3-2020

Adolescents' Attitudes and Intentions to Use a Smartphone App to Promote Safe Driving

Caitlin N. Pope
University of Kentucky, Caitlin.Pope@uky.edu

Emre Sezgin
Nationwide Children's Hospital

Simon Lin
Nationwide Children's Hospital

Nichole L. Morris
University of Minnesota

Motao Zhu
Nationwide Children's Hospital

Published in *Transportation Research Interdisciplinary Perspectives*, v. 4, 100090.

Digital Object Identifier (DOI)
https://doi.org/10.1016/j.trip.2020.100090

Transportation Research Interdisciplinary Perspectives 4 (2020) 100090

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

journal homepage: https://www.journals.elsevier.com/transportation-research-interdisciplinary-perspectives

Adolescents' attitudes and intentions to use a smartphone app to promote safe driving ☆

Caitlin N. Pope [a], Emre Sezgin [b], Simon Lin [b], Nichole L. Morris [c], Motao Zhu [b,*]

[a] University of Kentucky, United States of America
[b] Abigail Wexner Research Institute at Nationwide Children's Hospital, United States of America
[c] University of Minnesota, Twin Cities, United States of America

ARTICLE INFO

Article history:
Received 20 September 2019
Received in revised form 20 December 2019
Accepted 20 January 2020
Available online 8 February 2020

Keywords:
Cell phone
Mobile apps
Attitude
Integrated behavioral model
Teens

ABSTRACT

Purpose: Designing effective driving safety interventions is imperative as traffic crashes are the leading cause of injury and death for adolescents. Using concepts from the Integrated Behavioral Model, we investigated adolescents' attitudes and intentions towards engaging in safe driving practices and using smartphone-based driving safety technology.
Methods: Two-hundred and seven adolescents aged 14–18 ($M = 16.1$, $SD = 0.8$) completed a safe driving survey. A path model testing the associations between individual scores of attitudes, perceived norms, and perceived behavioral control with intentions controlling for demographic covariates was conducted.
Results: Greater intentions to drive safely was associated with greater perceived norms from family and peers ($\beta = 0.75$, $p < .001$) and perceived capability ($\beta = 0.19$, $p < .001$) to drive safely. Greater intentions to adopt a driving safety app was associated with greater perceived norms from family and peers ($\beta = 0.29$, $p = .007$). Females reported greater intentions to adopt a driving safety app than males ($\beta = -0.15$, $p = .044$).
Conclusions: Assessing attitudes and perceptions provides further understanding of what behavioral constructs are important for the development of adolescent driver safety interventions. Experimental research targeting and modifying behavior constructs is warranted.

1. Introduction

Traffic crashes are a leading cause of injury and death for adolescent drivers in the United States (Centers for Disease Control and Prevention - National Center for Injury Prevention and Control, 2018). The first six months of independent driving are the most dangerous as crash risk is the highest due to many cumulating factors, including driving inexperience and errors (Mayhew et al., 2003; Simons-Morton and Ehsani, 2016). To combat these factors, driving safety interventions have been designed to target different components of the learning-to-drive process. These interventions show promise, but are accompanied with limited long-term adherence and efficacy (Curry et al., 2015; Mirman et al., 2018; Mirman et al., 2014; Musicant and Lotan, 2016; Simons-Morton and Ehsani, 2016).

Paralleling our society and its dependence on technology, various forms of technological equipment have been used to modify adolescent driving behavior (e.g., using in-vehicle devices to provide driving performance feedback to adolescents and parents; Brovold et al., 2007). As smartphones have become ubiquitous in our daily lives, researchers have begun to incorporate smartphone applications ("apps") in efforts to promote safe driving by modifying risky driving behavior via telematics (Sezgin and Lin, 2019). Using internal smartphone sensors, these apps are able to detect vehicle movement, high-risk driving events (e.g., hard braking, sudden acceleration, cornering; Fazeen et al., 2012; Musicant and Lotan, 2016), and risky driving behaviors (e.g., distracted driving; Creaser et al., 2015). Using smartphone technology is a relatively new experimental tool to modify driving behavior (Kervick et al., 2015). To date there is limited understanding on adolescent drivers' adoption preferences towards using this type of technology to facilitate driving-related behavior change and intervention effectiveness (Creaser et al., 2015; Delgado et al., 2018; Kervick et al., 2015).

☆ Caitlin N. Pope, Graduate Center for Gerontology, University of Kentucky; Motao Zhu, Center for Injury Research and Policy at the Abigail Wexner Research Institute at Nationwide Children's Hospital; Emre Sezgin and Simon Lin, Research Information Solutions and Innovation at the Abigail Wexner Research Institute at Nationwide Children's Hospital; Nichole L. Morris, HumanFIRST Laboratory, Department of Mechanical Engineering University of Minnesota, Twin Cities.This research was supported in part by grants from the US National Institute of Child Health and Human Development (R21HD085122 and R01HD074594).The authors would like to acknowledge Dr. Neil Gupta, director of secondary education at Worthington City Schools (Columbus, Ohio) and the participating teachers for their support in recruitment and data collection.
* Corresponding author at: The Center for Injury Research and Policy at the Abigail Wexner Research Institute at Nationwide Children's Hospital, Columbus, OH, United States of America.
E-mail address: Motao.Zhu@nationwidechildrens.org. (M. Zhu).

http://dx.doi.org/10.1016/j.trip.2020.100090

Engagement in driving safety apps, ones that monitor driving behavior and provide feedback, is seen as a promising tool to promote safe driving. Thus, assessment of intentions to adopt a driving safety app in the context of safe driving is warranted.

