality and accident rates are considerably lower for locals than for people from countries that follow the RD system (Dobson et al., 2004). Therefore, the following hypothesis is proposed:

Hypothesis 1 (H1): Pedestrians' maladaptation in an unfamiliar driving system is negatively related to their hometown driving rule.

An experimental study on pedestrians in Switzerland (RD) found that when crossing streets, the eyes of most of the pedestrians were fixed toward the left side, which indicated that local pedestrians living in an RD system tend to have a left-looking habit (Zito et al., 2015). Hence, we propose the following hypothesis:

Hypothesis 2 (H2): Pedestrians' looking habit is positively related to their hometown driving rule.

2.2 Length of stay in a specific driving system

Repetition of a behavior in response to specific cues enhances behavioral automaticity (Lally et al., 2010). After living for a long time in a country, people become familiar with the local driving rules and develop habitual behaviors for repetitively crossing roads in their daily life. Longer length of stay in a specific driving system increases the frequency of looking around in the context of crossing streets as pedestrians, which may enhance behavioral automaticity and lead to the formation of a specific looking habit accordingly. Based on this theory, the following hypothesis is proposed:

Hypothesis 3 (H3): A pedestrian's looking habit that is consistent with the specific driving system is positively related to their length of stay in that system.

Moreover, based on theoretical inference, a longer length of stay in a given traffic system can possibly help pedestrians to better adapt to that traffic system.

Hypothesis 4 (H4): Pedestrians' maladaptation to an unfamiliar driving system is negatively related to their length of stay in the system.

2.3 Looking habit

In a recent study, people from different driving systems exhibited significant differences in their looking behaviors when crossing roads (Ye et al., 2020). Moreover, foreign pedestrians from different driving systems were found to be disproportionately affected by traffic-related pedestrian injuries (Latifi et al., 2015). Therefore, we assume that pedestrians' looking habits affect their maladaptation in an unfamiliar driving system and propose the following hypothesis.

Hypothesis 5 (H5): Pedestrians' maladaptation in a specific driving system is negatively related to their corresponding looking habit.

Our theoretical framework is illustrated in Fig. 1:

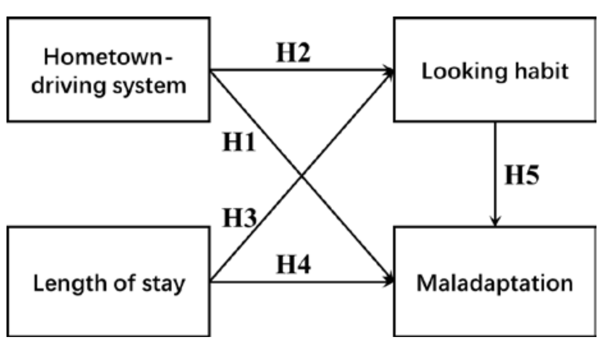

Fig. 1. Theoretical framework based on the proposed hypotheses.

3. Methods

3.1 Data collection

Before the main data collection, a pilot study was conducted within and outside the campus, in which 58 responses (43 local residents and 15 visitors) were collected in total. The questionnaire was modified based on this feedback.

The main study was conducted at seven locations (Table 1) across four districts (Central and Western, Yau Tsim Mong, Islands, and Tuen Mun) distributed in the three areas of Hong Kong (Hong Kong Island, Kowloon, and the New Territories) (Fig. 2). To obtain an adequate number of samples from foreign visitors, many sites popular among tourists were selected. With the help of well-trained research assistants, all of the participants were administered face-to-face questionnaires. A total of 581 random samples were collected, including 239 people (41.1%) from countries following LD rules and 342 people (58.9%) from countries following RD rules.

Table 1. Site locations.

Site	District	Area	Number (%)
University of Hong Kong campus	Central and Western	Hong Kong Island	93 (16.01%)
The Peak	Central and Western	Hong Kong Island	21 (3.61%)
Central	Central and Western	Hong Kong Island	163 (28.06%)
Tsim Sha Tsui	Yau Tsim Mong	Kowloon	91 (15.66%)
Kowloon Park	Yau Tsim Mong	Kowloon	45 (7.75%)
Tung Chung Station	Islands	New Territories	119 (20.48%)
Tuen Mun Park	Tuen Mun	New Territories	49 (8.43%)

