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Beyond general behavioral theories: Structural discrepancy in young motorcyclist's risky driving behavior and its policy implications

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ABSTRACT

While many studies examine the mean score differences of psychological determinants between heterogeneous driver groups, this study reveals a structural discrepancy in a causal behavioral framework. Using young motorcyclists (ages 18–28) as subjects, this study investigates the various roles of key influential factors in determining risky driving behavior. Multi-group analysis of structural equation modeling shows that age and gender are two factors that can effectively distinguish heterogeneous driver groups exhibiting different decision-making mechanisms in shaping their risky driving behaviors. When encountering undesirable traffic conditions, road rage can immediately increase male motorcyclists' intentions to engage in risky driving behaviors; on the other hand, young female motorcyclists further calculate their perceived risk to determine whether to engage in risky driving behaviors. This result shows that there is a significant link between risk perception and traffic condition awareness for experienced drivers (ages 25–28), but not for younger drivers (ages 18–24). This finding shows that while well-developed theories such as planned behavior and risk homeostasis provide general frameworks to explain risky driving behavior, heterogeneous driver groups may exhibit structural discrepancies that reflect their various decision-making mechanisms. This suggests that, in addition to mean differences, understanding structural discrepancies among heterogeneous groups could help researchers identify effective intervention strategies.

1. Introduction

In their efforts to reduce traffic collisions, researchers and traffic engineers have attempted to identify the causality of risky behavior and traffic accidents and discover reliable factors predicting driver behaviors. However, driver behaviors are typically heterogeneous and sometimes unpredictable. Even though drivers share similar features and experience similar traffic conditions and environments, their behaviors may vary. Though different factors may influence different risky driving behaviors (Fernandes et al., 2010), similar risky driving behaviors could result from different causes. For example, some drivers may speed just for fun or excitement, while others speed because they are unaware of potential dangers in the driving environment (Forward, 2010; Wong et al., 2010a). These differences make it difficult to devise a single intervention strategy for all drivers.

To account for these heterogeneous risky driving behaviors, previous researchers have focused on the correlation between various factors and risky driving behavior, testing the mean differences of factors between different driver groups, and identifying the characteristics of various types of risky drivers using factor or cluster analysis (Jonah, 1997). More recently, researchers have begun to examine the "causal structures" of various driving behaviors and investigate the relationships between affecting factors based on developed behavioral theories (Nelson et al., 2009; Vance et al., 2006; Wong et al., 2010b). For example, the theory of planned behavior proposes that attitudes (the degree to which performance of the behavior is positively or negatively valued), subjective norms (the perceived social pressure to engage or not engage in a behavior), and perceived behavioral control (people's perceptions of their ability to perform a given behavior) are important predictors of behavior through the intention to perform this behavior (Ajzen, 1991). This theory has been widely used to explain risky driving behaviors such as speeding (Elliott and Thomson, 2010), drunk driving (Chan et al., 2010a), and dialing and driving (Walsh et al., 2008). These studies focus on the association and predictability of risky driving behavior factors, and attempt to evaluate the hypothetical causal relationship between factors and risky driving behavior based on behavioral theories. As a result, they provide us with a better understanding of the formation of various risky driving behaviors.

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While some studies have demonstrated structural relationships for risky driving behavior, it remains unclear how these structural relationships appear among heterogeneous driver groups, and especially motorcyclists. Some drivers show distinct driving behaviors from their counterparts: young or novice drivers, male drivers, student drivers, or drivers with violation or accident history (Bina et al., 2006; Chang and Yeh, 2007; Dejoy, 1992; Forward, 2010; Hamed and Easa, 1998; Jonah, 1997; Lin et al., 2003; McKnight and McKnight, 2003; Simons-Morton et al., 2005; Taubman-Ben-Ari et al., 2004). Previous studies show that these drivers exhibit different psychological conditions while driving. For example, Hamed and Easa (1998) showed that male drivers demonstrate a higher level of perceived risk than female drivers. Clearly, various psychological conditions are partially responsible for the distinct driving behaviors between heterogeneous groups. However, merely examining the differences in psychological conditions provides only limited insights into the formation of heterogeneous driving behaviors. This study uses structural equation modeling to examine the discrepancy of causal behavioral structures between heterogeneous driver groups in a comprehensive manner that complements previous studies.

Given the growing popularity of motorcycles and the high accident rate of young motorcyclists, this study selects young motorcyclists as the subjects. Motorcycles offer the advantages of low initial cost and, for some models, good fuel efficiency. High fuel prices in recent years have led to an increasing number of registered motorcycles in some countries. In the United States, there are more than 6.2 million registered motorcycles. More than 5000 motorcyclists were killed in 2009, accounting for 12% of all highway fatalities (NHTSA, 2009). The situation is even worse in developing countries, where powered two-wheelers are a primary mode of transportation in urban areas. For example, motorcycles account for two thirds of all registered vehicles in Taiwan, and 45% of traffic accidents involve motorcyclists (MTC, 2007a). Compared to other drivers, young motorcyclists are more likely to engage in risky driving behavior and become involved in severe accidents (Tseng et al., 2001; Haque et al., 2009; Zamani-Alavijeh et al., 2010). This might result from various reasons, such as a relatively low helmet use rate (Ackaah and Afukaar, 2010), enjoyment of motorcycling (Zamani-Alavijeh et al., 2010), different personality traits (Chen, 2009; Wong et al., 2010b), limited awareness of potential dangers on the road (Haque et al., 2009; Wong et al., 2010b), and poor driving skills and little experience (Chang and Yeh, 2007). The variety of factors discussed in the literature suggests a need to analyze the formation of motorcyclist's heterogeneous driving behavior in a holistic manner. Therefore, this study investigates both the mean score differences of psychological determinants and the structural discrepancy between heterogeneous driver groups in a causal behavioral structure.

The remaining sections of this paper are organized as follows: Section 2 briefly reviews factors that define the formation of heterogeneous driving behaviors. Section 3 introduces the methodology used in this study. Section 4 presents analysis results, and Section 5 provides discussion and policy implications. Finally, Section 6 provides concluding remarks.

2. Factors defining the formation of heterogeneous driving behaviors

2.1. Personality traits

Wong et al. (2010a) is one of the few studies examining structural discrepancy between heterogeneous groups. The authors divided young motorcyclists into four groups based on their personality traits and examined structural discrepancies in conducting risky driving behavior. Their results confirm the existence of structural discrepancies. For example, when encountering undesired traffic conditions, young aggressive motorcyclists immediately increased their intention to conduct risky driving behavior; nevertheless, the actions of those in the risky group depended further on their confidence and perceived fun or excitement. Although personality traits can effectively demonstrate structural discrepancy in risky driving behavior, they are difficult to use in practice because they are latent constructs that require reliable and valid measurements.