1.1. Using health behavior theory to understand adolescents' intentions to use smartphone technology to promote safe driving behaviors

As understanding the determinants of behavior and ways to modify it can be complex, theoretical models have been developed to identify psychosocial and environmental constructs related to the health behavior of interest (i.e., engaging in driving safety apps) and can be modified to promote meaningful behavior change. One such theory, the Integrated Behavioral Model (IBM), adapted from the Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB; Ajzen, 1991; Ajzen and Fishbein, 1980; Fishbein and Ajzen, 1975), posits that attitudes (i.e., how favorable one is towards a behavior), perceived norms (i.e., the level of social pressure one feels to engage in a behavior), and personal agency (i.e., one's perceived control and belief that they can personally engage in a behavior) directly explains an individual's intentions to engage in a health behavior (see Fig. 1). IBM states that behavioral intention is one of the strongest predictors of the likelihood that one will engage in a subsequent health behavior. Additionally, other components aside from intent, influences engagement such as knowledge and skills one possesses to perform the behavior, saliency of the behavior, environmental constraints that may hinder engagement, and habituation of the behavior (Montaño and Kasprzyk, 2008).

Recent investigations have noted the utility of theoretical derived concepts to develop more adoptable driving safety smartphone apps (Kervick et al., 2015; Musicant and Lotan, 2016; Warren et al., 2018). Using a modified model incorporating components from the driver monitoring and technology acceptance literature, Kervick et al. (2015) tested the concept of a driving safety app to mitigate risky driving behavior with a sample of young adult drivers from Ireland, aged 18–24 years old. They found perceived gains (e.g., the opportunity to earn rewards or discounts) and social influences (e.g., beliefs and values of others) were directly associated with behavioral intention to use a driving app to promote safe driving (Kervick et al., 2015). Furthermore, both Warren et al. (2018) and Musicant and Lotan (2016) noted that perceptions and motivations, from various theories, also contributed to intentions to use driving safety apps as well as usage behavior with GreenBox driving technology, respectively. Interestingly, Warren et al. (2018) found that adolescent drivers expressed negative attitudes towards smartphone-based technology, primarily around the idea of additional parental monitoring and usability concerns. This literature highlights the importance of identifying the theoretical constructs (e.g., intention) that influence the adoption of driving safety smartphone apps.

While these studies begin the conversation on what theoretical constructs are important for adoption of this technology to promote engagement in safe driving behavior, ultimately much is left to understand on what modifiable factors can be targeted to promote adoption and long-term use in some of the most vulnerable road users. Even less is known about these associations when in the presence of key developmental covariates such as age, gender, and prior driving experience. While prior research has noted injurious behavior differences between genders in childhood (Morrongiello and Hogg, 2004; Schwebel and Barton, 2005), evidence that females have reported lower acceptance rates towards Advanced Driver Assistance Systems and may perceive the usability of supportive technologies differently than males has also been found (Kervick et al., 2015; Son et al., 2015). Even less is known how age and acquired driving experience may contribute to overall intention. Saliency of the behavior, strengthened through acquired experiences, may affect the strength of the associations with the investigated intentions but also correlate with their attitudes, perceived norms, and personal agency towards the behavior itself (Ajzen, 1991; Armitage and Conner, 2001; Montaño and Kasprzyk, 2008).

In efforts to understand adolescents' intentions to engage in safe driving practices we conducted a survey to investigate adolescents' attitudes and intentions towards engaging in safe driving practices and to adopt a smartphone app designed to promote safe driving. Based on the IBM conceptual framework, it was hypothesized that after accounting for age, gender, and driving experience, greater intentions to engage in safe driving behaviors and to adopt a driving safety app would be associated with more positive attitudes towards safe driving practices, greater perceived norms towards safe driving practices, and more personal agency in engaging in safe driving practices. Additionally, we hypothesized that intentions to engage in safe driving practices would be correlated with intentions to adopt a driving safety app.

2. Method

2.1. Participants

Two-hundred and forty-three adolescents aged 14–18 years old were contacted for participation, 85% (n = 207) agreed to participate. On average the participants who agreed to participate were 16.1 years old (SD = 0.8 years) and just over half of the sample

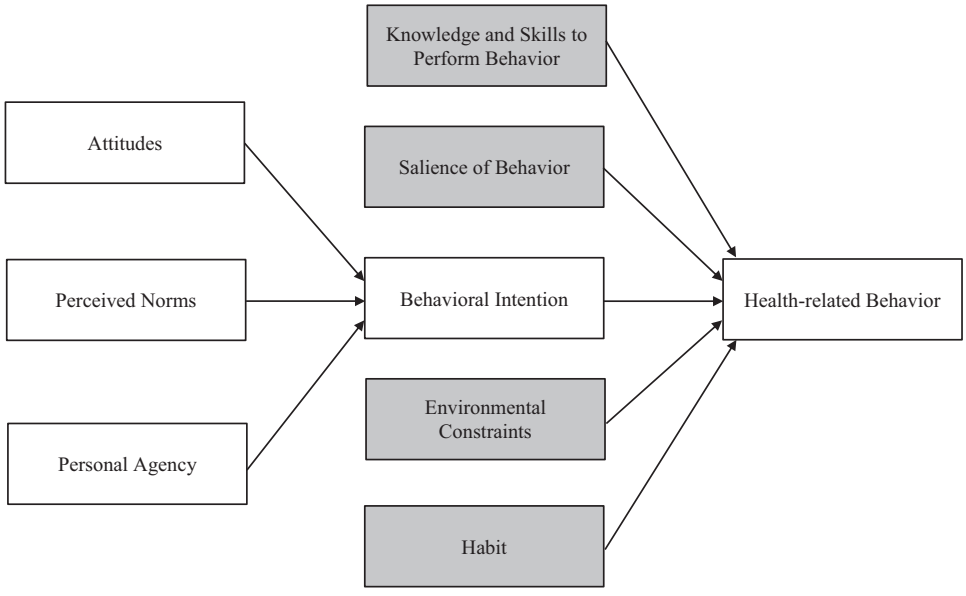

Fig. 1. Integrated Behavioral Model (IBM) Conceptual Model.