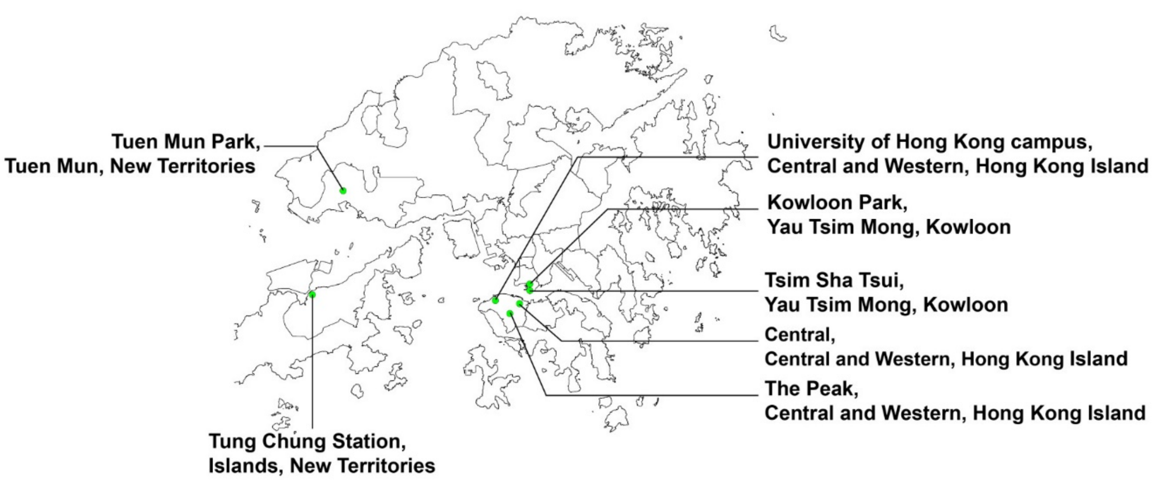

Fig. 2. Distribution of survey locations in Hong Kong.

3.2 Measures and variables

The questionnaire consisted of three parts: participants' demographic information, whether they habitually looked right before crossing a street, and the extent of their maladaptation to the LD system of Hong Kong. The participants' demographic data comprised sex, age, education level, driver status, hometown driving system, length of stay in Hong Kong, and travel purpose (Table 2).

Table 2. Demographic variables of participants.

Variables	Description	Coding	Number (%)
SEX	Sex	Female: 0	280 (48.19%)
		Male: 1	301 (51.81%)
AGE	Age	18–35 years old: 0	278 (47.85%)
		⩾35 years old: 1	303 (52.15%)
EDU	Education level	Non-tertiary level: 0	245 (42.17%)
		Tertiary level: 1	336 (57.83%)
DRIVER	Driver status	Non-driver: 0	303 (52.15%)
		Driver: 1	278 (47.85%)
HOMESYSTEM	Hometown driving system of participants	Right-driving: 0	342 (58.86%)
		Left-driving: 1	239 (41.14%)
STAYLENGTH	Length of stay in Hong Kong	≤ 3 months: 1	269 (46.30%)
		3–6 months: 2	12 (2.07%)
		6–12 months: 3	19 (3.27%)
		1–3 years: 4	21 (3.61%)
		3–5 years: 5	26 (4.48%)
		≥5 years: 6	234 (40.28%)
HKPR	Hong Kong Permanent Resident	Non-HKPR: 0	362 (62.31%)
		HKPR: 1	219 (37.69%)
VISITOR	Short-term visitor	Non-visitor: 0	301 (51.81%)
		Visitor: 1	280 (48.19%)
STUD&WORK	Student and worker	Neither: 0	494 (85.03%)
		Student or worker: 1	87 (14.97%)

In Hong Kong, because traffic drives on the left side of a street, it approaches pedestrians from the right side when they are crossing the street. We measured the participants' habit of looking toward the right (i.e., looking to the right side first before crossing a street) by means of five items in the questionnaire (Table 3), which was based on the Self-Report Habit Index (SRHI) developed by Verplanken and Orbell (2003). Three features of the habit strength were measured to adequately characterize the "Right-looking habit," including history of repetition (i.e., Items R1 and R5), automaticity (i.e., Items R2 and R4), and expressing identity (i.e., Item R3). The responses were recorded on a 5-point scale, where 1 represented strongly disagree and 5 represented strongly agree. Maladaptation (i.e., not being used to the Hong Kong traffic system) was measured using three items graded on a 5-point scale, where 1 represented never and 5 represented always, as presented in Table 4. To ensure that all of the participants explicitly understood the differences among all of the items, our research assistants guided the participants through all of the questions and clearly explained all of the items that confused the participants during the face-to-face interviews.

Table 3. Self-Report Habit Index of right-looking behavior.

"Right-looking behavior" means "Before crossing, I will first look to the right side to check for oncoming traffic."
"Right-looking behavior" is something …

R1. I do frequently.
R2. I do automatically.
R3. that makes me feel weird if I do not do it.
R4. I start doing before I realize I'm doing it.
R5. I have been doing for a long time.

Table 4. Maladaptation measurement.

Maladaptation in Hong Kong LD system
M1. I have had the experience of looking in a wrong direction before crossing in Hong Kong.
M2. I hesitate and think for a while about the traffic direction before crossing in Hong Kong.
M3. I feel confused and have not got used to checking the traffic direction before crossing in Hong Kong.

3.3 Statistical analysis

SEM was used in the data analysis because it can simultaneously model the relationships among all of the observed and unobserved variables. In the SEM, latent variables were introduced to represent the underlying concepts (i.e., right-looking habit and maladaptation), which were unobserved variables that were inferred from the observed variables. There were two sub-models in the SEM model: the measurement model and the structural model. The measurement model described the relationships between the latent and the measured variables, whereas the structural model described the relationships between the endogenous and exogenous variables. Therefore, the following two-step approach was used (Anderson and Gerbing, 1988):

i) Build and validate the measurement model;

ii) Build and assess the structural model.

