

Article

# Applying an Extended Theory of Planned Behavior to Predict Young Drivers' In-Vehicle Information System (IVIS) Use Intention and Behavior While Driving: A Longitudinal Two-Wave Survey

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**Abstract:** In-vehicle information system (IVIS) use while driving has raised concerns about driver distraction, especially for young drivers. To understand better their psychological factors, an extended theory of planned behavior (TPB) was employed to predict young drivers' IVIS use intentions and behavior while driving. A two-wave longitudinal survey was conducted to explore the temporal effects of 'intention-behavior' causality. At Time 1, 236 qualified participants completed a main questionnaire assessing the standard TPB constructs (attitude, subjective norms, and perceived behavior control) and the extended constructs (descriptive norms, moral norms, and perceived risks). At Time 2, 145 follow-up questionnaires measuring self-reported behavior were successfully administered. The hierarchical multiple regression analyses showed that the standard constructs account for 36.5% of the intention variance and 41.2% of the behavior variance. The extended constructs additionally contributed 20.3% of intention variance. All variables were identified as significant predictors of intentions, except for perceived crash risks and perceived risks of being caught and fined. The sole significant predictor of prospective behavior was intention. Theoretically, the findings further support the efficacy of the TPB in explaining IVIS use while driving. Practically, it is helpful to design non-legal interventions that sustainably reduce young drivers' engagement in IVIS-related distractions.

**Keywords:** driver distraction; in-vehicle information system; young drivers; theory of planned behavior; a longitudinal survey; road safety



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## 1. Introduction

The in-vehicle information system (IVIS) provides drivers with much supporting information (e.g., navigation, engine, and fuel condition) and entertainment/communication features (e.g., radio, music, and calls) [1]. From 2022 to 2027, the compound annual growth rate of IVIS sales is expected to be 9.44%, reaching 70.22 billion USD in 2027 [2]. Compared to traditional in-vehicle systems, the advances in intelligent networking technology have begun to erode the boundary between mobile phones and IVIS [3]. Given the explicit prohibition surrounding mobile phone use while driving in most countries and the growing incorporation of mobile phone technology in IVIS [4], it is essential to understand the challenges IVIS poses for driver distraction and traffic injury. IVIS-related distractions have drawn widespread concerns from the general public, automobile manufacturers, telecommunications companies, and legislators [5]. Therefore, it is imperative to understand the psychological factors influencing IVIS use while driving to develop sustainably targeted strategies to counter this prevalent but hazardous distracted driving practice.

IVIS use while driving (see Figure 1) is dangerous and even illegal when it endangers safe driving, as it diverts attention away from the primary task of driving and towards the

IVIS secondary tasks. A meta-analysis by Ziakopoulos et al. [6] revealed extensive evidence from official accident reports, simulators, and naturalistic observations demonstrating the negative consequences of IVIS-related distractions. For example, Dingus et al. [7] reported that interactions with in-vehicle devices (e.g., radio, GPS, and climate control) while driving increase the crash probability (odds ratio = 4.6) in Americans, which was higher than fatigued driving (odds ratio = 3.4) and mobile phone use while driving (odds ratio = 3.6). Zhong et al. [8–10] suggested that IVIS, especially the calls and texting features, was more visually demanding regarding total or average glance duration, glance frequency, and long glances over 2 s. Peng et al. [11] identified drivers exhibiting significantly longer visual attention while using IVIS to enter and read text. Unfortunately, there has been no clear legislation against IVIS-related distractions so far; they merely fall within the scope of broader legislation concerning ‘careless’ or ‘dangerous’ driving [12].



**Figure 1.** IVIS use while driving.

In particular, young drivers exhibit the highest usage of IVIS and are more prone to distraction-related injuries [13]. Similarly, Romer et al. [14] emphasized the importance of focusing on young drivers, considering their underdeveloped ability to allocate attention and limited driving experience, particularly regarding technology-based distractions. As evidence, a recent on-road experiment from Zhong et al. [15] revealed the distracting effects of IVIS interaction modalities and secondary task types on young driving behavior. Lansdown [16] indicated that young drivers were more prone to experiencing IVIS-related distractions compared to other age groups. In addition, young drivers may face heightened driver errors due to their use of IVIS, such as breaking a yellow light and failing to detect a pedestrian in a crosswalk [17]. Considering the combined influences of immature experience, fanaticism to use their IVIS, and subsequent rise in driving errors, it is essential to understand the underlying reasons behind young drivers’ continued use of IVIS while driving [18,19].

## 2. Theoretical Framework and Research Hypothesis

### 2.1. Understanding IVIS Use While Driving through the Theory of Planned Behavior (TPB)

A substantial body of research reports the prevalence and risks of young drivers’ IVIS use while driving, but fewer studies have focused on the psychological factors contributing to this behavior. The traffic safety community has often utilized theoretical frameworks, such as the TPB [20–22], to understand the determinants of specific driving behaviors. According to the TPB [20–22], the proximal predictor of an individual’s behavior is their behavioral intention, which is influenced by attitude, subjective norms, and perceived behavioral control (PBC). Attitude refers to an individual’s positive or negative evaluation of behavior and is determined by behavioral beliefs about the advantages or disadvantages of acting. Subjective norms refer to the perceived social pressures from essential other persons and are determined by normative beliefs about approval or disapproval of act-

ing. Finally, PBC refers to an individual's perception of how easy or difficult it is and is determined by control beliefs about barriers or facilitators of acting, which is also likely to influence behavior directly. TPB has been widely used to predict some risky or illegal driving behaviors, such as fatigued driving [23], speeding [24], drunk driving [25], and mobile phone distracted driving [26–30]. However, only limited studies have applied TPB to examine the psychological factors of IVIS use while driving.