(53%) was male. Driving experience varied with the majority reporting no driving experience (40%), 17% reporting up to 3 months, 9% reporting 3–6 months, 17% reporting 6–8 months, and 17% reporting 1 year or more.

2.2. Measures

A survey was developed to capture demographic characteristics, driving history, IBM constructs towards driving safety practices and behaviors, and preferences towards smartphone technology. Driving safety themes and initial reactions to a hypothetical driving safety app (e.g., features wanted/not wanted) was discussed with five adolescent drivers (independent of the final sample) prior to survey construction. Questions measuring IBM constructs are presented in Table 1 and constructed using behavioral construct question stems (Montaño and Kasprzyk, 2008). Questions were summed together to create scores for each IBM construct. Cronbach's alpha was conducted to assess construct internal reliability (Gliem and Gliem, 2003). It is important to note that the survey was not previously validated.

2.2.1. IBM constructs

2.2.1.1. Attitudes. Five questions were asked pertaining to how favorable (or unfavorable) one feels about engaging in safe driving practices and behaviors. Attitudes were presented on 100-point scales with 0 indicating a negative attitude and 100 indicating a positive attitude. Participants could move the indicator on the line to select their answer. Cronbach's alpha revealed good internal reliability ($\alpha = 0.9$). Higher attitudinal scores indicated more positive attitudes towards engaging in safe driving practices and behaviors.

2.2.1.2. Perceived norm. Four questions were asked pertaining to perceived social pressure one feels to engage in safe driving practices and behaviors. Perceived norm questions were presented on a 7-point Likert scale with 1 indicating strongly disagree and 7 indicating strongly agree. Cronbach's alpha revealed good internal consistency ($\alpha = 0.8$). Higher perceived norm scores indicated that engaging in safe driving practices and behaviors was perceived as more desirable by important social referents as well as greater perceived social pressure to perform the behavior.

2.2.1.3. Personal agency. Four questions were asked pertaining to one's perceived control and capability to effectively engage in safe driving practices and behaviors. Personal agency questions were presented on a 7-point Likert scale with 1 indicating strongly disagree and 7 indicating strongly agree. Cronbach's alpha revealed acceptable internal consistency ($\alpha = 0.7$). Higher personal agency scores indicated more behavioral control and self-efficacy in engaging in safe driving practices and behaviors.

2.2.1.4. Behavioral intention. Two behavioral intentions were assessed: (1) intentions to engage in safe driving practices and behaviors; and (2) intentions to use driving safety apps. Three questions were presented for each behavioral intention, all on a 7-point Likert scale with 1 indicating strongly disagree and 7 indicated strongly agree. Cronbach's alpha revealed good internal consistency for both (α's $= 0.9$). Higher behavioral intention scores indicated more intent to engage in safe driving practices and behaviors and to use driving safety apps.

2.3. Procedure

The study was approved by the Institutional Review Board (IRB) at Nationwide Children's Hospital. Adolescents were recruited from two Ohio metropolitan-area high school health education classes in May 2018. Study materials were introduced and supervised by high school health education teachers. The study lasted approximately 15 min and included a three-min video introducing the concept of a driving safety app followed by a confidential online questionnaire. Participation was voluntary and parents were notified of the study before the administration date. If the parent did not want their adolescent to participate or the adolescent decided to not participate, they were given the option to do other work instead of participating. Compensation included two iPads donated to the high schools for educational purposes.

2.4. Statistical analyses

Descriptive statistics for raw and summed scores of attitudes, perceived norms, personal agency, and behavioral intentions were calculated using SPSS 24 (IBM Corp., 2016). Visual inspection of trend scatterplots between summed scores of attitudes, perceived norms, personal agency, and behavioral intentions showed possibilities of a non-linear trend. To assess appropriateness of a linear trend, the curve fit estimator in SPSS was conducted. A linear trend significantly explained variation ($ps < .05$) for the association between behavioral constructs and behavioral intention outcomes, except for attitudes with intentions to use driving safety apps ($p = .194$). Behavioral intention outcomes were assessed for normality and homoscedasticity. The presence of outliers was detected (z-score standardized values >3.0, but <4.0), potentially aiding in the violations of normality (Shapiro-Wilk tests $ps < .001$) and homoscedasticity (visually evident from residual plots).

To preserve interpretability the variables were not transformed and path models were utilized using the robust, non-normal distribution extension of maximum likelihood (MLR) estimator in MPlus Version 8 (Muthén and Muthén, 1998-2017). MLR is appropriate for small-to-medium sample sizes, has no normality or independence assumptions, reduces the risk of inflating standard errors, and can accommodate small amounts of missing data (Wang and Wang, 2012). Additionally, no evidence of multicollinearity (tolerance values between 0.30 and 1.0, VIF values between 1.0 and 3.0) or autocorrelation was evident (Durbin Watson tests values approximately 2.0). The path model assessed the associations between scores of attitudes, perceived norms, personal agency, and behavioral intentions while accounting for age, gender, and driving experience. Standardized betas and standard errors are reported with statistical significance denoted as $p < .05$.

Table 1
IBM construct questions.