Confirmatory factor analysis (CFA) was used in the first step of SEM to estimate the measurement model and reduce the measurement of instrument error, which specifies which measured indicator loads on which construct. As Anderson and Gerbing (1988) argued, CFA can provide a stricter explanation of unidimensionality than other techniques. Thus, it helps test the reliability and validity of a measurement for confirming that a particular latent construct is measured by the corresponding items.

The adequacy of the measurement model with its latent constructs (i.e., right-looking habit and maladaptation in the Hong Kong LD system) and other indicators were assessed using CFA. SEM was then used to fit the structural model and test the hypothesized relationships among the variables. Maximum likelihood estimation was performed using AMOS 21.0. Several model fit indices were used to assess the adequacy of the proposed model. Bootstrapping was performed to test for mediation effects in the model, given that it was found to be the most powerful method for this purpose (Hayes, 2013).

4. Results

4.1 Descriptive analysis

The responses of participants toward the right-looking habit and maladaptation questions were recoded into binary categories. The associations between hometown driving rules and the right-looking habit and hometown driving rules and maladaptation were tested. The responses of the categories with high scores (agree and strongly agree, often and always) are presented in Table 5.

Table 5. Pedestrians' right-looking habit and maladaptation in the Hong Kong LD system.

	Mean (SD)	Agree and strongly agree/often and always (N, %)			
		Overall	LD	RD	p-value
Right-looking habit					
R1	3.21 (1.25)	253 (43.55%)	173 (72.38%)	80 (23.39%)	<0.001
R2	3.21 (1.24)	256 (44.06%)	168 (70.29%)	88 (25.73%)	<0.001
R3	2.97 (1.15)	188 (32.36%)	120 (50.21%)	68 (19.88%)	<0.001
R4	3.17 (1.17)	244 (42.00%)	161 (67.36%)	83 (24.27%)	<0.001
R5	3.28 (1.26)	277 (47.68%)	177 (74.06%)	100 (29.24%)	<0.001
Maladaptation					
M1	2.53 (1.03)	116 (19.97%)	14 (5.86%)	102 (29.82%)	<0.001
M2	3.03 (1.16)	221 (38.04%)	44 (18.41%)	177 (51.75%)	<0.001
M3	2.46 (1.11)	125 (21.51%)	16 (2.75%)	109 (18.76%)	<0.001

The overall mean scores of the participants' right-looking habit varied from 2.97 to 3.28. Significant differences were observed between the participants from LD hometown driving systems and those from RD hometown driving systems ($p < 0.001$). A considerably greater percentage of LD participants agreed that they exhibited right-looking behavior, whereas only a few RD participants agreed that they exhibited right-looking behavior.

With respect to maladaptation to the LD driving system followed in Hong Kong, the mean scores varied from 2.46 to 3.03. Significant differences ($p < 0.001$) were observed in all of the items related to maladaptation (M1 to M3) between participants from LD hometown driving systems and those from RD hometown driving systems, and the participants from RD hometown driving systems showed a considerably higher percentage of maladaptation than those from LD hometown driving systems.

4.2 CFA

The measurement model was checked with CFA to test whether the constructs adequately represented the proposed concepts. The CFA model with standardized estimates is illustrated in Fig. 3.