Specifically, Wang and Ju [31] initially proposed that it is necessary to use TPB to understand the influencing factors of IVIS use behavior while driving. Oviedo-Trespalacios et al. [32] launched a TPB-based interview investigating the behavioral, normative, and control beliefs associated with IVIS use while driving. IVIS receives inconsistent attitudes. The advantages (e.g., entertainment and driving assistance) and disadvantages (e.g., high price, low reliability, and distractibility) were considered critical beliefs. Regarding subjective norms, family and colleagues only exchanged IVIS during the early learning period and rarely mentioned the risks of IVIS. Around PBC, interviewees indicated that IVIS is usable but generally limited to basic entertainment or navigation features. Overall, the TPB is a helpful framework for exploring IVIS use behavior while driving. However, it is inherently qualitative, precluding researchers from quantitatively analyzing this risky driving behavior. Yao et al. [33] added additional constructs (involvement, information quality, and perceived distraction) based on TPB to investigate the psychological factors of in-vehicle navigation system use while driving and showed that attitude, subjective norms, PBC, navigation involvement, and information quality significantly predicted drivers' behavioral intentions. This study represents a pioneering effort to investigate the psychological predictors of IVIS use intentions using an extended TPB model. However, it must be acknowledged that it employs a cross-sectional survey, thereby constraining the ability to explore the causal relationship between intention and behavior accurately. Additionally, the explanatory capacity of other constructs has yet to be considered thoroughly.

## 2.2. Additional Constructs beyond the TPB

Despite previous studies supporting the ability of TPB to predict IVIS use behavior while driving [31–33], a significant amount of variance still needs to be explored. Expanding the TPB to incorporate other constructs may assist in explaining more variations in behavioral intention [34]. As Ajzen [20–22] stated, adding additional constructs is justified if they have theoretical relevance and contribute significantly to the variance in people's intentions or behavior. Referring to the existing literature on psychological predictors of mobile phone use while driving, in addition to the standard TPB constructs of attitude, subjective norms, and PBC, other predictors have been included, such as descriptive norms [35–39], moral norms [40–44], and perceived risks [45–49]. As a result, this study attempts to apply an extended TPB model to predict young drivers' intention and engagement in IVIS use while driving.

### 2.2.1. Descriptive Norms

Armitage and Conner [34] commented that subjective norms often have the weakest predictability due to their narrow construct components. Adding other normative constructs is of complementary value. Descriptive norms refer to an individual's beliefs regarding behavior that are acquired through observing the actions of others [35–39]. Donmez's research team [35,36] observed that drivers reported higher technology-based distractions if they perceived other drivers on the road also engaging in such distractions. Additionally, Berenbaum et al. [37] and Brown et al. [38] proposed that descriptive norms significantly predict young drivers' texting intentions while driving. Nicolls et al. [39] indicated that young drivers perceive their peers to use mobile phones frequently, and descriptive norms were significantly associated with increased mobile phone use behavior while driving. Hence, young adults who perceive that most drivers around them regularly use IVIS while driving would be more inclined to engage in this behavior.

### 2.2.2. Moral Norms

Moral norms refer to an individual's sense of moral obligation when determining right or wrong to engage in a particular behavior based on societal values [40–44]. Adding moral norms can be worthwhile when investigating unethical or illegal behaviors. In support of this proposal, Nemme and White [40] documented that moral norms significantly predicted young drivers' intention and behavior to text while driving. Similarly, Gauld et al. [41] support the inclusion of moral norms in understanding the intentions and engagement of young drivers in concealed texting. Additionally, Gauld et al. [42] suggested that moral norms had a significant negative relationship with social technology use behavior while driving. Kim [43] and Khanjani et al. [44] found that moral norms consistently inhibited texting intention while driving. Therefore, young drivers who consider using IVIS while driving as morally wrong would exhibit a decreased likelihood of intending to engage in such behavior.

### 2.2.3. Perceived Risks

One crucial factor contributing to unsafe driving practices is an individual's risk perception [45–49]. Similar to mobile phone use while driving, drivers face two significant risks when interacting with IVIS, including perceived crash risks and perceived risks of being caught and fined by the police. Prat et al. [45] observed that perceived crash risks were positively associated with texting intentions while driving. Przepiorka et al. [46] documented that perceived crash risks negatively predicted texting intentions while driving, but perceived risks of being caught and fined were not. Sullman et al. [47] proposed that the two perceived risks did not significantly increase the variability of mobile phone intentions among Ukrainian drivers. Phuksuksakul et al. [48] also found that perceived crash risks do not significantly impact either intention or behavior. However, Sullman et al. [49] suggested that two perceived risks were significant predictors of texting intentions while driving in the UK. Hence, young drivers' perceived risks would inhibit IVIS use while driving.

## 2.3. Knowledge Gaps and Research Objective

In summary, despite the increasing amount of TPB-based research on psychological predictors of young drivers' mobile phone use behavior while driving, limited studies explicitly investigated the intention to use IVIS while driving and the prospective behavior. The most significant difference between mobile phone use behavior and IVIS use behavior while driving is that, by contrast, there is no explicit legal ban on IVIS-related distractions, which may result in young drivers being less aware of the risks of crashing or being caught and fined. In addition, existing TPB surveys of IVIS have used cross-sectional designs, which limit the testing of causality between IVIS use intention and subsequent actual behavior.

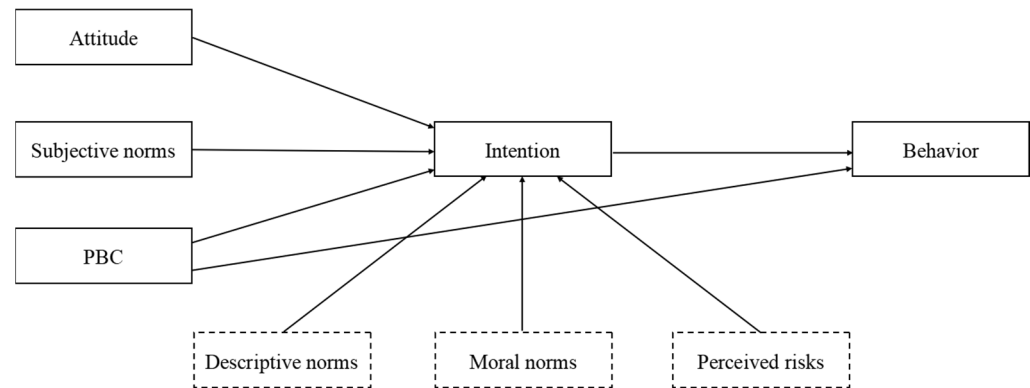
Therefore, this study aimed to address these gaps and launch a two-wave longitudinal survey to explore factors influencing young drivers' intentions and behavior regarding IVIS use while driving based on an extended TPB. In line with the theoretical tenets of the TPB and previous literature about extended constructs, the following hypotheses were proposed:

**Hypothesis 1.** *The standard TPB constructs of attitude, subjective norms, and PBC will corporately predict young drivers' IVIS use intention while driving.*

**Hypothesis 2.** *The extended constructs of descriptive norms, moral norms, and perceived risks (perceived crash risks and perceived risks of being caught and fined) will jointly explain young drivers' IVIS use intention while driving beyond the standard constructs.*

**Hypothesis 3.** *Intention and PBC will collectively predict prospective young drivers' IVIS use behavior while driving.*

According to the above assumptions, an extended TPB model was made (see Figure 2). On the one hand, it supplements the current literature on young drivers' IVIS use behavior. On the other hand, developing a focused driver intervention strategy that sustainably reduces the prevalence of IVIS-related distractions is practically significant.

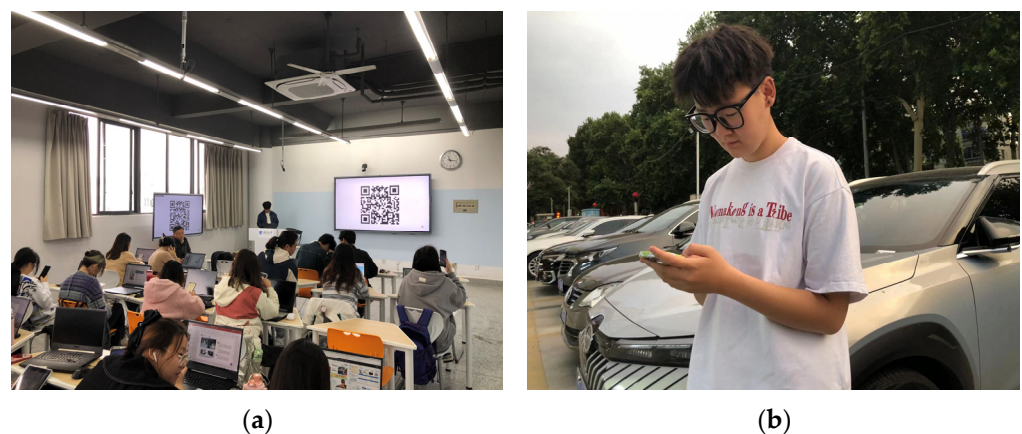


**Figure 2.** An extended TPB model (Solid box: original TPB variables. Dotted box: extended TPB variables).

### 3. Methods

#### 3.1. Participants

The target behavior of this exploratory survey is young drivers' IVIS use behavior while driving. Therefore, a convenience sampling method was employed in the Time 1 survey to gather questionnaires from a total of 236 participants (116 males, 120 females) aged 18–25 years ( $M = 21.66$ ;  $SD = 1.88$ ), who had a current driver's license, owned a car equipped with IVIS, and resided in Chengdu, China. The recruitment snapshot is shown in Figure 3. The college course or lectures about sustainable transportation enlisted 50% ( $n = 118$ ) of the participants. The 25.4% ( $n = 60$ ) of the participants were enlisted by direct approaches on campus or at shopping center parking lots. A snowball sampling technique enlisted all the remaining participants through social media applications (e.g., TikTok, WeChat, and QQ).



**Figure 3.** The recruitment snapshot and locations of participants. (a) College classroom; (b) shopping center parking lots.

As shown in Table 1, most participants had a college education or higher on average ( $n = 169$ ) and mainly drove automatic vehicles ( $n = 167$ ) in urban areas ( $n = 152$ ). They reported driving an average of 4.5 h per week ( $M = 4.50$ ;  $SD = 1.43$ ). The top five functions commonly utilized on their IVIS, in descending order, are as follows: radio ( $n = 213$ ), music ( $n = 208$ ), navigation ( $n = 199$ ), calls ( $n = 191$ ), and social media ( $n = 185$ ). With the co-authors' efforts, 145 participants completed the Time 2 survey, resulting in an attrition

rate of 38.6%. It is agreed that the attrition rate is relatively high, which is discussed further in succeeding sections. The top five IVIS functions, in descending order, are as follows: radio ( $n = 130$ ), music ( $n = 126$ ), navigation ( $n = 119$ ), social media ( $n = 116$ ), and calls ( $n = 114$ ). However, the difference was less than 5%.

**Table 1.** Demographic statistics of Time 1 survey ( $n = 236$ ) and Time 2 survey ( $n = 145$ ).

Demographics	Classification	Time 1 Survey (n)	Time 2 Survey (n)
Gender	Male	116	67
	Female	120	78
Education level	Junior school or below	11	5
	High school	56	31
	College or above	169	109
Transmission type	Automatic	167	110
	Manual	69	35
Driving location	Largely urban area	152	97
	Both urban and rural areas	61	36
	Largely rural area	23	12
Top five IVIS functions	Radio	213	130
	Music	208	126
	Navigation	199	119
	Calls	191	114
	Social media	185	116

### 3.2. Measures

The present study adopted a longitudinal design to explore better the temporal effects of ‘intention-behavior’ causality. It employed a two-wave online survey approach with a one-week time interval. The Time 1 survey focused on intentions as the primary outcome, while the Time 2 survey focused on the actual behavior exhibited by participants during the interval week. This one-week duration was chosen because it provides a suitable timeframe for participants to use IVIS while driving and to recall accurately their behavior [40,41,50].