IBM Construct	Question
Attitudes	Engaging in safe driving practices and behaviors is:
A1.	Bad – Good
A2.	Harmful - Beneficial
A3.	Unpleasant - Pleasant
A4.	Worthless - Useful
A5.	Unimportant - Important
Perceived Norms	
PN1.	Most people who are important to me think I should engage in safe driving practices and behaviors.
PN2.	Most people who are important to me want me to engage in safe driving practices and behaviors.
PN3.	It is expected of me to engage in safe driving practices and behaviors.
PN4.	I feel under social pressure to engage in safe driving practices and behaviors.
Personal Agency	
PA1.	I am confident that I could engage in safe driving practices and behaviors.
PA2.	For me to engage in safe driving practices and behaviors is easy.
PA3.	Whether I engage in safe driving practices and behaviors or not is not entirely up to me.
Intentions	
Safe Driving	
IN1.	As a driver, I expect to engage in safe driving practices and behaviors.
IN2.	As a driver, I want to engage in safe driving practices and behaviors.
IN3.	As a driver, I intend to engage in safe driving practices and behaviors.
Driving Safety App	
BTWIN1.	As a driver, I expect to use driving safety apps.
BTWIN2.	As a driver, I want to use driving safety apps.
BTWIN3.	As a driver, I intend to use driving safety apps.

Note. IBM = Integrated Behavior Model.

Table 2
Descriptive statistics.

Variable	Raw scores	Summed scores
Attitudes	*M* (*SD*)	M (SD)
A1.	92.2 (12.4)	444.9 (62.1)
A2.	91.1 (14.4)	
A3.	81.9 (19.5)	
A4.	89.0 (14.3)	
A5.	90.6 (14.5)	

Variable	Strongly Disagree % (n)	Disagree % (n)	Somewhat Disagree % (n)	Neither % (n)	Somewhat Agree % (n)	Agree % (n)	Strongly Agree % (n)	Summed scores
Perceived norms								22.6 (5.8)
PN1.	7.2 (15)	1.0 (2)	0.5 (1)	4.3 (9)	3.4 (7)	18.8 (39)	63.3 (131)	
PN2.	7.2 (15)	0.5 (1)	1.0 (2)	3.9 (8)	2.9 (6)	20.8 (43)	62.3 (129)	
PN3.	7.2 (15)	0 (0)	0.5 (1)	3.9 (8)	3.4 (7)	17.9 (37)	65.7 (136)	
PN4.	15.0 (31)	9.7 (20)	9.2 (19)	20.3 (42)	11.1 (23)	15.9 (33)	17.4 (36)	
Personal agency								16.0 (4.5)
PA1.	6.8 (14)	1.0 (2)	1.0 (2)	4.8 (10)	5.3 (11)	25.1 (52)	54.1 (112)	
PA2.	7.2 (15)	1.0 (2)	1.4 (3)	8.2 (17)	10.1 (21)	27.1 (56)	43.5 (90)	
PA3.	17.4 (36)	13.0 (27)	7.2 (15)	13.0 (27)	9.2 (19)	12.1 (25)	26.6 (55)	
Intentions								
Safe Driving								18.5 (4.8)
IN1.	7.7 (16)	0 (0)	0 (0)	4.3 (9)	3.9 (8)	21.7 (45)	61.8 (128)	
IN2.	7.7 (16)	0 (0)	0 (0)	2.9 (6)	1.4 (3)	23.7 (49)	63.8 (132)	
IN3.	6.8 (14)	0 (0)	0.5 (1)	2.9 (6)	1.9 (4)	22.2 (46)	63.8 (132)	
Driving Safety App								12.4 (5.3)
BTWIN1.	13.0 (27)	8.7 (18)	9.2 (19)	27.5 (57)	15.9 (33)	9.7 (20)	11.6 (24)	
BTWIN2.	13.5 (28)	6.3 (13)	6.8 (14)	27.5 (57)	14.0 (29)	15.9 (33)	11.6 (24)	
BTWIN3.	13.0 (27)	7.7 (16)	6.3 (13)	26.1 (54)	17.9 (37)	13.5 (28)	11.1 (23)	

Note. Variable names are defined in Table 1. Attitudes are raw scores reported on a continuous scale from 0 to 100.

3. Results

All variables, except for gender, had some level of missingness with only 3% of total data points considered missing. Investigation of raw scores (see Table 2) revealed that on average adolescents had very positive attitudes towards engaging in safe driving, as all scores were close to 100. Regarding perceived norms, over half of the sample strongly agreed that most people who were considered important to them wanted and expected them to engage in safe driving practices. A different pattern of endorsement was present for the question, "I feel under social pressure to engage in safe driving practices and behaviors", as 44% agreed and 33% disagreed to some degree. Over half of the sample (54%) strongly agreed that they felt confident that they could engage in safe driving practices, while only 44% strongly agreed that it was easy for them to engage. Additionally, 27% of participants strongly agreed that it was not entirely up to them whether they engaged in safe driving practices. For behavioral intentions, almost 90% of the sample agreed to some degree that as the driver they expected, wanted, and intended to engage in safe driving practices. When assessing intentions to use driving safety apps, responses were more variable as 37% agreed to some degree that they expected to use a driving safety app and just over 40% agreed to some degree that they wanted to use and intended to use a driving safety app. Given the large variability in driving experience, independent samples Kruskal-Wallis tests were performed on all summed scores. No significant differences, based on driving experience, were found (*p*s > .05).

3.1. Path models

The path model was identified. Significant correlations were seen between IBM constructs (attitudes, perceived norms, and personal agency) and demographic covariates (see Table 3). The path model (see Fig. 2) included the summed scores of attitudes, perceived norms, and personal agency which were regressed onto the summed scores of behavioral intentions to engage in safe driving and to use driving safety apps, while controlling for age, gender, and driving experience. Significant associations were found between perceived norms and intentions to engage in safe driving practices ($\beta = 0.76, p < .001$) and to use driving safety apps ($\beta = 0.30$, $p = .006$). These findings suggest greater adolescent perceptions of social pressures towards safe driving along with more normative beliefs from important individuals (e.g., family members and peers) were associated with greater intentions to engage in safe driving and to adopt driving safety apps.