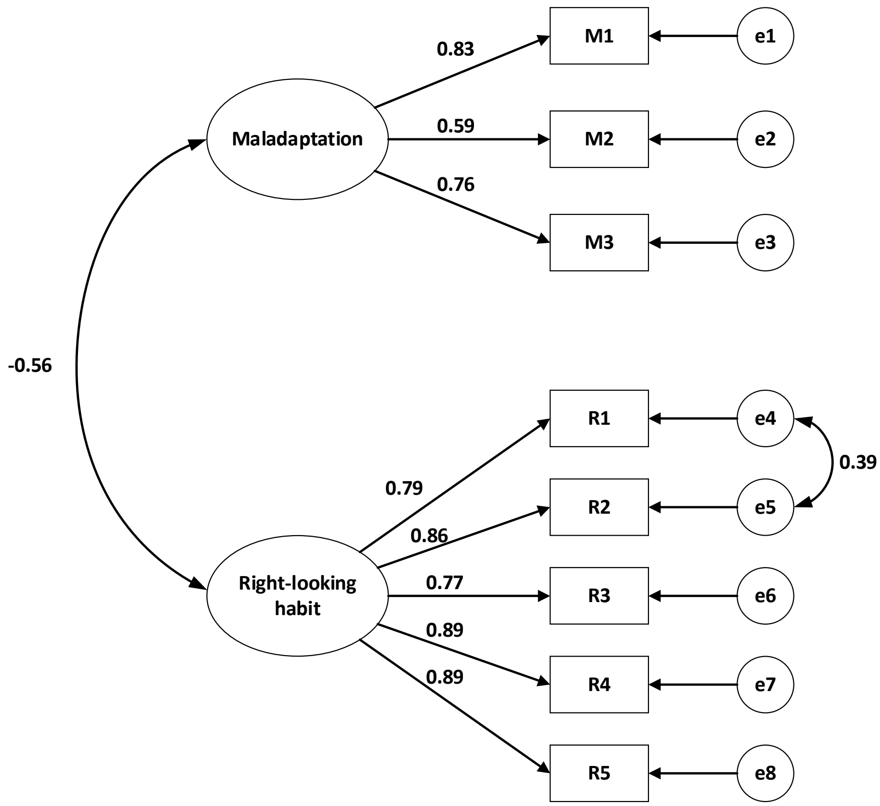

Fig. 3. Measurement model (where M = Maladaptation, R = Right-looking habit, e = error term).

In addition, several fit indices were calculated to reflect the ability of the model to reproduce the data. The fit results were all acceptable based on the commonly used criteria, indicating a good fit between model measurements and the collected data.

Table 6. Goodness-of-fit indices of the measurement model.

Fit category	Fit index	Value	Criterion of acceptance
Absolute fit	RMSEA	0.057	<0.08 (Wheaton, 1987)
	GFI	0.978	>0.90 (Joreskog and Sôrbum, 1984)
Incremental fit	CFI	0.989	>0.90 (Bentler, 1990)
	TLI	0.982	>0.90 (Bentler and Bonett, 1980)
Parsimonious fit	χ^2/df	2.853	<5.0 (Marsh and Hocevar, 1985)

RMSEA = root-mean-square error of approximation; GFI = goodness-of-fit index; CFI = comparative fit index; TLI = Tucker–Lewis index; df = degrees of freedom.

Furthermore, to test the validity and reliability, the factor loading, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) were computed. The results are presented in Table 7.

Table 7. Results of factor loading, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) tests.

Construct	Item	Factor loading	Cronbach's alpha	CR	AVE
Maladaptation	M1	0.833	0.766	0.775	0.539
	M2	0.585			
	M3	0.762			
Right-looking habit	R1	0.791	0.928	0.924	0.710
	R2	0.856			
	R3	0.772			
	R4	0.894			
	R5	0.893			

Convergent, construct, and discriminant validities were then checked. All of the items in the measurement model were found to be highly significant (p-value < 0.001), and the AVE values of maladaptation and right-looking habit were greater than 0.50, indicating adequate convergent validity (Fornell and Larcker, 1981; Hair et al., 2006) (Table 8). Based on the results of the fit indices in Table 6, all of the indices satisfied the criteria of acceptance, so the construct validity reached the required level (Ahmad et al., 2016). In addition, Table 8 shows the results of discriminant validity. The square roots of AVE of the constructs were greater than the correlations between the respective constructs, which implied that discriminant validity was achieved (Zainudin, 2015).

Moreover, internal reliability, construct reliability, and AVE were assessed. The Cronbach's alpha values of both constructs were greater than 0.70, which confirmed their internal reliability (Cortina, 1993; Nunnally and Bernstein, 1994) (Table 8). The CR values of both constructs were greater than 0.70, indicating that construct reliability was achieved and internal consistency existed (Hair et al., 2014). As the average percentage of variation that is explained by the items of a construct, AVE should be greater than 50% (Ahmad et al., 2016). The AVEs of both maladaptation and right-looking habit were greater than 0.50, which fulfilled the above requirement.

Table 8. Results of discriminant validity tests.

Construct	Maladaptation	Right-looking habit
Maladaptation	**0.734**	
Right-looking habit	-0.555	**0.843**

4.3. SEM

SEM was performed in the AMOS 21.0 software environment to examine the structural relationships after CFA, and a simplified path diagram of the SEM with standardized estimates is illustrated in Fig. 4, where only the factors with significant direct effects are shown. The detailed full-path diagram with all of the possible confounders (i.e., travel purpose of participations (short-term visitor, Hong Kong permanent resident, student and worker), sex, age, education, and driver status) is shown in the Appendix. The model exhibited good fitness with the collected data based on the results of the fitness indices (Table 9), and the path coefficients and the tests of the direct effects are presented in Table 10.

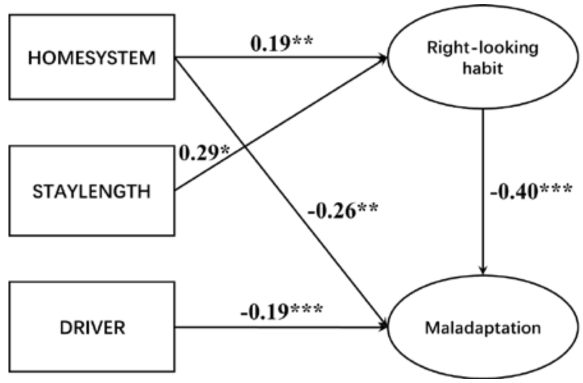

Fig. 4. A simplified path diagram of SEM with standardized estimates of only the factors that have significant direct effects (where HOMESYSTEM = hometown driving system; STAYLENGTH = length of stay in Hong Kong; DRIVER = driver status; *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$. The detailed full-path diagram and coefficients table are given in the Appendix).