#### 3.2.1. Main Questionnaire

The main questionnaire listed the standard TPB self-report format, including questions about attitude, subjective norms, PBC, and intention. It also included additional predictors of descriptive norms, moral norms, and perceived risks. All measurement items were adapted from existing literature, during which we consulted two experts in the transportation community to ensure the clarity and reliability of the questionnaire. As TPB-based driver behavior literature was outlined, the questions concerned the target behavior, action, context, and time. Thus, the target behavior under investigation was ‘IVIS use while driving in the next week.’ The scenario follows: ‘Imagine operating the vehicle you typically use. You are traversing an urban road with a designated speed limit of 60 km/h. The current weather conditions are favorable, with a pleasant temperature.’ Attitudes were measured using three 7-point semantic differential scales anchored with (1) unwise to (7) wise, (1) unnecessary to (7) necessary, and (1) unpleasant to (7) pleasant. All the following scales were answered on a 7-point Likert scale, with anchors ranging from (1) strongly disagree/unlikely to (7) strongly agree/likely. Table 2 displays each construct’s measurement items, adapted source, and Cronbach’s Alpha. Each Cronbach’s Alpha is greater than 0.75, confirming the reliability of the questionnaire. The questionnaire also assessed demographic data (e.g., gender, age, and education level), daily functions (e.g., radio, music, and calls), and IVIS frequency of utilization while driving.

**Table 2.** The measurement items, adapted source, and Cronbach’s Alpha of the constructs.

Constructs	Measurement Items	Adapted Source	Cronbach’s Alpha
Intention	I will use the IVIS while driving in the next week. I will interact with the IVIS while driving in the next week. I will adjust the settings of the IVIS while driving in the next week.	[31–33]	0.835
Attitude	For my part, using IVIS while driving next week would be unwise (1) to wise (7). For my part, using IVIS while driving next week would be unnecessary (1) to necessary (7). For my part, using IVIS while driving next week would be unpleasant (1) to pleasant (7).	[31–33]	0.823
Subjective norms	People important to me think it is okay for me to use IVIS while driving next week. People important to me would approve of me using IVIS while driving next week. People important to me would want me to use IVIS while driving next week.	[31–33]	0.830
PBC	I believe that I can drive well even when using IVIS while driving next week. I am confident that I could use IVIS while driving and still drive safely next week. I have complete control over whether or not I use IVIS while driving next week.	[31–33]	0.875
Descriptive norms	Most drivers around me use IVIS while driving next week. Most drivers around me interact with IVIS while driving next week. Most drivers around me adjust the settings of IVIS while driving next week.	[35–39]	0.755
Moral norms	I think that using IVIS while driving next week is wrong. It would be against my principles to use IVIS while driving next week. I will feel guilty if I use IVIS while driving next week.	[40–44]	0.857
Perceived crash risks	How likely is it that you will have a crash if you use IVIS while driving next week?	[45–49]	-
Perceived risks of being caught and fined	How likely is it that you will be caught and fined by the police if you use IVIS while driving next week?	[45–49]	-

Note: Perceived crash risks and perceived risks of being caught and fined are single-measurement items, and neither has Cronbach’s Alpha.

### 3.2.2. Follow-Up Questionnaire

The Time 2 survey comprised questions about drivers’ responses regarding their (a) driving practice and (b) the frequency they use IVIS during the intervening week. Only participants who reported having the opportunity to use IVIS while driving in the previous week were presented with three items asking about the IVIS frequency of utilization (e.g., “How often did you use IVIS while driving in the past week?”; “How often did you interact with IVIS while driving in the past week?”; “How often did you adjust the settings of IVIS while driving in the past week?”), adapted from existing literature [40,41,50]. The participants’ responses were recorded on a 7-point Likert scale, ranging from (1) never to (7) very often. Each participant generated a unique ID code as directed to link the two surveys to ensure confidentiality.

### 3.3. Procedures

Participants were asked to complete two surveys, administered one week apart. The participant information sheet was presented at the beginning of the Time 1 survey. It outlined details of the project, including its purpose, what participation would involve, expected benefits and risks, and information regarding anonymity and confidentiality. Participants were then asked to answer three questions to create a unique identification code, which was also recorded in the second survey to link their survey responses. The first survey took approximately 15 min to complete, and submitting a completed survey was considered consent to participate. Participants with the same internet protocol address could not complete the survey more than once. They had the option to leave the survey midway without completing it. At the end of the Time 1 survey, participants were asked to provide an email address to receive the Time 2 survey one week later. The Time 2 survey took approximately 5 min to complete. Upon completing both surveys, student participants from Southwest Jiaotong University were rewarded with a partial course credit. In contrast, the other participants could enter a draw to win one of five 100 RMB bill vouchers. This longitudinal study program was approved by the Ethics Committee of the School of Design at Southwest Jiaotong University, China (Approval Number: 2022120903).

## 4. Results

Statistical analysis of the data obtained from the questionnaire was performed using the IBM SPSS Statistics, Version 29.0. The chosen significance level for all analyses was set at 0.05. Each construct's score was determined by calculating the mean of all items. Comparatively, the average age in the Time 2 sample was 0.49 years older, with a slightly lower proportion of men. Overall, the participants of Time 1 and Time 2 are relatively consistent, although there is a certain degree of attrition. However, the Chi-square test showed insignificant non-response bias ( $p < 0.05$ ). The multivariate analysis of variance (MANOVA) was launched on all the main questionnaire measures (e.g., intention, attitude, subjective norm, PBC) and reported no statistically significant differences in the scores between participants who completed the follow-up questionnaire and those who did not [Wilks's = 0.94,  $F(7, 148) = 1.55$ ,  $p = 0.181$ ].

### 4.1. Time 1 Survey

First, statistical assumptions, including linearity, normality of residuals, and heteroscedasticity, were evaluated to determine the suitability of the dataset for the planned analyses. Second, the absence of multicollinearity was initially evaluated by examining the bivariate correlations among the predictors and further confirmed by assessing the variance inflation factors. Finally, descriptive statistics and hierarchical multiple regressions were implemented. In the present study, the independent variables consisted of demographic variables (i.e., gender and age), along with the standard TPB constructs (i.e., attitude, subjective norms, and PBC) and extended constructs (i.e., descriptive norms, moral norms, and perceived risks), which were examined at each step of the hierarchical multiple regression. The dependent variables were the intentions to use IVIS while driving.

#### 4.1.1. Descriptive Statistics (Time 1 Survey)

Table 3 presents a comprehensive overview of participants' frequency of using IVIS while driving. Most participants (71.4%) indicated they utilized IVIS regularly, specifically at least 1–2 times per week. Individually, it was found that 69.9% of the participants reported regularly searching for a music song while driving at least 1–2 times per week. In the second position, most participants (67.6%) reported frequently making contact calls while driving, at least 1–2 times per week. In the third position, 66.2% of the participants reported regularly changing radio stations while driving, precisely at least 1–2 times per week. In the fourth position, most participants (59.5%) reported setting a navigation destination while driving, with a frequency of at least 1–2 times per week. In the fifth position, a notable percentage of respondents (53.7%) reported consistently posting social

content while driving, specifically 1–2 times per week. The data above indicate that IVIS use while driving is prevalent among the young drivers included in this sample.