Personal agency was also significantly associated with intentions to engage in safe driving ($\beta = 0.18, p < .001$), but not intentions to adopt a driving safety app ($\beta = 0.10, p = .319$). This suggests that greater perceptions of behavioral control and personal capability to engage in safe driving were associated with greater intentions of that behavior. No statistically significant association was found for attitudes with either intentions to engage in safe driving ($\beta = 0.04, p = .231$) or to adopt a driving safety app ($\beta = -0.01, p = .950$).

When assessing the associations with demographic factors, gender did not significantly differ with intentions to engage in safe driving ($\beta = -0.01, p = .812$), but females were more likely to report greater intentions to adopt driving safety apps ($\beta = -0.15, p = .044$). No statistically significant association was found for either intentions to engage in safe driving ($\beta = -0.01, p =$

Table 3
Exogenous variable correlations and standard errors.

Variables	1	2	3	4	5	6
1. Attitudes	–					
2. Perceived norms	0.23 (0.09)**	–				
3. Personal agency	0.18 (0.09)*	0.80 (0.04)***	–			
4. Age	0.10 (0.07)	0.08 (0.07)	0.03 (0.07)	–		
5. Gender	−0.19 (0.08)*	0.05 (0.07)	0.04 (0.07)	0.04 (0.07)	–	
6. Driving experience	0.13 (0.07)	0.12 (0.06)*	0.06 (0.06)	0.46 (0.06)***	−0.01 (0.07)	–

Note. All path model coefficients and standard errors are standardized.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

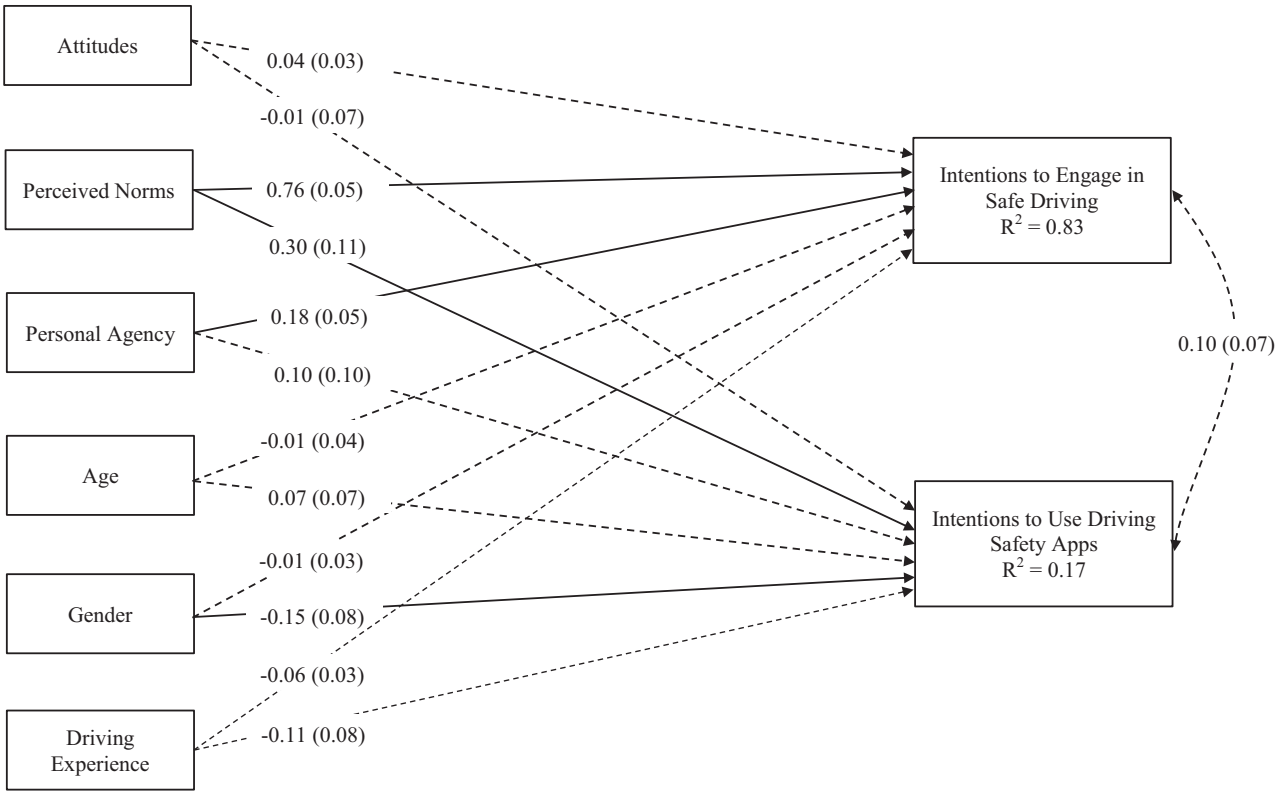

Fig. 2. Path model. All coefficients and standard errors are standardized. Single headed arrows indicate paths, double-headed arrows indicate correlations. Correlations between exogenous variables were estimated, but not depicted. Solid lines denote $p < .05$.

.722) or to use driving safety apps ($\beta = 0.02, p = .333$) with age or driving experience. Furthermore, the correlation between the two types of behavioral intentions was also not statistically significant ($r = 0.10, p = .155$). Lastly, the IBM constructs along with age, gender, and driving experience explained 83% of the variance in intentions to engage in safe driving practices ($p < .001$) and 17% of the variance in intentions to adopt a driving safety app ($p = .001$).

4. Discussion

This study aimed to incorporate behavioral constructs from the IBM conceptual framework in efforts to better understand adolescents' intentions to engage in safe driving, including hypothetical adoption of a smartphone app designed to monitor driving safety and provide constructive feedback. After accounting for developmental covariates, greater perceived norms and personal agency was significantly associated with the behavioral intentions of interest, partially supporting the hypotheses.