Table 9. Goodness-of-fit indices of structural equation model.

Fit category	Fit index	Value	Criterion of acceptance
Absolute fit	RMSEA	0.045	<0.08 (Wheaton, 1987)
	GFI	0.970	>0.90 (Joreskog and Sôrbum, 1984)
Incremental fit	CFI	0.989	>0.90 (Bentler, 1990)
	TLI	0.980	>0.90 (Bentler and Bonett, 1980)
Parsimonious fit	χ^2/df	2.154	<5.0 (Marsh and Hocevar, 1985)

RMSEA = root-mean-square error of approximation; GFI = goodness-of-fit index; CFI = comparative fit index; TLI = Tucker–Lewis index; df = degrees of freedom.

Table 10. Standardized path coefficients of significant factors.

Path	β	SE	CrRa	p-value
HOMESYSTEM → Right-looking habit	0.194	0.141	2.769	<0.01
STAYLENGTH→ Right-looking habit	0.287	0.058	2.088	<0.05
Right-looking habit → Maladaptation	-0.400	0.043	-8.034	<0.001
HOMESYSTEM →Maladaptation	-0.255	0.124	-3.571	<0.001
DRIVER→ Maladaptation	-0.190	0.077	-4.218	<0.001

β = standardized coefficient; SE = standard error; CrRa = critical ratio; HOMESYSTEM = hometown driving system; STAYLENGTH = length of stay in Hong Kong; DRIVER = driver status.

The results indicated that both HOMESYSTEM (β = 0.194, CrRa = 2.769, p-value <0.01) and STAYLENGTH (β = 0.287, CrRa = 2.088, p-value <0.05) had significant positive effects on the right-looking habit. Therefore, H2 and H3 were supported, indicating that a pedestrian from an area with an LD system and longer length of stay would have a stronger right-looking habit. A significant negative relationship was confirmed between right-looking habit and maladaptation (β = -0.400, CrRa = -8.034, p-value <0.001). Therefore, H5 was supported, indicating that pedestrians with a strong right-looking habit tend to show less maladaptation in Hong Kong's LD system. The direct effect of HOMESYSTEM (β = -0.255, CrRa = -3.571, p-value <0.001) on maladaptation was significantly negative. Thus, H1 was supported. However, the direct effect of length of stay on maladaptation was not significant (p-value = 0.457 > 0.05). Therefore, H4 was rejected at the 5% significance level. Moreover, driver status had a significantly negative effect on maladaptation (β = -0.190, CrRa = -4.218, p-value <0.001) but no effect on right-looking habit. Furthermore, other demographic factors (short-term visitor, student and worker, Hong Kong permanent resident, sex, age, and education) were controlled in the SEM analysis (see Appendix). The results showed that all of the other factors were not significant and thus did not confound the relationships in the proposed structural model.

Bootstrapping was applied to measure the mediation effects (Preacher and Hayes, 2008). The results demonstrated that right-looking habit had significant partial mediation effects between HOMESYSTEM ($\beta = -0.078$) and maladaptation. Moreover, right-looking habit had full mediation effects between length of stay ($\beta = -0.115$) and maladaptation (Table 11).

Table 11. Mediation effects.

Hypothesis	Direct effect (β)	Indirect effect (β)	Result
HOMESYSTEM→Right-looking habit→Maladaptation	-0.255***	-0.078*	Partial mediation
STAYLENGTH→Right-looking habit→Maladaptation	-0.103	-0.115*	Full mediation

*** = $p < 0.001$; * $p < 0.05$.

5. Discussion

5.1 Right-looking habit

Right-looking habit refers to pedestrians' habituation to look first toward the right before crossing a street, and this was measured using an SRHI in this study. The results of a chi-square analysis suggested that right-looking habit was significantly associated with participants' hometown driving rules, and people from countries that follow RD rules showed considerably weaker right-looking habit than those from countries that follow LD rules. In Switzerland (RD rules), an experiment was conducted with three screens indicating the left, middle, and right sides when crossing streets, and participants' eye and head movements were recorded. The results showed that most of the participants' gaze was fixated on the left part of the screen (Zito et al., 2015), which is consistent with the results of our study. The same conclusion was drawn from the results of the SEM analysis, which indicated that pedestrians' hometown driving rules shaped their original looking habit, possibly because the experiences of looking around and crossing streets in their hometowns were associated together through repetition (Gardner, 2012).

Moreover, the SEM results indicated that a longer stay in a country with a particular driving rule would help enhance the corresponding looking habit, probably because of long-term exposure to an unfamiliar system. As people frequently look around and cross streets in a new context, they keep receiving feedback from the traffic direction, thus gradually forming a new looking habit corresponding to the new driving rule.