**Table 3.** Reported frequencies of IVIS use behavior while driving (%).

How Often Do You Engage in the Following IVIS Activities While Driving?	More than Once a Day	Daily	1–2 Times Weekly	1–2 Times Monthly	1–2 Times Semi-Annually	1–2 Times Annually	Never
Use IVIS for any purpose	14.9	27.3	29.2	11.5	8.2	2.5	6.4
Search for music	14.4	26.6	28.9	12.1	7.6	1.9	8.5
Make a contact call	14.1	25.4	28.1	10.9	8.3	3.8	9.4
Adjust a radio station	14.6	24.9	26.7	17.0	8.5	2.6	5.7
Set a navigation destination	12.8	22.1	24.6	16.5	9.4	4.7	9.9
Post a social content	11.5	20.7	21.5	18.2	12.1	5.9	10.1

Table 4 displays each construct's means, standard deviations, and bivariate correlations between these predictors and intentions. In general, the descriptive statistics reveal that the participants demonstrated favorable attitudes toward the use of IVIS while driving. They also held the belief that influential individuals within their social circles would express disapproval towards their practice of using IVIS while driving. Furthermore, the participants strongly believed in their competence to interact safely with IVIS while driving. They also expressed a strong inclination or intention to use IVIS while driving.

**Table 4.** Means, standard deviations, and bivariate correlations between predictors and intentions (n = 236).

Constructs	M (SD)	1	2	3	4	5	6	7	8	9	10
1. Gender #	-	1	−0.02	0.10	−0.07	0.18 *	−0.03	0.10	−0.16 *	−0.05	0.04
2. Age	21.63 (2.14)		1	−0.32 **	−0.35 **	0.07	0.11	0.17 *	0.41 **	−0.16 *	0.11
3. Attitude	3.95 (1.77)			1	0.42 **	0.38 **	0.29 **	−0.37 **	−0.39 **	−0.20 *	0.27 **
4. Subjective norms	2.93 (1.42)				1	0.28 **	0.32 **	−0.36 *	−0.17 *	−0.10	0.18 *
5. PBC	4.03 (1.13)					1	0.30 **	−0.34 **	−0.44 **	−0.42 **	0.35 **
6. Descriptive norms	4.46 (1.69)						1	−0.15 *	−0.43 **	−0.46 **	0.33 **
7. Moral norms	3.72 (1.70)							1	0.52 ***	−0.53 ***	−0.55 ***
8. Perceived crash risks	2.15 (1.02)								1	0.60 ***	−0.21 *
9. Perceived risks of being caught and fined	2.07 (0.98)									1	−0.51 ***
10. Intention	3.74 (1.05)										1

Note: # Categorical variable: Female = 0, Male = 1; Statistical significance: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

Regarding extended constructs, the higher scores for the descriptive norms indicated that participants generally believed using IVIS while driving was a prevalent behavior among drivers around them. In addition, the participants believed in the ethical standards linked to safe driving. The low scores for the perceived risks indicate that participants perceive a lower probability of being involved in a car crash and being caught and fined by law enforcement, even when using an IVIS while driving. Attitude, subjective norms, PBC, and descriptive norms demonstrated significant positive correlations to the use of IVIS while driving. The intention to use IVIS while driving was found to be significantly negatively correlated with moral norms, perceived crash risks, and perceived risks of being caught and fined. Interestingly, there was no significant correlation between driver characteristics, such as gender and age, and the intention to use IVIS while driving.

#### 4.1.2. Hierarchical Multiple Regressions Predicting Intention to IVIS Use While Driving

The current study employed hierarchical multiple regressions to examine the psychological factors influencing the intention to use IVIS while driving. In order to control for potential confounding factors, the variables of age and gender were incorporated as covariates in Step 1. The standard TPB constructs, namely attitude, subjective norms, and PBC were included in Step 2. Step 3 incorporated the expanded constructs of descriptive norms, moral norms, and perceived risks (perceived crash risks and perceived risks of being caught and fined). The main aim was to determine if incorporating extended TPB

constructs contributed to a more significant explanation of variance in intentions to use IVIS while driving beyond the standard TPB constructs.

The results are displayed in Table 5. The model analyzed in Step 1 did not produce statistically significant results [ $F(2, 233) = 2.95, p = 0.088, \Delta R^2 = 0.003$ ]. The model exhibited statistical significance in Step 2 [ $F(3, 230) = 73.54, p < 0.001, \Delta R^2 = 0.365$ ]. The study findings indicate that a substantial portion, precisely 36.5%, of the variance in intentions to use IVIS while driving was adequately explained. Attitude, subjective norms, and PBC were identified as significant positive predictors of intention. The extended TPB constructs in Step 3 substantially enhanced the explanatory power of the intention to engage in IVIS use while driving. This improvement accounted for an additional 10.3% of the variance [ $F(4, 226) = 44.16, p < 0.001, \Delta R^2 = 0.203$ ]. Descriptive norms and moral norms emerged as significant predictors.