Previous driving studies using the TPB, a precursor to the IBM, have begun to document how drivers' perceptions of social desirability and norms may influence intentions and engagement in risky driving behaviors, specifically distracted driving in college-aged students (Gauld et al., 2014; Nemme and White, 2010; Shevlin and Goodwin, 2019). After accounting for other theoretical constructs, greater perceptions of social pressure towards distracted driving from people perceived as important to the driver were significantly associated with greater intentions to engage in texting while driving (Gauld et al., 2014; Nemme and White, 2010; Shevlin and Goodwin, 2019). This is of great interest in understanding adolescent risk-taking behaviors behind the wheel, as adolescents spend a large amount of time with same-age peers (Albert et al., 2013); known risk factors for unsafe driving behaviors (Chein et al., 2011; Simons-Morton et al., 2014). How desirable adolescents perceive these unsafe driving behaviors from their peers may influence their intentions and engagement in unsafe driving behaviors to some degree (Albert et al., 2013; Lee, 2007).

Additionally, Kervick et al. (2015) found that greater reported social influence was associated with greater intentions to accept smartphone driver support systems. While they did not use TPB or IBM, the construct of social influence which encompasses the saliency of beliefs, values, and norms of important others is similar in operational definition to the construct of perceived norms. We found similar associations between perceived norms and intentions such that greater intentions to engage in safe driving behaviors and to adopt a driving safety app were associated with greater perceived social pressure towards safe driving practices. Despite methodological differences across studies such as the theory used, sample age, and driving-related intentions, the replication of findings with perceived norms and driving behaviors identifies a consistent link between the expectations and beliefs adolescents have of others and how these perceptions are associated with their intentions. More research is needed to determine how different types of norms (e.g., injunctive norm, descriptive norms) may impact behavioral intentions and related driving behavior as previous research has shown differential patterns between norms, intentions, and health behaviors in other areas of adolescent health (Conner et al., 2017; van de Bongardt et al., 2015).

How one perceives their own capability to perform health or safety behaviors (i.e., personal agency) may also influence intention formation and goal-directed behavior. Conner et al. (2017) found that the more perceived control a person had over performing a protective health behavior, the greater their intention was to engage in that particular health behavior in a sample of adults, after controlling for frequency of prior engagement. The opposite association was seen with risky health behaviors, such that perceived control was negatively associated with intentions to engage in the risky health behavior and varied by how much control the person thought they had (Conner et al., 2017). Similarly, we found that greater personal agency (one's perceived control and capability) was associated with greater intentions to engage in safe driving. Although the association between personal agency and intentions to adopt a driving safety app was also in the same direction (i.e., positive direction for a protective health

behavior) it was not statistically significant. Important to note in the context of driving safety apps, Kervick et al. (2015) also failed to find a significant association between perceptions of usability (i.e., how easily the user perceives using the smartphone technology) and willingness to adopt similar smartphone-based technology.

Surprisingly, adolescents' attitudes towards safe driving were not significantly associated with either of the investigated intentions. This is in opposition to theoretical support for the hypothesis that an individual's attitude is an important factor in assessing intentions (Conner et al., 2017; Montaño and Kasprzyk, 2008). More research is needed to determine the expected associations between attitudes towards safe driving and observed engagement to better inform theoretical modeling and hypothesis-driven studies. One possible reason that attitudes did not play a more significant role in the overall model could be attributed to the importance of the theoretical construct regarding the surveyed situation as there is evidence the strength of this association varies across health behavior domains (Ajzen, 1991; Armitage and Conner, 2001; Montaño and Kasprzyk, 2008). Another possible cause for this lack of association could be attributed to a ceiling effect, as the majority of the sample reported very positive attitudes towards engagement in safe driving (scores ranging from 81.9–92.2 out of a scale of 100).

Although gender, age, and driving experience were used as developmental covariates, prior research in the context of driving technology intentions is lacking. Whereas an association was found between female gender and intentions to adopt driving safety apps, it remains unclear why. Previous research has shown gender-based differences in risk taking and injurious behavior in elementary-aged children (Morrongiello and Hogg, 2004; Schwebel and Barton, 2005) that persists into adolescence and adulthood (Kervick et al., 2015; Pope et al., 2018; Rhodes and Pivik, 2011; Son et al., 2015). In addition, some evidence suggests that females may be more agreeable than males (Costa Jr. et al., 2001). Lastly, statistically non-significant associations were found between age, driving experience, and behavioral intentions. While the goal of the study was to include adolescents (irrespective of driver license status), the variability in age may have consequently interacted other model factors as it was accompanied with multiple levels of driving experience and exposure. To date, there is little empirical investigation on the stability and change of adolescents' perceptions towards driving in regards to age and gained driving experience.

4.1. Limitations and strengths

Strengths of the study included the use of a tested behavior theory to guide hypotheses and model creation and the use of a robust estimator (MLR) to account for smaller sample sizes, non-normality, and missing data. However, important limitations exist and should be further discussed.

Although the sample size was over the conventional minimum adequate sample size (i.e., $n = 200$; see Meyers et al., 2013), Monte-Carlo simulation showed model complexity and expected effect size should guide adequate sample size (Wolf et al., 2013). Psychosocial constructs tend to have smaller effect sizes, therefore larger sample sizes may be needed. Increased sample size along with the creation and validation of latent constructs is necessary to assess the stability of the current findings by minimizing measurement error, which cannot be removed using path analysis techniques. Creation of latent constructs would also allow for the assessment of bias related to the common method variation (i.e., items clustering together or showing overlapping variation potentially due to survey placement). Future investigation should include the entire IBM theoretical framework to aide in the creation and validation of a confirmatory factor analysis and structural equation modeling in independent samples of adolescents.