To best of our knowledge, our study is among the first to confirm that both original (hometown driving rules) and acquired (length of stay in an environment with unfamiliar driving rules) factors influence looking habits. Moreover, these effects exist across travel purpose, sex, age, and education. The results confirm the findings of previous research and support our hypotheses (H2 and H3).

5.2 Maladaptation to the Hong Kong LD system

Maladaptation refers to the scenario in which participants are not adapted to the LD system in Hong Kong. In such a case, they exhibit different behaviors and commit errors when crossing a street in Hong Kong compared with the participants who have already adapted to Hong Kong's system. Maladaptation falls under the category of pedestrian errors (e.g., failure to look in the correct direction before crossing), and it has been demonstrated that pedestrian errors contribute significantly to walking-related crashes (Useche et al., 2020) and severity of injuries (Barrero et al., 2013; Stefanova et al., 2015). Therefore, it is important to reduce pedestrians' maladaptation in areas with an unfamiliar driving system.

The descriptive analysis results indicated that maladaptation to the Hong Kong LD system was significantly associated with hometown driving system, and similar results were obtained from the SEM analysis. Noticeably, the participants from hometowns with an RD rule had more severe maladaptation to the Hong Kong LD system because they felt strange and unaccustomed to the different driving rules and needed time to adapt to the unfamiliar driving system. In addition, the looking habit acted as a mediator between hometown driving system and maladaptation because a stronger corresponding looking habit can help reduce maladaptation.

As for the length of stay in Hong Kong, it had no significant direct effect on maladaptation, but it still affected maladaptation through mediation of right-looking habit. The mechanism of this mediated effect is that a longer stay in an unfamiliar driving system enhances the corresponding looking habit, thus reducing maladaptation to that system. This highlights the need to consider foreign visitors' original looking habits with respect to their hometown driving rules when trying to improve foreign pedestrians' safety, especially that of short-term visitors who are newly exposed to a setting with different driving rules. Moreover, the effect of length of stay can be further addressed, for instance, the time required by a foreign visitor to become well adapted to an unfamiliar driving system.

Interestingly, we found that holding a driver's license can help foreign pedestrians to become better accustomed to the local driving system, probably because they have experiences as a driver and have a better understanding of driving rules, which would enhance their adaptability to the unfamiliar system.

This case study has demonstrated that foreign visitors who are from hometowns that follow the RD system and have a short length of stay show greater maladaptation to Hong Kong's LD traffic system. This confirms that when traveling to places with unfamiliar driving rules, visitors tend to make more errors and might, as pedestrians, be exposed to a higher risk of injury or death. Dobson et al. (2004) reported that people born in other countries showed higher rates of fatalities in traffic crashes than local residents in Australia. In Qatar, it was found that expatriate workers were highly affected by traffic-related pedestrian injuries (Latifi et al., 2015). Recently, a study in Spain concluded that the rate of traffic accidents among foreign visitors was higher than that among locals (Castillo-Manzano et al., 2018). The findings of our study provide further evidence on the pedestrian looking habit and reveal potential risks faced by pedestrians in settings with unfamiliar driving rules, and they are consistent with the findings of previous studies (Dobson et al., 2004; Latifi et al., 2015; Castillo-Manzano et al., 2018; Ye et al., 2020). However, they are novel in identifying the role of pedestrian looking habit in mediating the influences of hometown driving rules and length of stay on maladaptation based on a real-world questionnaire survey in Hong Kong.

5.3 Implications of findings

The results have significant implications for transportation policymakers. To improve pedestrian safety in an environment with unfamiliar driving rules, an in-depth understanding of the relationships among looking habits, maladaptation, and other significant factors is indispensable. This indicates the importance of incorporating foreign pedestrians' safety into road safety policy planning. In this regard, the findings of this study are useful for transportation departments and other stakeholders to develop evidence-based countermeasures for reducing foreign pedestrians' risk. The three traditional road safety measures, called the "three Es," are engineering, education, and enforcement (Rothengatter, 1982; McKenna, 2012; Zhou et al., 2020). Below, we discuss the implications of the findings in the context of this framework:

(1) Engineering: Pedestrians who are familiar with different driving rules have different looking habits before crossing, which would lead to maladaptation in an environment with unfamiliar driving rules. In Hong Kong, although considerable efforts have been made to address this problem, such as marking "Look Left" and "Look Right" on the road at unsignalized crossings, it has not been sufficiently effective (Ye el al., 2020). Initiatives should be taken to systematically improve existing transportation infrastructure, and differences in looking habits should be explicitly considered when designing new pedestrian facilities. For example, more reminders about traffic directions could be placed at popular tourist spots and in central business districts, which are frequented by foreign visitors. Such reminders should be easily visible to (and hard to miss by) pedestrians. For instance, pedestrians are more likely to notice a standing board signaling the traffic direction than they are to notice road markings, because

a pedestrian's line of sight is more forward than downward. From the drivers' perspective, a reminder to slow down at popular pedestrian crossings would be helpful, so that drivers can slow down and pay attention to pedestrians, giving pedestrians more time to observe the traffic direction and make correct decisions.