2.2. Demographic factors and driving experience

Previous research shows that demographic factors and driving experience have significant effects on distinguishing heterogeneous driver groups. Age and gender are the two most commonly used demographic factors. Previous studies consistently connect young male drivers to risky driving behaviors, and have thoroughly discussed the underlying factors that distinguish young male drivers. Inexperience in young drivers might cause them to engage in risky driving behavior, such as a failure to employ routine safe operating practices or failure to recognize potential dangers in the driving environment (Chang and Yeh, 2007; McKnight and McKnight, 2003). Young drivers might also engage in risky driving behaviors such as speeding and drunk driving because their immediate temptation overrides their knowledge of the possible consequences (Taubman-Ben-Ari et al., 2004).

Similar to young drivers, male drivers are over-represented in risky driving behaviors and traffic accidents (Simons-Morton et al., 2005). Compared to female drivers, male drivers are more sensation seeking and perceive certain risky driving behaviors as less serious and less likely to result in accidents. Consequently, previous studies consistently report more risky driving behaviors in males (Dejoy, 1992; Jonah, 1997).

Occupation is another important demographic factor distinguishing risky driving behaviors, especially for student drivers. Student drivers, who are young and over-represented in risky driving behavior and traffic accidents, demonstrate risky driving behavior patterns different from non-student drivers because of their different lifestyle. This often results in various driving exposures, risk levels, alcohol consumption, etc. (Bina et al., 2006; Lin et al., 2003).

Driving experience is another frequently discussed factor in the literature, and shows a significant relationship with risky driving behavior and traffic accidents. Less-experienced drivers generally exhibit poor driving skills, leading to dangerous driving situations and more traffic accidents (Chang and Yeh, 2007; Forward, 2010). Compared to more experienced drivers, less-experienced drivers may also fail to anticipate hidden hazards and tend to commit driving errors more frequently, due to inappropriate attention allocation (Chan et al., 2010b).

Note that while age and driving experience are typically highly correlated, they are two different concepts. For example, even young people can be experienced drivers if they drive motorcycles frequently. However, given similar driving experience, adult drivers may drive in a more sensible and reasonable way than young drivers because they are more physically and mentally mature than the young drivers.

2.3. Violation and accident history

Traffic law violations are typical aberrant driving behaviors that endanger drivers themselves and other road users. While some driver groups, such as young or male drivers, exhibit more violation behaviors than their counterparts, previous studies have shown that psychological factors can more effectively explain or

predict traffic law violation behaviors than demographic factors. Yagil (1998) suggested that due to their weaker instrumental and normative motives to obey the law and less perceived negative risk on disobeying the law, young drivers have stronger connections to traffic violations than old drivers. Begg and Langley (2004) showed that personality traits are connected to traffic violations more directly than demographic factors such as gender, especially for repeated violation behaviors. By focusing on young drivers, Bingham et al. (2006) found that while demographic factors may predict different violation behaviors with various significance levels, psychological adjustment (e.g. tolerance of deviance, peer vs. parent-orientedness) consistently plays a significant role in determining traffic violation behaviors, and particularly for younger drivers (e.g., those in their 20s). Blincoe et al. (2006) discovered that unlike drivers who never exceed speed limits, drivers who slow only at camera locations and those who exceed limits regardless of cameras did not perceive speeding as a serious traffic law violation. Based on the theory of planned behavior, Forward (2010) demonstrated that attitudes, subjective norms, control beliefs, and perceived behavioral control are effective indicators of the intention to speed on a major road. Apparently, traffic law violation behaviors are significantly related to driver's psychological conditions, which may change as drivers mature.

As for accident history, previous studies show that drivers who have been involved in accidents typically report higher levels of risk-taking behavior (Lin et al., 2004). Using GPS speed data, Jun et al. (2011) found that drivers who had accident experiences tend to drive at higher speeds than drivers not involved in accidents. Wells-Parker et al. (2002) also found that accident experience is highly correlated with road rage. Similar to violation experience, accident experience can be used to define heterogeneous driver groups, exhibiting different driving behaviors, various psychological conditions, and levels of maturity.

3. Methodology

Three elements are required to examine the structural discrepancy between heterogeneous driver groups: a causal behavioral structure, factors defining heterogeneous driver groups, and data. The following subsections present these elements and the analysis procedure.

3.1. Adopted causal behavioral structure

Many researchers have developed their own structural frameworks to explain risky driving behaviors or accidents (Sumer, 2003; Ulleberg, 2001). Numerous factors can influence risky driving behaviors: demographic characteristics, environmental factors, road and vehicle conditions, enforcement intensification, and personality (Sumer, 2003). However, the way in which these factors relate to each other and connect with risky driving behavior depends on the researcher's scope of study and purpose.

Although many studies show a direct connection between the aforementioned factors and risky driving behaviors, other studies demonstrate that these factors could affect risky driving behavior through intermediate factors such as driver's attitude or risk perception (Ulleberg and Rundmo, 2003; Wong et al., 2010b). For example, in addition to direct effects, Machin and Sankey (2008) found that personality has indirect effects on speeding via risk perception. Nelson et al. (2009) examined the relationships between driver's perceived risk, reported emotionality, perceived importance, and cell phone usage (including initiating and answering) while driving. Nordfjaern et al. (2010) found significant relationships between driver attitudes and driver behavior in rural and urban areas while controlling for age, gender, educational achievement, and personality.

In one of the few studies targeting motorcyclists, Chen (2009) found that an altruistic personality has a direct effect on risky driving behavior, while a personality that includes anxiety, anger, sensation-seeking, and lack of norms has an indirect effect on behavior through attitude towards risky driving. Wong et al. (2010b) also developed a framework specific to young motorcyclists. Their framework considers two primary behavior theories – the theory of planned behavior and the risk homeostasis theory – to mediate between personality and risky driving behavior. This framework consists of the comprehensive factors discussed in previous studies, such as driver's attitude and risk perception.

The framework adopted in this study is the same one developed by Wong et al. (2010b), as Fig. 1 illustrates. This framework includes three levels: (1) an explanatory level, which consists of three personality traits that explain the internal characteristics of individual differences and demonstrates consistent patterns and tendencies in individual reactions to the external environment; (2) a latent intermediate level, which contains five constructs that act as social cognitive factors mediating between personality traits and risky driving behaviors; (3) a dependent level, which consists of two constructs that represent motorcyclist's risky driving behaviors.

The three personality traits used in this study are sensation seeking, amiability, and impatience. Sensation seeking is defined as a personality trait involving an individual desire for excitement or stimuli. Amiability refers to a friendly, sociable, and congenial personality trait. Impatience is the personality trait of being annoyed easily due to undesired conditions, such as delays.

The five social cognitive factors used in this study include riding confidence, affective risk perception, utility perception, traffic condition unawareness, and attitude towards unsafe riding. Riding confidence refers to the perceived behavioral control, as in the theory of planned behavior (Wong et al., 2010b). Affective risk perception includes the concern of risky driving behaviors, which reflects the risk that drivers assign to such behavior based on their experience instead of actual rider risks. Utility perception represents risky behavior beliefs, and is measured by accepting certain risky riding behaviors to save time or simply for fun. Traffic condition unawareness refers to the individual's situational awareness in a given riding environment, and reflects the driver's prevailing manners or safety culture. Finally, attitudes towards unsafe riding indicate the continuous tendency of people to like or dislike such behavior.