Second, the current model violated assumptions of normality and homoscedascitiy. In efforts to reduce potential bias from model misspecification we used a robust estimator that does not have normality assumptions. Important to note, linear trends significantly accounted for variance in tested associations, but possible non-linear relationships might exist that should be examined in larger samples. Violation of these assumptions may present unexplained bias into the model. Additionally, survey items were framed on intentions to use a hypothetical smartphone technology that adolescents may have been unfamiliar with or unsure how it would work. Theoretical constructs should be assessed after the adolescents have used the technology to see if perceptions change post hoc. Lastly, the varying range of age and driving experience may have lessened the saliency of the targeted behaviors. Arguably, there were no significant group differences based on acquired driving experience for any of the summed scores.

5. Conclusions

This theory-guided investigation of adolescents' intentions to engage in safe driving and to adopt a smartphone app designed to promote safe driving contributes to the understanding of what behavioral determinants are important for safe adolescent driving. Additionally, it contributes to the growing body of studies investing smartphone technology as a tool for driving safety interventions.

Smartphone technology is relatively easy to use, cheap to acquire, and available to drivers of all ages with differential needs, increasing the accessibility and usability from an intervention perspective. As future studies experiment with the benefits of telematics from an experimental perspective, more behavioral interventions and experimental studies are needed to assess preferences, long-term adoption, and efficacy of smartphone-based driving-safety technology to promote safe driving practices in adolescent drivers. These findings highlight the potential utility of perceived norms and how they may influence not only intentions to engage in safe driving as well as adoption of driving safety technology, such as driving safety apps. Furthermore, efforts should be directed to promote this type of technology to enhance adolescent driver safety and to not provide further distraction while driving or to facilitate negative driving behaviors (e.g. adolescents competing or bragging about bad driving behavior or unsafe performance).

CRediT authorship contribution statement

Caitlin N. Pope: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Emre Sezgin:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. **Simon Lin:** Conceptualization, Funding acquisition, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **Nichole L. Morris:** Formal analysis, Validation, Visualization, Writing - original draft, Writing - review & editing. **Motao Zhu:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing.

References

Ajzen, I., 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50, 179–211. https://doi.org/10.1016/0749-5978(91)90020-T.

Ajzen, I., Fishbein, M., 1980. Undersing Attitudes and Predicting Social Behavior. Prentice Hall, Engelwood Cliffs, NJ.

Albert, D., Chein, J., Steinberg, L., 2013. Peer influences on adolescent decision making. Curr. Dir. Psychol. Sci. 22 (2), 114–120. https://doi.org/10.1177/0963721412471347.

Armitage, C.J., Conner, M., 2001. Efficacy of the theory of planned behaviour: a meta-analytic review. British Jounral of Social Psychology 40 (Pt 4), 471–499.

Brovold, S., Ward, N., Donath, M., Simon, S., Shankwitz, C., Creaser, J.I., 2007. The use of technology to address patterns of risk among teenage drivers. J. Saf. Res. 38 (4), 413–422. https://doi.org/10.1016/j.jsr.2007.01.011.

Centers for Disease Control and Prevention - National Center for Injury Prevention and Control, 2018. Web-based injury statistics query and reporting system (WISQARS). Retrieved from. http://www.cdc.gov/injury/wisqars/index.html.

Chein, J., Albert, D., O'Brien, L., Uckert, K., Steinberg, L., 2011. Peers increase adolescent risk taking by enhancing activity in the brain's reward circuitry. Dev. Sci. 14 (2), F1–F10. https://doi.org/10.1111/j.1467-7687.2010.01035.x.

Conner, M., McEachan, R., Lawton, R., Gardner, P., 2017. Applying the reasoned action approach to understanding health protection and health risk behaviors. Soc. Sci. Med. 195, 140–148. https://doi.org/10.1016/j.socscimed.2017.10.022.

Costa Jr., P.T., Terracciano, A., McCrae, R.R., 2001. Gender differences in personality traits across cultures: robust and surprising findings. J. Pers. Soc. Psychol. 81 (2), 322–331. https://doi.org/10.1037/0022-3514.81.2.322.

Creaser, J.I., Edwards, C.J., Morris, N.L., Donath, M., 2015. Are cellular phone blocking applications effective for novice teen drivers? Journal of Safety Research 54. https://doi.org/10.1016/j.jsr.2015.06.014 (75.e29-78).

Curry, A.E., Peek-Asa, C., Hamann, C.J., Mirman, J.H., 2015. Effectiveness of parent-focused interventions to increase teen driver safety: a critical review. J. Adolesc. Health 57 (10), S6–S14. https://doi.org/10.1016/j.jadohealth.2015.01.003.

Delgado, M.K., McDonald, C.C., Winston, F.K., Halpern, S.D., Buttenheim, A.M., Setubal, C., ... Lee, Y.C., 2018. Attitudes on technological, social, and behavioral economic strategies to reduce cellphone use among teens while driving. Traffic Injury Prevention, 1–8 https://doi.org/10.1080/15389588.2018.1458100.

Fazeen, M., Gozick, B., Dantu, R., Bhukhiya, M., González, M.C., 2012. Safe driving using mobile phones. IEEE Trans. Intell. Transp. Syst. 13 (3), 1462–1468. https://doi.org/10.1109/TITS.2012.2187640.

Fishbein, M., Ajzen, I., 1975. Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research. Addison-Wesley, Reading, MA.

Gauld, C.S., Lewis, I., White, K.M., 2014. Concealing their communication: exploring psychosocial predictors of young drivers' intentions and engagement in concealed texting. Accid. Anal. Prev. 62, 285–293. https://doi.org/10.1016/j.aap.2013.10.016.

Gliem, J.A., Gliem, R.R., 2003. Calculating, interpreting, and reporting Cronbach's alpha reliability coefficient for likert-type scales. Paper Presented at the Midwest Research-to-Practice Conference in Adult, Continuing, and Community Education. State University, Columbus, OH, The Ohio.

IBM Corp, 2016. IBM SPSS Statistics for Windows (Version 24.0). IBM Corp, Armonk, NY.