**Table 5.** Hierarchical multiple regressions: Predicting intention to IVIS use while driving ( $n = 236$ ).

Step	Constructs	B	95% CI	$\beta$	F	$R^2$	$\Delta R^2$	$sr^2$
1	Gender <sup>#</sup>	0.11	(−0.04, 0.23)	0.09	5.95	0.003	0.003	0.20
	Age	−0.13	(−0.21, 0.27)	−0.10				0.30
2	Gender	0.10	(−0.04, 0.23)	0.08	73.54 ***	0.368 ***	0.365 ***	0.15
	Age	−0.11	(−0.21, 0.27)	−0.09				0.22
	Attitude	0.51	(0.37, 0.69)	0.40 ***				0.47
	Subjective norms	0.16	(0.01, 0.31)	0.11 *				0.25
	PBC	0.43	(0.31, 0.59)	0.32 ***				0.40
3	Gender	0.08	(−0.04, 0.23)	0.05	93.18 ***	0.571 ***	0.203 ***	0.11
	Age	−0.09	(−0.21, 0.27)	−0.07				0.16
	Attitude	0.46	(0.37, 0.69)	0.40 ***				0.40
	Subjective norms	0.15	(0.01, 0.31)	0.11 *				0.21
	PBC	0.40	(0.31, 0.59)	0.32 ***				0.37
	Descriptive norms	0.34	(0.22, 0.54)	0.26 **				0.31
	Moral norms	−0.24	(−0.53, −0.07)	−0.15 *				0.25
	Perceived crash risks	−0.11	(−0.22, 0.15)	−0.08				0.11
	Perceived risks of being caught and fined	0.10	(0.10, 0.38)	0.04				0.10

Note: <sup>#</sup> Categorical variable: Female = 0, Male = 1; Statistical significance: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

In the final step, the overall model exhibited statistical significance [ $F(9, 226) = 108.18, p < 0.001, R^2 = 0.571$ ]. Furthermore, the model demonstrated a significant explanatory power, explaining 57.1% of the variance in the dependent variable. All conventional TPB constructs and supplementary constructs were identified as significant predictors of intention, except for perceived crash risks and perceived risks of being caught and fined. Specifically, the attitude explained 40% of the distinct variance in intention ( $sr^2 = 0.40$ ). Subjective norms ( $sr^2 = 0.21$ ) and PBC ( $sr^2 = 0.37$ ) individually contributed 21% and 37% of the unique variance in intention, respectively. Descriptive norms ( $sr^2 = 0.31$ ) and moral norms ( $sr^2 = 0.25$ ) contributed distinctly to the intention variance, accounting for 31% and 25%, respectively.

#### 4.2. Time 2 Survey

Despite the researchers' efforts, a relatively high attrition rate of 38.6% was observed between the two surveys, which could be because they had not used their car in the past week and, if they had, had not used IVIS. In addition, it could also be due to a lack of motivation, which further reduced the sample size utilized in the analyses. However, paralleling the previous two-wave longitudinal studies about mobile phone use while driving [40,41,50], the final sample size of 145 participants was deemed modest yet acceptable for conducting a scaled-down analysis in this context. That is to say, in contrast to exploring the comprehensive extended TPB constructs for predicting prospective behavior, the final

regression analyses focused solely on investigating the standard TPB constructs, namely attitude, subjective norms, intention, and PBC, as predictors of behavior.

#### 4.2.1. Descriptive Statistics (Time 2 Survey)

Table 6 presents summary statistics regarding IVIS use behavior while driving. The average score for behavior exhibited a marginal high, indicating that participants actively engaged in IVIS throughout the intervening week. Intention and PBC exhibited a statistically significant correlation with behavior. The correlation between intention and PBC was strongly positive ( $r = 0.69$ ), indicating the possibility of multicollinearity concerns. In line with the TPB, it is considered appropriate to include both variables in the predictive analysis of behavior. Therefore, both constructs were retained for the regression analyses to predict behavioral engagement.

**Table 6.** Means, standard deviations, and bivariate correlations between predictors and intentions (n = 236).

Constructs	M (SD)	1	2	3	4	5
1. Attitude	3.91 (0.85)	1	0.41 **	0.33 **	0.34 **	0.42 **
2. Subjective norms	2.98 (0.77)		1	0.21 **	0.25 **	0.18 *
3. PBC	4.15 (0.84)			1	0.69 ***	0.36 **
4. Intention	3.56 (0.91)				1	0.70 ***
5. Behavior	3.53 (1.06)					1

Note: Statistical significance: \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ .

#### 4.2.2. Hierarchical Multiple Regressions Predicting IVIS Use Behavior While Driving

Table 7 displays the secondary hierarchical multiple regression results examining the predictive capacity of TPB in predicting actual IVIS use behavior while driving within the previous week. According to the TPB, intention and PBC are considered influential predictors of behavior and were included in step 1. The combined influence of these factors explained a substantial 40.2% of the variability in behavior [ $F(2, 142) = 81.50$ ,  $p < 0.001$ ,  $\Delta R^2 = 0.402$ ]. Attitude and subjective norms were included in step 2 of the model. Consistent with the theoretical expectations, they did not explain any significant additional variance beyond intention and PBC [ $F(2, 140) = 0.13$ ,  $p = 0.560$ ,  $\Delta R^2 = 0.01$ ]. In the final step, the overall model demonstrated statistical significance [ $F(4, 140) = 84.13$ ,  $p < 0.001$ ,  $R^2 = 0.412$ ]. Intention emerged as the sole significant predictor of behavior, explaining 39% of the variance in intention ( $sr^2 = 0.39$ ).

**Table 7.** Hierarchical multiple regressions: Predicting intention to IVIS use while driving (n = 236).

Step	Constructs	B	95% CI	$\beta$	F	$R^2$	$\Delta R^2$	$sr^2$
1	Intention PBC	0.69 0.13	(0.40, 0.77) (−0.03, 0.28)	0.58 *** 0.09	81.50 ***	0.402 ***	0.402 ***	0.41 0.11
2	Intention PBC Attitude Subjective norms	0.67 0.11 0.07 −0.04	(0.40, 0.77) (−0.03, 0.28) (−0.02, 0.24) (−0.11, 0.15)	0.53 *** 0.08 0.05 −0.01	84.13 ***	0.412 ***	0.01	0.39 0.10 0.08 0.05

Note: Statistical significance: \*\*\*  $p < 0.001$ .

## 5. Discussion

This study launched a two-wave longitudinal survey and used an extended TPB model to investigate the psychological factors of intention and behavior of young drivers' IVIS use while driving. In general, there was a unanimous agreement regarding the efficacy of TPB in predicting IVIS use during driving. Incorporating additional constructs enhances the explanation of intention variance, surpassing the standard TPB constructs. Individually, the predictors of descriptive norms and moral norms demonstrated facilitating effects, whereas the perceived crash risks and perceived risks of being caught and fined did not

exhibit significant effects. Regarding prospective behavior, the sole significant predictor was the intention.