Fast riding and riding violation are two common risky riding behaviors in Taiwan, and were therefore chosen as the two types of risky driving behavior in the dependent level.

Appendix A (Table A1) provides questionnaire items for each construct. Readers interested in the development of this framework and a detailed discussion of these constructs can refer to Wong et al. (2010b).

3.2. Selected grouping factors

While both psychological factors and manifest variables[1] are effective indicators of heterogeneous driving behaviors, this study chooses manifest variables as the grouping variables. Unlike psychological factors, which are latent constructs that require reliable and valid measurements, manifest variables are relatively easy to use.

This study uses five manifest variables to define heterogeneous driver groups: gender, age, occupation, violation experience, and

[1] Manifest variables typically refer to measurements that researchers can directly observe or obtain, such as gender or age (Hatcher, 1994).

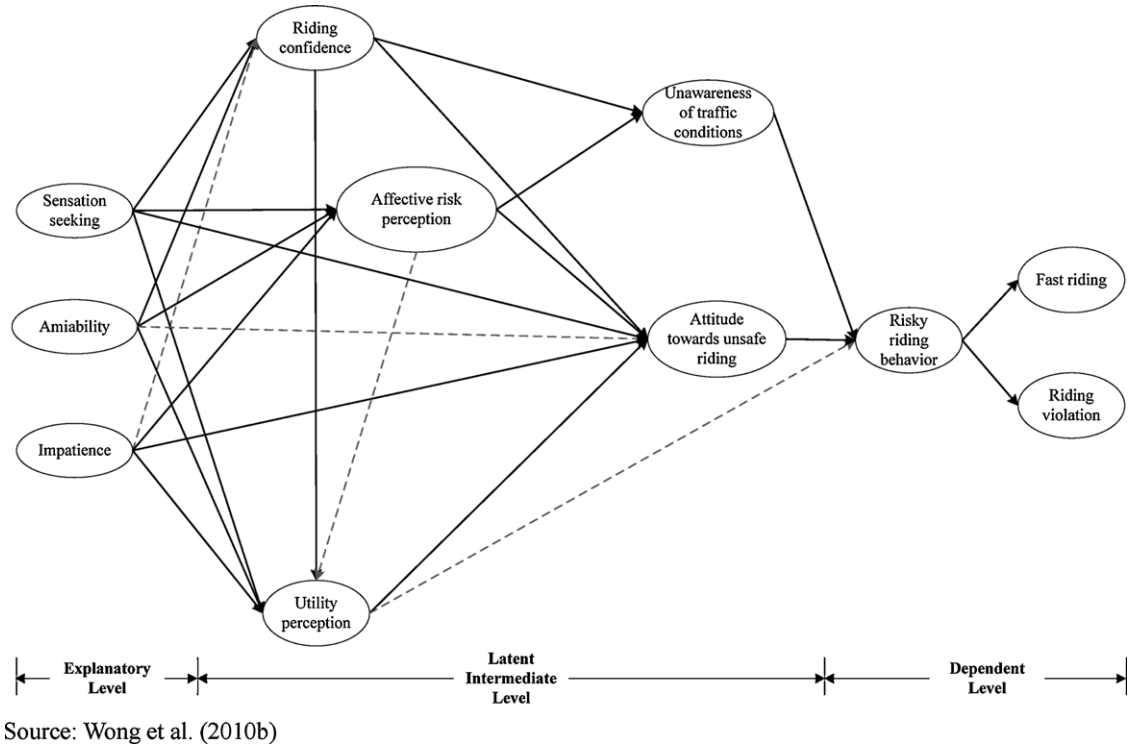

Fig. 1. Risky riding behavior model.

accident experience. These five factors were chosen for their importance in the literature. Sample size is another consideration when choosing grouping variables. That is, each driver group defined by these variables should contain at least 150 samples. This is the smallest sample size needed to provide reliable SEM results, given that the framework was validated using a larger sample size (Fabrigar et al., 2010; Iacobucci, 2010).

Among these factors, gender, occupation, violation experience, and accident experience are categorical variables and thus divided the samples based on their original definition in the survey, i.e. "male vs. female," "non-student vs. student," "violation experience vs. no violation experience," and "accident experience vs. no accident experience." Violation experience includes all kinds of traffic law violations, while accident experience represents the accidents occurring in the past two years. This study treats the only continuous variable, age, as a categorical variable. Twenty-four years of age was chosen as the cut-off point for the sample for the following reason. According to a nationwide report (MTC, 2007b), Taiwanese motorcyclists aged 24 or below have a significantly higher accident rate than those age above 24. This is also a transition point for most young males in Taiwan, as they are graduating from schools, finishing obligatory military service, and stepping into society. The same is true for young females, who are finishing their graduate degrees and starting their careers at this age. Therefore, this study divides the samples into two groups – 18–24 and 25–28.

There are two reasons why this study uses age, rather than driving experience, to define heterogeneous driver groups. First, age is a more comprehensive measure than driving experience. The maturity of motorcycle drivers does not merely depend on driving skills and knowledge; it is also determined by their physical and mental ability. Therefore, grouping drivers by age can explain the structural discrepancy in a causal behavioral framework more clearly than driving experience. Second, while structural discrepancy could also appear between groups with different driving experiences, the result may be affected by the adopted definition of driving experiences.

3.3. Data

This study uses 91 items to represent the constructs in the adopted framework. The questionnaire used in this study includes these 91 items and background information, including grouping variables. College students and transportation professionals were invited to participate in a pilot test. The verified questionnaire was administered to participants satisfying three criteria: (1) 18–28 years old, (2) hold a valid riding license, and (3) have motorcycle-riding experience during the past month. Motorcyclists aged 18–28 have the highest accident rate in Taiwan, and are therefore the subjects of this study. Given the Internet's high penetration rate in Taiwan (more than 70% of Taiwanese people have access to the Internet) and to help reach young riders, the questionnaire was posted on the Internet. Subjects completing the questionnaire qualified for a prize drawing to encourage participation, and a total of 683 valid samples were collected. The composite reliability of most constructs satisfied the conventional threshold of 0.7 (Hatcher, 1994; Wong et al., 2010a). Wong et al. (2010a) used this survey data to investigate heterogeneous driving behavior in drivers with distinct personality traits. This study adopts the same data to take advantage of the data validity and the comparability of heterogeneous driver groups defined by personality traits with those defined by manifest variables. Readers interested in questionnaire development and detailed characteristics of collected samples can refer to Wong et al. (2010a, 2010b).