(2) Education: Because length of stay is a highly significant factor that affects pedestrians' looking habits, policymakers should focus on individuals who are new to the local system and help them through the adaptation period. For instance, a traffic safety brochure can be distributed to foreign visitors who are from countries that follow different driving rules to remind them of the local driving rules and appropriate looking habits. The safety education of drivers should be revised first to teach them that foreign pedestrians may experience maladaptation in an environment with unfamiliar driving rules. Second, through education, drivers' spot reaction should be improved so that they can react to dangerous situations resulting from the maladaptation of foreign pedestrians (e.g., inattentive or indecisive behavior). Emerging technologies, such as simulator-based training (Park et al., 2015) and in-vehicle monitoring systems (Musicant & Lampel, 2010), are helpful in these educational aspects.

(3) Enforcement: Enforcement refers to the laws and regulations developed to regulate the aggressive behavior of road users. The maladaptation of pedestrians in an environment with unfamiliar driving rules is often an unintentional error rather than an intentional violation. Hence, the authorities should be more vigilant in regulating aggressive driving behaviors. For instance, more speed cameras could be installed to monitor the speed of vehicles approaching pedestrian crossings, as low vehicle speeds give pedestrians a longer reaction time if they have misjudged the traffic direction. In addition, police patrols should be increased at pedestrian crossings at popular tourist spots and in central business districts.

5.4 Limitations and future studies

To reduce sample bias, this study was conducted on representative and randomly selected samples from all administrative areas and many districts of Hong Kong, and statistical procedures were rigorously followed. To reduce perception bias, face-to-face interviews were conducted to help the participants understand the meaning of the questions. Despite these efforts, there remain several limitations that should be acknowledged. First, our study is based on a questionnaire survey, which may be affected by the inherent limitations related to data collection from biased sources, because participants may be affected by common social cognition and thus provide biased responses. Second, the effects of pedestrians' walking frequency and duration warrant investigation, as pedestrians can better adapt to an unfamiliar system through experience. Unfortunately, these factors were not included in our formal survey because in our pilot study, the participants found it fairly difficult to recall this information accurately. Nevertheless, visitors' adaptation to an unfamiliar driving system is expected to be affected by the use of multiple travel modes (e.g., driving a private or rented car, taking the bus or a taxi, and cycling), not just walking.

We therefore included participants' length of stay in Hong Kong as the surrogate for their adaptation duration to Hong Kong's LD system. Future research efforts could explore the following: (a) integration of information on daily walking activities into our model if additional data sources, such as walking app data, are available; (b) variations in looking habits at various crossing locations (e.g., mid-block crossings, and signalized and unsignalized intersections) and the associated severity of conflicts with motor vehicles; (c) possible situations that might exacerbate pedestrian risk in unfamiliar driving systems; and (d) potential interventions to improve pedestrian safety in settings with unfamiliar driving rules.

6. Conclusion

In this study, we examined pedestrians' looking habits and maladaptation in areas with unfamiliar driving rules. To better investigate the problem, a case study was conducted in Hong Kong, which follows LD rules. Pedestrians' looking habits and maladaptation were measured using a questionnaire survey. SEM was used to model the relationships among hometown driving rule, length of stay, right-looking habit, and maladaptation to the Hong Kong LD system. Based on previous empirical studies, five hypotheses regarding the relationships were proposed and tested.

The results of our study showed significant differences in right-looking habit and maladaptation between pedestrians from areas that follow different driving rules and local pedestrians. Furthermore, hometown driving rules, length of stay in a driving system, and driver status were involved in the significant path relations of the SEM model, and the relationships were robust without being confounded by other demographic factors. Right-looking habit partially mediated the effect of hometown driving system on maladaptation in Hong Kong's LD system and fully mediated the effect of length of stay on maladaptation to Hong Kong's LD system. Pedestrians who had a driver's license adapted better to Hong Kong's LD system.

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Appendix A. Detailed full path diagram and standardized coefficients table.