#### 5.1. Hypothesis 1: Efficacy of the Original TPB Constructs to Predict Intention

Hypothesis 1 was fully validated. After controlling for gender and age, the standard TPB variable explained 36.5% of the variance in the intention of young drivers to use IVIS while driving in the upcoming week. This finding supports the argument that the TPB offers a valuable and organized framework for comprehending the psychological factors influencing young drivers' decision-making regarding the use of IVIS while driving [31–33]. However, it is crucial to acknowledge that the TPB's predictive efficacy in this study is relatively lower than that of Yao et al. [33], which accounted for 41.46% of the variation. The potential explanation for this phenomenon is that the current survey did not target specific IVIS usage or function (in-car navigation), as Yao et al. [33] did, but instead focused on the overall IVIS usage, including calls, radio, music, navigation, and social media. Therefore, we infer that the predictive utility of TPB may be higher for specific IVIS behavior than general, which is also replicated in mobile phone use behavior while driving [26–30].

Specifically, all three standard TPB variables were determined to be statistically significant predictors of young drivers' intention to use IVIS while driving in the forthcoming week. Attitude emerged as the most influential factor, with PBC closely behind, while subjective norms had the most negligible impact. These findings align with the existing literature, which examined the factors influencing young drivers' intention to use mobile phones while driving [26–30]. Therefore, this may represent a common law regarding the psychological factors influencing technology-based distractions, specifically IVIS and mobile phone use. Furthermore, subjective norms' influence on the intention to use mobile phones while driving may only sometimes be significant [27,43,49]. This preliminary finding suggests that the normative beliefs surrounding using IVIS and mobile phones while driving may differ. However, it is essential to gather additional evidence to substantiate this claim.

The findings revealed that young drivers with a more positive attitude about IVIS use while driving were more inclined to perform IVIS secondary tasks. Additionally, young drivers who received more significant approval from essential other persons (e.g., parents, family, and friends) were more likely to interact with IVIS while driving. Finally, young drivers who thought IVIS was easier to use and experienced less resistance while driving expressed a high intention to engage in this behavior.

#### 5.2. Hypothesis 2: Efficacy of the Additional Constructs to Predict Intention beyond the Standard TPB Constructs

Hypothesis 2 garnered limited empirical backing. After controlling for demographics and standard TPB variables, the extended variable exhibited a noteworthy impact, accounting for an additional 20.3% of the intention variability of young drivers' IVIS use while driving the following week. Descriptive norms and moral norms were recognized as influential factors. In contrast, perceived risks, whether related to the risks of crashing or being caught and fined, did not demonstrate a substantial impact.

Descriptive norms were found to enhance the ability to predict young drivers' intentions to use IVIS while driving in the upcoming week. This finding is consistent with prior studies investigating the intention to use mobile phones while driving [35–39]. Therefore, including descriptive norms in the extended TPB model proves advantageous when examining the behavior of using IVIS or mobile phones while driving. Individuals who hold the belief that using IVIS while driving is morally objectionable demonstrated a decreased propensity to engage in such behavior. This finding further supports and expands the conclusions drawn in the existing literature [40–44]. In other words, moral norms significantly predicted IVIS and mobile phone use behavior while driving. Moral norms can serve as a valuable indicator in cases where behavior is deemed unethical or illegal, such as in-vehicle technology distraction. Additionally, it was observed that descriptive norms and moral norms exert a more significant influence on normative effects compared to subjective norms.

This finding supports the prevailing viewpoint that the TPB should be broadened with additional normative constructs due to narrow normative beliefs of subjective norms [34].

Surprisingly, compared to previous research [45–49], this study did not confirm the inhibiting action of perceived crash risks on young drivers' intention to use IVIS while driving in the upcoming week. Several factors contribute to this outcome. One plausible explanation is that young drivers demonstrate a heightened sense of confidence, leading them to underestimate the probability of an accident occurring due to IVIS use while driving [13–16]. Another potential explanation may be that young drivers perceive the benefits of using IVIS while driving to outweigh the potential risks of accidents, leading them to believe that the benefits justify their actions [46–48]. In addition, the perceived risks of being caught and fined also have no significant predictive impact on behavioral intention, which contradicts existing literature [49]. In other words, drivers who perceive a higher risk of being caught and fined for using IVIS while driving are not necessarily deterred from engaging in such behavior. One plausible explanation is that the driver made a rational choice and willingly engaged in the IVIS use behavior while driving. They know the potential consequences of arrest and fines when using IVIS poses a threat to safe driving (e.g., watching videos while driving). Nevertheless, they believe it is challenging for law enforcement to detect their IVIS use inside the confines of windows and effectively enforce stringent regulations [5,12,51]. Another potential explanation is that these young drivers may need a greater understanding of the legal regulations regarding IVIS use while driving. As Parnell et al. [51] summarized, legislative countermeasures available in most countries or regions do not explicitly prohibit the use of IVIS while driving, in contrast to mobile phone use. Instead, it falls within the scope of broader legislation concerning 'careless' or 'dangerous' driving [12].

### 5.3. Hypothesis 3: Efficacy of PBC and Intention to Predict Prospective Behavior

The Time 2 survey assessed the self-reported IVIS use behavior while driving the preceding week. Given the small sample size ( $n = 145$ ) resulting from a slightly high attrition rate (38.6%) between Survey 1 and Survey 2, it is important to interpret these findings with caution due to the suboptimal level of statistical power. With this caveat in mind, Hypothesis 3 receives only partial support. The findings revealed that the standard TPB variable explained 41.2% of the variance in the young drivers' IVIS use behavior while driving. There are considerable variations in addition to the standard TPB that require further explanation. Jumping out of the rational behavior assumption of TPB, some non-volitional factors (e.g., habits, automaticity, and mindfulness) may have played a significant role, which may help to explain why individuals consistently utilize their IVIS across various contexts [52,53].

Intention was crucial in predicting behavior, whereas PBC influence was not statistically significant. In other words, young drivers' perceived control to perform safely the target behavior did not indeed impact their engagement. Previous research [40,41,50] also found that PBC did not emerge as a significant predictor of self-reported smartphone use behavior while driving. However, it is still worth further subdividing PBC into the perceived self-control and self-efficacy constructs to identify the predictive validity of these two constructs. Because there is only limited literature reporting the efficacy of the TPB in explaining young drivers' IVIS use behavior while driving [31–33], it is not possible to conduct a systematic review or meta-analysis to conclude. In addition, the impact of PBC on behavior is possibly mediated by intention, necessitating further investigation.