3.4. Analysis procedure

The analysis in this study includes three steps: First, participants were grouped separately based on selected grouping factors. Second, the resulting groups were examined for their mean score differences in latent constructs such as personality, attitude, and risky driving behavior. Third, the structural discrepancy between groups was tested and investigated using multi-group analysis in structural equation modeling.

4. Results

4.1. Cluster characteristics

Table 1 presents the mean scores and statistical tests of the construct means between clusters defined by gender, age, occupation, violation experience, and accident experience. These results reveal significant differences in construct scores between clusters defined by gender and violation variables. Gender clusters revealed that male motorcyclists are more sensation seeking and less impatient[2] than female motorcyclists. Males also have a higher level of driving confidence, perceive less risk and more utility from risky driving behavior, and are less aware of traffic conditions. Finally, males are more likely to exhibit risky driving behavior, including fast driving and driving violations. The aforementioned contrasts between male and female drivers are also apparent between drivers with traffic law violations and those without traffic law violations. Drivers with violation experience are more sensation seeking and amiable than drivers without such experience, have a higher level of driving confidence, perceive less risk and more utility from risky driving behavior, are less aware of traffic conditions, and are more likely to exhibit risky driving behaviors.

Clusters defined by occupation and accident experience show limited differences in constructs. Compared to non-student motorcyclists, student motorcyclists are more sensation seeking and impatient, and have stronger attitudes towards unsafe driving. Drivers with accident experience are less amiable, perceive more utility from risky driving, and are more likely to demonstrate fast-riding behavior than drivers without accident experience.

Age is the only variable that does not show any significant difference between clusters. In other words, there is insufficient evidence to show differences between 18–24-year-old and 25–28-year-old motorcyclists in their personality traits, driving confidence, attitude, traffic awareness, risk perception, utility perception, and risky driving behaviors.

The discussion above shows various patterns in mean score differences of constructs defined by the selected five variables. The clusters defined by gender and violation experience exhibit the most significant differences throughout most constructs in the behavioral structure, while those defined by age are not very different, and those defined by occupation and accident experience are partially different.

4.2. Multi-group equivalence tests

This subsection shows the results of multi-group statistical tests. These tests include two steps. The first step is to conduct an equivalence test of the measurement model to examine whether the questionnaire items for each construct and the variance and covariance relationships between constructs are consistently valid and reliable across groups. The second step is to implement the equivalence test of the structure model to analyze whether the proposed causal relationship is consistently appropriate across groups. If the measurement model equivalence is satisfied and the proposed causal relationships are inappropriate for groups, path analyses must be performed separately for each group to determine the best causal relationships for each cluster.

Table 2 summarizes the equivalence tests of measurement and structure consistency across clusters. Results show that the consistency of measurement models between clusters defined by all five variables is satisfactory at the 0.05 significance level;

[2] Impatience represents how respondents feel involved in undesired traffic conditions, such as blocked views or traffic jams. Table A1 shows the associated questionnaire items.

Table 1
Mean score of constructs and statistical tests between clusters defined by demographic factors and driving experience.

Construct	Overall mean	Gender			Age			Occupation			Violation			Accident experience		
		Male	Female	t	18–24	25–28	t	Student	Non-student	t	Yes	No	t	Yes	No	t
Sensation seeking	0.93	1.00	0.84	5.95**	0.94	0.90	1.62	0.95	0.89	2.00*	0.99	0.87	4.80**	0.94	0.92	0.55
Amiability	2.49	2.53	2.46	1.13	2.46	2.56	−1.51	2.49	2.51	−0.34	2.58	2.41	2.84**	2.39	2.54	−2.13*
Impatience	1.80	1.74	1.88	−2.72**	1.83	1.76	1.25	1.84	1.73	1.98*	1.8	1.81	−0.15	1.86	1.78	1.30
Riding confidence	2.04	2.17	1.89	7.25**	2.01	2.08	−1.68	2.04	2.04	−0.03	2.15	1.94	5.17**	1.98	2.06	−1.85
Affective risk perception	2.30	2.21	2.40	−4.18**	2.32	2.26	1.14	2.30	2.29	0.29	2.26	2.34	−1.72	2.33	2.28	1.01
Utility perception	1.96	2.08	1.83	4.91**	1.99	1.92	1.27	1.99	1.90	1.60	2.08	1.86	4.29**	2.07	1.92	2.55**
Attitude towards unsafe riding	1.15	1.30	0.98	7.48**	1.15	1.15	−0.11	1.18	1.07	2.37*	1.24	1.07	3.84**	1.15	1.15	0.06
Unawareness of traffic conditions	0.87	0.93	0.81	3.21**	0.89	0.85	0.92	0.88	0.87	0.25	0.93	0.82	2.64**	0.92	0.85	1.71
Risky riding behavior	1.14	1.26	1.00	6.97**	1.14	1.12	0.44	1.15	1.11	1.09	1.23	1.05	4.94**	1.17	1.12	1.00
Fast riding	1.47	1.66	1.26	7.2**	1.46	1.49	−0.59	1.47	1.47	0.04	1.71	1.25	8.31**	1.58	1.43	2.35*
Riding violation	0.78	0.87	0.68	4.82**	0.79	0.78	0.11	0.79	0.77	0.62	0.86	0.71	3.82**	0.81	0.77	0.88

* $p < 0.05$.
** $p < 0.01$.

Table 2
Statistical tests of multi-group equivalence.

Variable	Test	df	Chi-square	*p*-value
Gender	Equivalence of measurement model	17	23.047	0.15
	Equivalence of structure model	40	62.587	0.01*
Age	Equivalence of measurement model	17	25.910	0.08
	Equivalence of structure model	40	56.706	0.04*
Occupation	Equivalence of measurement model	17	13.299	0.72
	Equivalence of structure model	40	42.169	0.38
Accident experience	Equivalence of measurement model	17	15.782	0.54
	Equivalence of structure model	40	41.731	0.40
Violation experience	Equivalence of measurement model	17	12.230	0.79
	Equivalence of structure model	40	42.152	0.38

* $p < 0.05$.

in other words, the construct indicators (i.e., the questionnaire items) used for the whole sample are also satisfactory for each group. On the other hand, this study provides sufficient evidence for the age and gender variables to reject structure equivalence between the associated clusters. This suggests that the path structure for male motorcyclists differs from that for female motorcyclists, while the path structure for 18–24-year-old motorcyclists differs from that for 25–28-year-old motorcyclists. The results of non-significant differences for the remaining three variables suggest that the path structure for the whole sample (i.e., the structure shown in Fig. 1) is also appropriate for motorcyclists with different occupations, violation experience, and accident experience.

Based on the results of significant structural differences for age and gender variables, this study re-calibrates the path structures for the associated clusters to reflect appropriate causal relationships between constructs.