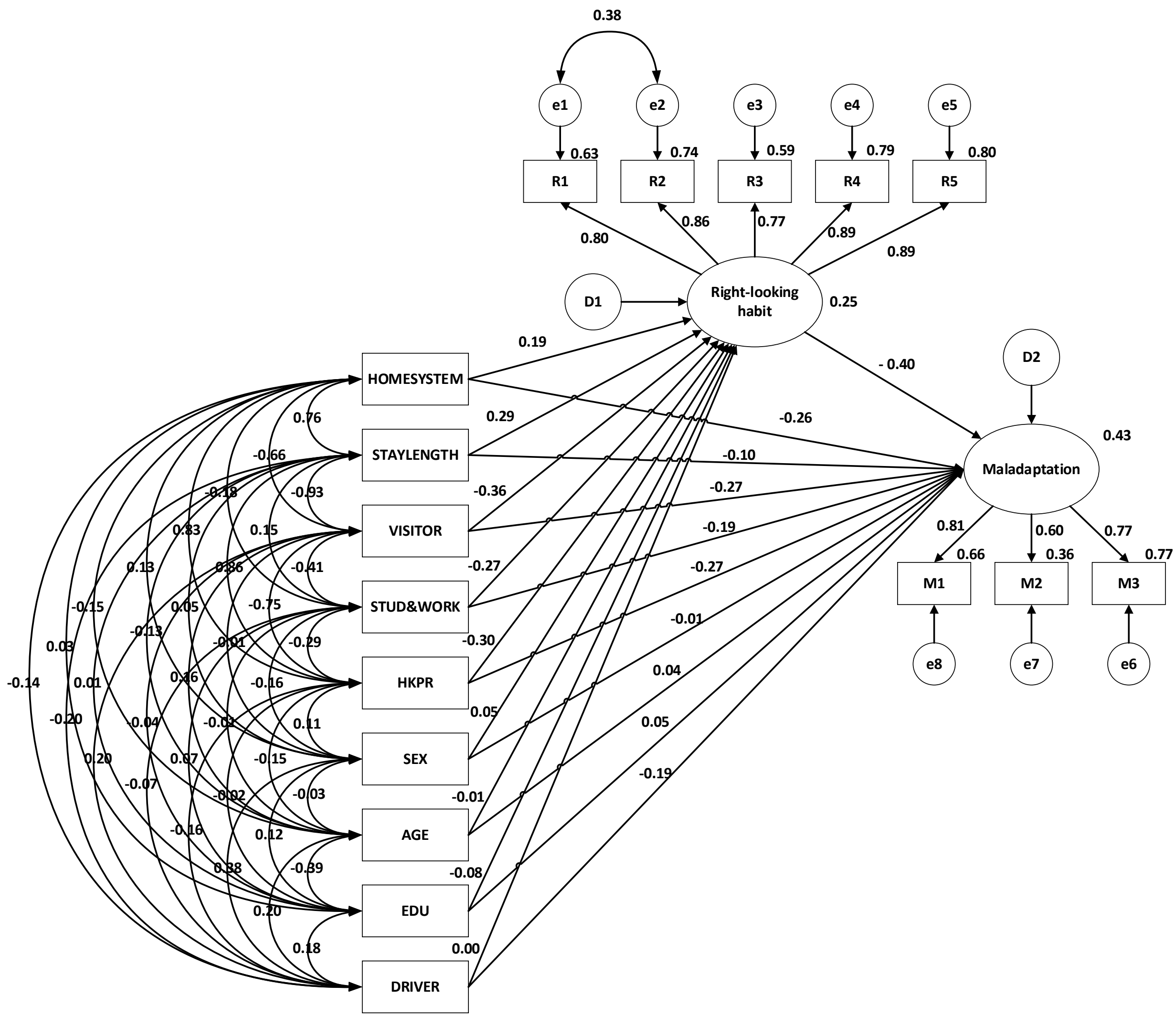

Fig. A1. Detailed full diagram of SEM with standardized estimates (where HOMESYSTEM = hometown driving system; STAYLENGTH = length of stay in Hong Kong; VISITOR = short-term visitor; STUD&WORK = student or worker; HKPR = Hong Kong permanent resident, SEX = sex, AGE = age, EDU = education, DRIVER = driver status).

Table A1. Standardized path coefficients.

Path	β	SE	CrRa	*p*-value
HOMESYSTEM → Right-looking habit	0.194	0.141	2.769	<0.01
STAYLENGTH→ Right-looking habit	0.287	0.058	2.088	<0.05
VISITOR→ Right-looking habit	-0.355	0.505	-1.399	0.162
STUD&WORK→ Right-looking habit	-0.273	0.459	-1.659	0.097
HKPR → Right-looking habit	-0.299	0.490	-1.256	0.209
SEX→ Right-looking habit	0.045	0.084	1.070	0.285
AGE→ Right-looking habit	-0.013	0.087	-0.303	0.762
EDU→ Right-looking habit	-0.080	0.087	-1.854	0.064
DRIVER→ Right-looking habit	0.002	0.088	0.038	0.970
Right-looking habit → Maladaptation	-0.400	0.043	-8.034	<0.001
HOMESYSTEM →Maladaptation	-0.255	0.124	-3.571	<0.001
STAYLENGTH→ Maladaptation	-0.103	0.050	-0.743	0.457
VISITOR→ Maladaptation	-0.267	0.439	-1.042	0.297
STUD&WORK→ Maladaptation	-0.187	0.401	-1.122	0.262
HKPR → Maladaptation	-0.269	0.428	-1.116	0.265
SEX→ Maladaptation	-0.013	0.073	-0.304	0.761
AGE→ Maladaptation	0.042	0.076	0.963	0.335
EDU→ Maladaptation	0.054	0.076	1.229	0.219
DRIVER→ Maladaptation	-0.190	0.077	-4.218	<0.001

β = standardized coefficient; SE = standard error; CrRa = critical ratio; HOMESYSTEM = hometown driving system; STAYLENGTH = length of stay in Hong Kong; VISITOR = visitor; STUD&WORK = student and worker; HKPR = Hong Kong permanent resident; SEX = sex; AGE = age; EDU = education; DRIVER = driver status.