In contrast, Prat et al. [45] suggest that PBC can predict individuals' past texting behavior variability. The most likely explanation for this phenomenon is that Prat et al.'s study is a cross-sectional survey designed to assess individuals' retrospective behavior, which is essentially different from the two-wave longitudinal study in this study. Therefore, there may be different motivating factors for retrospective and prospective behavior, highlighting the value of conducting a longitudinal design to explore the psychological factors of IVIS- or mobile phone-distracted driving behavior using the extended TPB.

#### 5.4. Practical Implications

Practically speaking, this study can offer valuable insights for road traffic authorities in formulating targeted and sustainable strategies to prevent IVIS-related distraction. Given the lack of clarity and enforcement challenges surrounding the regulations associated with IVIS use while driving, it is necessary to implement additional non-threatening measures, such as advertising campaigns, public education messages, and in-vehicle feedback technology [54], as part of a comprehensive strategy to tackle this problem. Psychological predictors of young drivers' IVIS use behavior while driving were identified in this study, indicating the need for tailored interventions to reduce this behavior sustainably.

##### 5.4.1. Interventions for the Standard Constructs

Viewing the standard TPB constructs, it is feasible to design interventions that specifically address behavioral, normative, and control beliefs [20–22]. For instance, the positive assessments of IVIS use while driving may encounter resistance when considering the heightened probability of accidents and the legal consequences. Interventions can also be targeted toward addressing disapproval within significant reference populations, such as parents, relatives, colleagues, and partners. In addition, it is imperative to implement interventions to address the prevalent misconception among young drivers that they can effortlessly use IVIS while driving. Finally, there is a pressing need to educate young drivers about the potential consequences of distracted driving, including the risks associated with executing sharp turns, crossing medians, and rear-end collisions.

##### 5.4.2. Interventions for the Extended Constructs

In terms of extended constructs, it is recommended that interventions prioritize the descriptive norms and moral norms. Around descriptive norms, it is imperative to enhance the understanding of safe driving behavior. For instance, it can be advertised that most drivers refrain from utilizing their IVIS while driving. Furthermore, interventions can effectively target moral norms by emphasizing the inherent dangers, legal implications, and the importance of adhering to traffic regulations. Additionally, interventions should aim to address the cognitive dissonance that occurs when individuals perceive the benefits of IVIS use while driving to outweigh the associated risks. Conducting real-world or simulated driving experiments to broadcast the adverse impact of IVIS on road safety is a feasible measure. Similar to cell phone interventions, the use of IVIS while driving with high-definition cameras may be feasible, but its effectiveness needs further evaluation. Currently, the dominant viewpoint advocates for implementing a socio-technical system approach to prevent IVIS-related distraction, and all stakeholders within this framework should be held accountable for the resulting traffic injuries [5,12,51].

##### 5.4.3. Interventions for the 'Intention–Behavior' Gap

In addition to interventions that reduce intention, it is equally worth developing ways to disrupt or moderate the causal relationship between intention and behavior. For instance, implementing a 'per se lockout' feature that turns off visual–manual interactions and retains audio–speech interaction of IVIS while driving could be a viable recommendation [55]. Nevertheless, it is necessary to design strategies that can effectively address the issue of IVIS- and mobile phone-related distraction simultaneously. As previously stated [31–33], mobile phones have become the preferred 'driving support device' over IVIS. Consequently, blocking IVIS functionality could contribute to an increase in illegal mobile phone use while driving. Therefore, it is imperative to employ a cohesive strategy that advocates reducing mobile phone usage while driving, particularly when implementing interventions to prevent risky visual–manual interactions with IVIS [32].

#### 5.5. Strengths, Limitations, and Further Study

This study represents the first attempt to launch a two-wave longitudinal TPB-based survey focusing on IVIS use while driving, which facilitates the assessment of the extent to

which individuals' intentions correspond with their behaviors. The study emphasizes the practical relevance of focusing on young drivers at a heightened risk of crashes who are the heaviest IVIS service users. Some sustainable and actionable intervention strategies to prevent IVIS-related distraction are proposed to lay the foundation for the subsequent intervention practice.

The study has certain limitations and needs further research. First, self-report measures for risky behavior may suffer from social desirability biases, which may underestimate the response to IVIS use while driving. Future research should explicitly examine this matter. Second, the target behavior was IVIS use in general and not about particular tasks (e.g., radio, music, navigation, videos). Investigating specific IVIS use behaviors may yield more nuanced findings in the future. Third, it would be interesting to determine the applicability of these findings to other age cohorts and regions or whether the outcomes are specific to young drivers in Chengdu, China. Fourth, the single-item measurement of perceived risk may not guarantee this construct's reliability and validity, and more items can be further expanded in future studies. Fifth, the first sample was a relatively small convenience sample, which may not represent young drivers in Chengdu, China. In addition, due to the high attrition rate in the second sample, this study did not examine the predictive efficacy of extended variables (i.e., descriptive norms, moral norms, and perceived risks) on IVIS use behavior while driving. Future studies need to increase the participant pool of the Time 1 and Time 2 surveys to facilitate uniform longitudinal modeling using structural equation models. Last but not least, it is essential to acknowledge that the countermeasures mentioned above are intended as suggestions and should be subject to empirical evaluation to determine their potential persuasiveness.

## 6. Conclusions

This two-wave longitudinal study successfully employed an extended TPB model to investigate the psychological predictors of both intention and behaviors of IVIS use while driving among young drivers. The traditional TPB constructs of attitude, subjective norms, and PBC, along with the supplementary constructs of descriptive norms and moral norms, were identified as significant predictors of young drivers' intention to use IVIS while driving. The sole determinant of behavior was found to be intention. These findings can serve as the central focus for TPB-based interventions, such as advertising campaigns, public education messages, and in-vehicle feedback technology, to prevent sustainably the prevalent and risky IVIS-related distractions among young drivers.

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