4.3. Discrepancy of causal structures between clusters

Fig. 2 shows the best structures for groups defined by gender and age variables. In this figure, the paths for significant coefficients and the relationships between constructs are labeled with plus/minus signs to indicate positive/negative relationships. Appendix A summarizes the estimation results (Table A2). The goodness of fit indicators for all clusters mostly satisfy or nearly satisfy the conventional requirements, including $\chi^2/df < 2$, GFI (goodness-of-fit index) greater than or equal to 0.9, and RMSEA (root mean square error of approximation) less than or equal to 0.05 (Hatcher, 1994). Therefore, these estimation results are appropriate for discussing the structural discrepancy between male and female motorcyclists and between 18–24-year-old and 25–28-year-old motorcyclists.

4.3.1. Male and female motorcyclists

Fig. 2(a) and (b) show the best structures for male and female motorcyclists. These groups exhibit several key differences. Compared to female motorcyclists, male motorcyclists exhibit additional links from amiability (F2) to risk perception (F5), impatience (F3) to utility perception (F6), riding confidence (F4) to attitude towards unsafe riding (F7), and from utility perception (F6) to risky riding behavior (F9). On the other hand, female motorcyclists exhibit additional links from sensation seeking (F1) to risk perception (F5), risk perception (F5) to unawareness of traffic conditions (F8), and from utility perception (F6) to attitude towards unsafe riding (F7). These different links reveal structural discrepancies and distinct ways in which personality traits affect risky driving behaviors in young male and female motorcyclists. To clarify this point, Table 3 lists all the paths from three personality traits (constructs F1, F2, and F3) to risky driving behaviors (construct F9), and calculates the corresponding path effects and the percentage of their contribution to the formation of risky driving behavior.

Half of the effect of the sensation seeking personality trait on risky driving behavior occurs through male and female driver attitudes (i.e., path F1 → F7 → F9) as Table 3 shows. The other half of its effect occurs through different paths for male and female motorcyclists. Perceived utility greatly influences sensation-seeking male motorcyclists (i.e., path F1 → F6 → F9), accounting for 38.9% of total effect. In other words, sensation-seeking male motorcyclists are more likely to conduct risky driving behavior due to their perceived utility from risky driving, such as excitement or fun. On the other hand, the way in which sensation-seeking female motorcyclists conduct risky driving behavior is rather sophisticated. The most obvious examples are the two paths through risk perception, F1 → F5 → F7 → F9 and F1 → F5 → F8 → F9, which account for more than 35% of the total effect. These two paths suggest that, unlike straightforward response of their male counterpart's, sensation-seeking female motorcyclists take a step back and carefully calculate their perceived driving risk before conducting risky driving behaviors.

The paths linking amiability to risky driving behavior and the associated total effects are extremely different between male and female motorcyclists. Amiable male motorcyclists conduct risky driving behaviors based on a balance between two paths: the positive effects of riding confidence (i.e. path F2 → F4 → F7 → F9) and the negative effects of risk perception (i.e. path F2 → F5 → F7 → F9). Amiable male motorcyclists are less likely to conduct risky driving behaviors because their perceived risk due to risky driving outweighs their confidence. Compared to less amiable male drivers, amiable female motorcyclists, through their riding confidence (F4), utility perception (F6) and attitude towards unsafe riding (F7), are more likely to conduct risky driving behavior because this path consists of only positive links.

As for motorcyclists with an impatient personality, males and females alike depend on a balance between positive and negative path effects to determine their risky driving behaviors. Most of the positive path effects for male and female motorcyclists come from the same path, F3 → F7 → F9. This shows that impatient motorcyclists, whether male or female, conduct risky driving behavior simply because their attitudes towards unsafe riding are triggered by their impatience with traffic conditions. Regarding paths with negative effects, both male and female motorcyclists have the path F3 → F5 → F7 → F9. This indicates that perceived risk triggers a safer attitude, which reduces a motorcyclist's intention to engage in risky driving behavior. Young impatient female motorcyclists show an additional path with a substantial negative impact: path F3 → F5 → F8 → F9. This path includes the construct of unawareness of traffic conditions (F8), suggesting that when impatient female motorcyclists perceive risks, they have a safer

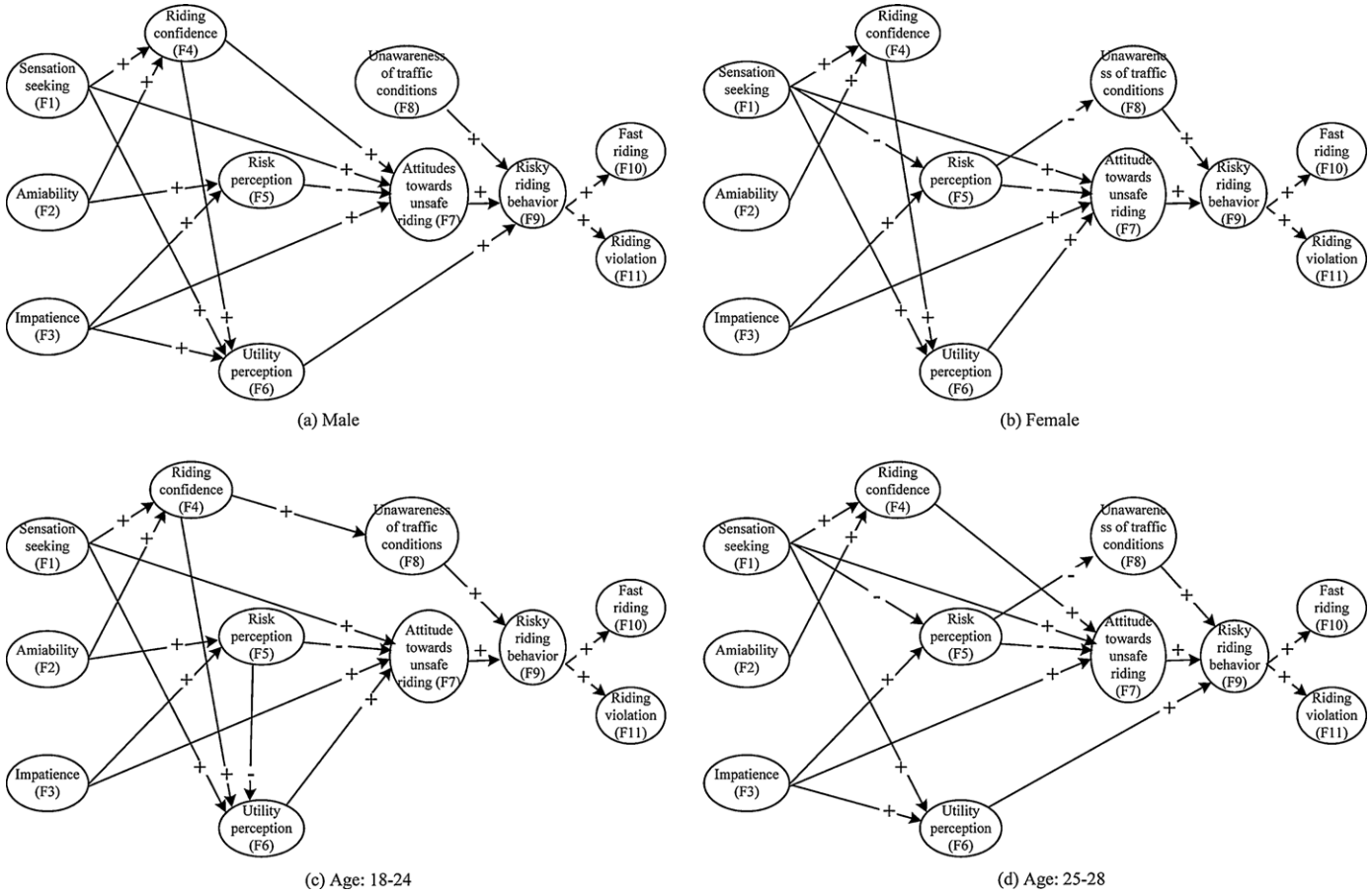

Fig. 2. Calibrated structures and relationships between constructs.

Table 3
Effects[a] of personality traits on risky riding behavior.

Personality trait	Impact path	Gender		Age	
		Male	Female	18–24	25–28
Sensation seeking	F1 → F4 → F7 → F9	0.030 (10.1)[b]			0.024 (5.8)
	F1 → F4 → F6 → F7 → F9		0.002 (1.1)	0.008 (3.3)	
	F1 → F4 → F8 → F9			0.027 (11.2)	
	F1 → F5 → F7 → F9		0.030 (16.7)		0.080 (19.1)
	F1 → F5 → F8 → F9		0.036 (20.0)		0.044 (10.5)
	F1 → F6 → F9	0.116 (38.9)			0.105 (25.1)
	F1 → F6 → F7 → F9		0.032 (17.8)	0.052 (21.5)	
	F1 → F7 → F9	0.152 (51.0)	0.080 (44.4)	0.155 (64.0)	0.165 (39.5)
	Total effect[c]	0.298 (100.0)	0.180 (100.0)	0.242 (100.0)	0.418 (100.0)
Amiability	F2 → F4 → F6 → F7 → F9		0.002 (100.0)	0.006 (120.0)	
	F2 → F4 → F7 → F9	0.024 (−342.9)			0.014 (100.0)
	F2 → F4 → F8 → F9			0.020 (400.0)	
	F2 → F5 → F6 → F7 → F9			−0.001 (−20.0)	
	F2 → F5 → F7 → F9	−0.031 (442.9)		−0.020 (−400.0)	
	Total effect	−0.007 (100.0)	0.002 (100.0)	0.005 (100.0)	0.014 (100.0)
Impatience	F3 → F4 → F6 → F7 → F9		−0.007 (10.1)	0.010(10.0)	
	F3 → F5 → F6 → F7 → F9			−0.004(−4.0)	
	F3 → F5 → F7 → F9	−0.067 (−46.5)	−0.057 (82.6)	−0.071 (−71.0)	−0.098 (251.3)
	F3 → F5 → F8 → F9		−0.069 (100.0)		−0.054 (138.5)
	F3 → F6 → F9	0.030 (20.8)			0.031 (−79.5)
	F3 → F7 → F9	0.181 (125.7)	0.064 (−92.7)	0.165 (165.0)	0.082 (−210.3)
	Total effect	0.144 (100.0)	−0.069 (100.0)	0.100 (100.0)	−0.039 (100.0)

[a] Effects are the products of coefficients along the path between the two specified constructs that involve intervening constructs.
[b] Numbers in the parentheses represent percentages.
[c] Total effect is the sum of all impact path effects.

attitude, are more aware of traffic conditions, and are less likely to conduct risky driving behaviors. Due to this path difference, the total effect of impatience is negative for female motorcyclists, but positive for male motorcyclists. When young motorcyclists are impatient, males are more likely to demonstrate risky driving behavior, but females do not. This difference may depend on whether perceived risk affects traffic condition awareness. This phenomenon again reveals that females have a relatively cautious driving style.

A noticeable link for both male and female motorcyclists is the positive link between riding confidence (F4) and attitude towards unsafe riding (F7). This is the only link that male motorcyclists have but female motorcyclists do not, and that distinguishes how riding confidence affects attitudes differently in male and female motorcyclists. While male motorcyclists with a higher level of driving confidence directly relate to stronger attitude towards unsafe riding, female motorcyclists with higher confidence consider the perceived utility from risky driving, and then determine their attitude on driving. In other words, male motorcyclists have stronger attitude towards unsafe riding even without perceiving any benefits as long as they have a higher level of driving confidence.

4.3.2. 18–24-year-old and 25–28-year-old motorcyclists

Fig. 2(c) and (d) shows the best structures for 18–24-year-old and 25–28-year-old motorcyclists. The structure discrepancy between these two groups is more obvious than that between male and female groups. This result seems to contradict the one shown in Table 1, where the mean score differences of constructs between age groups are mostly non-significant. This result reveals that merely investigating the mean scores of constructs without exploring the structural relationships of the constructs could lead to incorrect conclusions.

The 18–24-year-old group has five links not shared with its counterpart: amiability (F2) to risk perception (F5), riding confidence (F4) to utility perception (F6), riding confidence (F4) to unawareness of traffic conditions (F8), risky perception (F5) to utility perception (F6), and utility perception (F6) to attitude towards unsafe riding (F7). On the other hand, the 25–28-year-old group has four different links: sensation seeking (F1) to risky perception (F5), impatience (F3) to utility perception (F6), riding confidence (F4) to attitude towards unsafe riding (F7), risky perception (F5) to unawareness of traffic conditions (F8), and utility perception (F6) to risky riding behavior (F9). Table 3 shows how these links produce different paths connecting personality traits and risky driving behavior.

As for the personality trait of sensation seeking, the path F1 → F7 → F9 plays the most significant role in determining the total effect for both groups. For the 18–24-year-old group, this path accounts for 64% of the total effect. In other words, the primary reason why 18–24-year-old motorcyclists conduct risky driving behavior is their unsafe driving attitude, which is due to their sensation-seeking personality trait. Utility perception (F6) also plays a critical role for both groups, accounting for more than 20% of total effects. The corresponding paths include path F1 → F6 → F7 → F9 for the 18–24-year-old group and path F1 → F6 → F9 for the other group. In spite of these similarities, risk perception (F5) (shown in paths F1 → F5 → F7 → F9 and F1 → F5 → F8 → F9) is unique to the more experienced group, motorcyclists aged between 25 and 28. These two paths are responsible for approximately 30% of the total effect. With more sensation seeking, 25–28-year-old motorcyclists perceive less risk, reducing their awareness of traffic conditions and exhibiting a stronger attitude towards unsafe riding. As a result, they conduct more risky driving behavior. In other words, sensation seekers can transform experience into incorrect risk perceptions, which endangers road safety. Obviously, this result is not what we would like to see. Due to the inexperience of novice motorcyclists (i.e., 18–24-year-olds), attitude determines most of their risky driving behavior.

The paths starting from amiability are extremely different for the two age groups. The more experienced group only contains one path, F2 → F4 → F7 → F9, indicating the likelihood of 25–28-year-old amiable motorcyclists to conduct risky driving behaviors when they are more confident about their own driving skills. The younger group exhibits four paths starting from amiability; two of the paths produce positive effects and the other two produce negative effects. Whether they conduct risky driving behavior depends primarily on the balance between the positive effect resulting from unawareness of traffic conditions due to riding confidence (F4 → F8) and the negative effect resulting from a safer attitude due to perceived risk (F5 → F7).

As for the effect of impatient personality trait, both age groups depend on the balance between positive and negative paths to determine the likelihood of conducting risky driving behavior. The most significant positive and negative paths are the same for both groups: path F3 → F5 → F7 → F9 and path F3 → F7 → F9. The former produces a negative effect, while the latter produces a positive effect. These two paths imply that young, impatient motorcyclists conduct risky driving behavior partially due to an unsafe attitude. However, the risk perception (F5), which mediates between impatience (F3) and attitude towards unsafe riding (F7), has a negative effect that partially offsets the positive effect. The positive effect of the younger-aged group outweighs the negative effect and the consequent total effect is positive, indicating a higher likelihood of risky driving behavior for an impatient, novice motorcyclist. On the other hand, the more experienced group shows a more powerful negative effect from path F3 → F5 → F7 → F9. This group also has one additional negative path, F3 → F5 → F8 → F9, and consequently produces a negative total effect. Impatient experienced motorcyclists are less likely to conduct risky driving behavior due to a safer attitude and greater traffic condition awareness resulting from more perceived driving risk.

5. Discussion and the policy implications

This study investigates the roles of manifest variables, including age, gender, occupation, violation experience, and accident experience, on the heterogeneity of young motorcyclists in determining risky driving behavior by examining the construct mean scores and their structural discrepancies. Using statistical tests and multigroup analysis of structural equation modeling, this study shows that structural discrepancy exists between some driver groups, which is not explicitly implied by mean score differences. Mean score differences do not necessarily indicate structural discrepancy, as demonstrated by driver groups with different violation experiences. In addition, the similarity between mean scores does not suggest structural likeness, as illustrated by different age groups of young motorcyclists. Results show that while the theories of planned behavior and risk homeostasis might explain the general causal structure of risky driving behavior, the significance of causal links between constructs may vary among heterogeneous driver groups. Thus, intervention strategies that focus on reducing the strength of construct mean scores may have a slight effect on preventing risky driving behavior if the construct does not connect with risky driving behavior or if the total effects of the corresponding paths are relatively small.

5.1. Mean score differences and structural discrepancies

The mean score differences obtained in this study agree with the findings of past studies, especially for groups defined by gender

and violation experience (Chang and Yeh, 2007). Male motorcyclists and motorcyclists with violation experience are generally more sensation seeking, have a higher level of driving confidence, perceive less risk and higher utility (e.g., fun or excitement), have a stronger inclination toward unsafe driving, are more unaware of traffic conditions, and show more risky driving behaviors. The limited differences between driver groups defined by accident experience may be due to the relatively infrequent and random occurrence of accidents. The enhanced perceived risk due to accident experience may also fade away and become non-significant as time goes by (Lin et al., 2004). The limited differences between driver groups defined by occupation suggests that student drivers are generally more sensation seeking and impatient, but are not significantly different from young non-student drivers in exhibiting risky driving behavior.

Young motorcyclists of different age groups did not show any significant difference in the mean scores of psychological determinants and risky driving behavior. This result seems to contradict previous studies, in which novice drivers significantly reduce their risky driving behaviors two or three years after obtaining their driver's license (Langley et al., 1996; Simpson, 2003). Taiwan's lack of a sophisticated licensing program may be reason for the different findings in this study. While 18 is the minimum age to obtain a motorcyclist's license, Taiwanese motorcyclists require a certain period of time to become experienced drivers. The licensing procedure for mopeds and light motorcycles in Taiwan requires no prior experience or compulsory training. Instead, novice motorcyclists learn practical driving skills by themselves after obtaining a driver's license (Chang and Yeh, 2007; Chen, 2009; Wong et al., 2010b).

The significant structural discrepancy between drivers of different age ranges suggests that even though it is difficult to alter the psychological status of young motorcyclists, their driving behaviors can be adapted through learning and experience. This study shows that risk perception is a critical construct determining the structural discrepancy between 18–24-year-old and 25–28-year-old drivers. The latter group is particularly cautious because of their awareness of traffic conditions and perceived road risk. On the contrary, the younger group does not exhibit this causal path. This may reflect the over-simplified tests for acquiring a motorcyclist's license in Taiwan: a written test only for mopeds and light motorcycles with an engine capacity of less than 50 cm^3, and a written and track test[3] for those with an engine capacity less than 250 cm^3. Moreover, a motorcyclist's license can be immediately obtained after passing the exams without any sophisticated licensing procedures such as learner's permit, probationary licensing, provisional licensing, or graduated licensing (Simpson, 2003). The results above suggest that some measures, such as graduated licensing schemes, may be necessary to address this problem.

In addition to age groups, this study reveals structural discrepancies between male and female motorcyclists. Compared to female motorcyclists, male motorcyclists, exhibit a simpler causal behavioral structure in terms of fewer links with negative path coefficients and fewer paths connecting personality to risky driving behavior. This discrepancy partially explains why male and female motorcyclists behave differently even when they have similar personality traits or encounter similar traffic conditions. For example, seeking excitement or fun is a simple reason for male motorcyclists to conduct risky driving behavior if they are relatively sensation seeking. On the other hand, the perceived risk and awareness of traffic conditions might inhibit female motorcyclists from conducting risky driving behavior even if they are relatively sensation seeking.

Though there are structural discrepancies in some driver groups, critical constructs consistently play roles in different driver groups. Among the social psychological determinants adopted in this study, the utility perception and driver attitude constructs include more incident and emanating links and are associated with relatively stronger path effects. This result echoes the findings of many studies (Ajzen, 1991; Chen, 2009; Forward, 2010; Iversen, 2004; Kim and Yamashita, 2007), and reinforces the importance of educating young motorcyclists regarding safe driving and the severity of traffic accidents caused by risky driving.

5.2. A more comprehensive approach to devising intervention strategy

Previous studies use the mean score difference to devise intervention strategies to reduce risky driving behavior and traffic accidents. However, this study shows that the effectiveness of reducing the strength of construct mean scores depends on the importance of the constructs in a causal behavioral structure. Thus, the findings of this study provide at least three types of intervention strategies: reducing the strength of undesired constructs, adding desired links, and removing or reducing the strength of undesired links.

For example, a driver's attitude is apparently the most critical construct connecting personality and risky driving behavior because it is associated with the most paths and the strongest total effects. Thus, a unit change in the driver's attitude has a greater effect on risky driving behavior than other constructs. Nonetheless, it can be very difficult to change driver's attitude.

Due to structural discrepancies, a change in the construct score means can have different effects on driver groups. For example, strategies to reduce the overconfidence of young motorcyclists could have a greater effect on male motorcyclists than female motorcyclists. This is because riding confidence is associated with more paths and stronger total effects for male drivers than female drivers.

The links between constructs are also critical elements to consider when devising intervention strategies. One way is to build desired links. For example, the negative link between risk perception and unawareness of traffic conditions helps reduce risky driving behavior for female motorcyclists, but this link is absent for male motorcyclists. Educating young male motorcyclists about the possible dangers and related risks hidden in the driving environment could build this link. Another way to devise an intervention strategy is to avoid undesired links. For example, research shows a link between utility perception and risky driving behavior for male motorcyclists, but not for female motorcyclists. This link increases the possibility of male motorcyclists conducting risky driving behavior because of the excitement or fun of it. Educating young male motorcyclists about the possible severity of risky driving behavior or providing them with accident archives might reduce the strength of this link.

6. Concluding remarks

Previous studies on this topic use psychological and demographic factors to distinguish heterogeneous driver groups. This study complements previous studies by demonstrating the advantages of using demographic factors to divide young motorcyclists into groups with significant structural discrepancies and explore the source of heterogeneity.

[3] This is a road test at an indoor site where all driving conditions are pre-specified and no other vehicles are present.

Wong et al. (2010a) used the same survey data to investigate how drivers with different personality traits shaped risky driving behavior in distinct ways; their study shows significant structural discrepancies among four driver groups: risky, aggressive, conservative, and nervous drivers. The structures they discovered using personality traits are somewhat different from the current structures, discovered by demographic factors. This might result from two reasons. First, because a driver has a mixture of personality traits, the structures defined by demographic factors could be averages of the structures defined by personality traits. For example, although male drivers are more aggressive than female drivers, not all male drivers are aggressive. According to Wong et al. (2010b), the average male motorcyclist is 33.33% aggressive, 26.78% conservative, 23.77% risky, and 16.12% nervous. Second, personality traits are only one of the factors characterizing demographic groups. The findings of this study show that demographic factors, such as gender, are effective indicators to distinguish heterogeneous driver groups in terms of both mean score differences and structural discrepancy. However, the other factors causing structural discrepancy are well worth further studies.

Despite the high correlation between age and driving experience[4] in the survey data (correlation coefficient 0.79, significantly at 0.001), age and driving experience function differently in licensing procedures (Simpson, 2003). Therefore, it would be helpful to distinguish between the effects of age and driving experience on structural discrepancy to devise safety strategies, especially for graduated licensing programs. Nevertheless, due to the limited sample size, this study did not control driving experience while examining the structural discrepancies between different age groups.

Because this study focuses on young motorcyclists, the age of participants ranged from 18 to 28 years only. This may partially result in the non-significant differences in personality traits between the two age subgroups. Future studies could expand this age range to better reflect the characteristics of young driver's heterogeneous behaviors and make the results more persuasive.

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Appendix A. Appendix A

Table A1
Questionnaire items for each construct.

Explanatory constructs: personality traits	
Sensation seeking	
	I often crave excitement.
	I sometimes do things just for kicks or thrills.
	It is OK to get around laws and rules as long as you do not break them directly.
	If something works, it is less important whether it is right or wrong.
Amiability	
	Few people think I am selfish and egotistical.
	Few people think of me as calm and calculating.
Impatience	
	Pedestrians block my way while I am riding in an alley.
	I am stuck in a traffic jam.
	I am riding behind a truck and my views are blocked.
	Someone is weaving in and out of traffic.
Latent intermediate constructs	
Riding confidence	
	I can handle any unexpected situation even when riding on unfamiliar roads.
	If I run into danger while riding, I have the skills to get out of it safely.
Affective risk perception	
	Rush running at the start instance of the green light.
	Ride between two lanes of fast moving traffic.
	Ride so close to the front vehicle that it would be difficult to stop in an emergency.
	Merge onto major roads from a minor road when there is oncoming traffic.
	Ride so fast into a corner that I feel like I am losing control.
Utility perception	
	Riding is not only for transportation but also for fun or recreation.
	Riding a motorcycle makes me feel relaxed.
Attitude towards unsafe riding	
	It is acceptable to ride in the opposite lane of a two-lane road for convenience.
	In order to save time, riding against the direction on a one-way road is acceptable.
	With good skills, speeding is OK.
	I think it is OK to speed if the traffic condition allows me to do so.
Unawareness of traffic conditions	
	Do not use mirror to check surrounding vehicles while riding or turning.
	Do not use turn signals when turning.
	Do not use mirror to check surrounding vehicles while riding or turning.
Dependent constructs: risky riding behavior	
Fast riding	
	In order to ride faster, I squeeze through an extremely narrow space between one vehicle and another.
	Compared to the surrounding traffic flow, I ride much faster.
	Disregard the speed limit late at night or in early morning.
Riding violation	
	Drink and ride.
	Run through red lights.
	Ride the wrong way.
	Do not wear a helmet while riding.

[4] Defined as the number of years the participant has ridden a motorcycle.

Table A2
Standardized path coefficients and goodness of fits.

Path	Gender		Age	
	Male	Female	18–24	25–28
F1 → F4	0.293**	0.207**	0.299**	0.351**
F2 → F4	0.239**	0.241**	0.227**	0.209#
F1 → F5		−0.205**		−0.312**
F2 → F5	0.146#		0.111#	
F3 → F5	0.315**	0.395**	0.385**	0.381**
F1 → F6	0.492**	0.493**	0.477**	0.546**
F3 → F6	0.128*			0.159*
F4 → F6	0.183**	0.126#	0.23**	
F5 → F6			−0.086#	
F1 → F7	0.312**	0.216*	0.288**	0.322**
F3 → F7	0.371**	0.172*	0.307**	0.16#
F4 → F7	0.208**			0.133
F5 → F7	−0.438**	−0.391**	−0.343**	−0.5**
F6 → F7		0.173*	0.203**	
F4 → F8			0.111#	
F5 → F8		−0.223**		−0.19*
F6 → F9	0.235*			0.192*
F7 → F9	0.487**	0.372**	0.538**	0.512**
F8 → F9	0.782**	0.788**	0.807**	0.74**
F9 → F10	0.575	0.652	0.591	0.622
F9 → F11	0.64**	0.799**	0.723**	0.639**
Goodness of fit	Chi-square/df = 1.745 GFI = 0.905 AGFI = 0.882 RMSEA = 0.045	Chi-square/df = 1.728 GFI = 0.893 AGFI = 0.868 RMSEA = 0.048	Chi-square/df = 1.775 GFI = 0.917 AGFI = 0.897 RMSEA = 0.042	Chi-square/df = 1.742 GFI = 0.867 AGFI = 0.835 RMSEA = 0.055

* $p < 0.05$.
** $p < 0.01$.
\# $p < 0.1$

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