Kervick, A.A., Hogan, M.J., O'Hora, D., Sarma, K.M., 2015. Testing a structural model of young driver willingness to uptake smartphone driver support systems. Accid. Anal. Prev. 83, 171–181. https://doi.org/10.1016/j.aap.2015.07.023.

Lee, J.D., 2007. Technology and teen drivers. J. Saf. Res. 38 (2), 203–213. https://doi.org/10.1016/j.jsr.2007.02.008.

Mayhew, D.R., Simpson, H.M., Pak, A., 2003. Changes in collision rates among novice drivers during the first months of driving. Accid. Anal. Prev. 35 (5), 683–691. https://doi.org/10.1016/S0001-4575(02)00047-7.

Meyers, L.S., Gamst, G., Guarino, A.J., 2013. Applied Multivariate Research: Design and Interpretation. 2nd ed. SAGE Publications, Inc., Thousand Oaks, CA.

Mirman, J.H., Curry, A.E., Winston, F.K., Wang, W., Elliott, M.R., Schultheis, M.T., ... Durbin, D.R., 2014. Effect of the teen driving plan on the driving performance of teenagers before licensure: a randomized clinical trial. JAMA Pediatr. 168 (8), 764–771. https://doi.org/10.1001/jamapediatrics.2014.252.

Mirman, J.H., Curry, A.E., Elliott, M.R., Long, L., Pfeiffer, M.R., 2018. Can adolescent drivers' motor vehicle crash risk be reduced by pre-licensure intervention? J. Adolesc. Health 62 (3), 341–348. https://doi.org/10.1016/j.jadohealth.2017.09.015.

Montaño, D.E., Kasprzyk, D., 2008. Theory of reasoned action, theory of planned behavior, and the integrated behavioral model. In: Glanz, K., Rimer, B.K., Viswanath, K. (Eds.), Health Behavior and Health Education, 4th ed. Jossey-Bass, San Francisco, CA, pp. 67–96.

Morrongiello, B.A., Hogg, K., 2004. Mothers' reactions to children misbehaving in ways that can lead to injury: implications for gender differences in children's risk taking and injuries. Sex Roles 50 (1), 103–118. https://doi.org/10.1023/B:SERS.0000011076.43831.a6.

Musicant, O., Lotan, T., 2016. Can novice drivers be motivated to use a smartphone based app that monitors their behavior? Transport. Res. F: Traffic Psychol. Behav. 42, 544–557. https://doi.org/10.1016/j.trf.2015.10.023.

Muthén, L.K., Muthén, B.O., 1998-2017. Mplus User's Guide. Eighth ed. Muthén & Muthén, Los Angeles, CA.

Nemme, H.E., White, K.M., 2010. Texting while driving: psychosocial influences on young people's texting intentions and behaviour. Accid. Anal. Prev. 42 (4), 1257–1265. https://doi.org/10.1016/j.aap.2010.01.019.

Pope, C.N., Mirman, J.H., Stavrinos, D., 2018. Adolescents' perspectives on distracted driving legislation. J. Saf. Res. https://doi.org/10.1016/j.jsr.2018.12.013.

Rhodes, N., Pivik, K., 2011. Age and gender differences in risky driving: the roles of positive affect and risk perception. Accid. Anal. Prev. 43 (3), 923–931. https://doi.org/10.1016/j.aap.2010.11.015.

Schwebel, D.C., Barton, B.K., 2005. Contributions of multiple risk factors to child injury. J. Pediatr. Psychol. 30 (7), 553–561. https://doi.org/10.1093/jpepsy/jsi042.

Sezgin, E., Lin, S., 2019. Technology-based interventions, assessments, and solutions for safe driving training for adolescents: rapid review. JMIR mHealth and uHealth 7 (1), e11942. https://doi.org/10.2196/11942.

Shevlin, B.R.K., Goodwin, K.A., 2019. Past behavior and the decision to text while driving among young adults. Transport. Res. F: Traffic Psychol. Behav. 60, 58–67. https://doi.org/10.1016/j.trf.2018.09.027.

Simons-Morton, B., Ehsani, J.P., 2016. Learning to drive safely: reasonable expectations and future directions for the learner period. Safety (Basel, Switzerland) 2 (4), 20. https://doi.org/10.3390/safety2040020.

Simons-Morton, B., Bingham, C.R., Falk, E.B., Li, K., Pradhan, A.K., Ouimet, M.C., ... Shope, J.T., 2014. Experimental effects of injunctive norms on simulated risky driving among teenage males. Health Psychol. 33 (7), 616–627. https://doi.org/10.1037/a0034837.

Son, J., Park, M., Park, B.B., 2015. The effect of age, gender and roadway environment on the acceptance and effectiveness of advanced driver assistance systems. Transport. Res. F: Traffic Psychol. Behav. 31, 12–24. https://doi.org/10.1016/j.trf.2015.03.009.

van de Bongardt, D., Reitz, E., Sandfort, T., Deković, M., 2015. A meta-analysis of the relations between three types of peer norms and adolescent sexual behavior. Personal. Soc. Psychol. Rev. 19 (3), 203–234. https://doi.org/10.1177/1088868314544223.

Wang, J., Wang, X., 2012. Structural Equation Modeling. Higher Education Press, United Kingdom.

Warren, I., Meads, A., Whittaker, R., Dobson, R., Ameratunga, S., 2018. Behavior change for youth drivers: design and development of a smartphone-based app (Backpocketdriver). JMIR Formative Research 2 (2), e25. https://doi.org/10.2196/formative.9660.

Wolf, E.J., Harrington, K.M., Clark, S.L., Miller, M.W., 2013. Sample size requirements for structural equation models: an evaluation of power, bias, and solution propriety. Educ. Psychol. Meas. 76 (6), 913–934. https://doi.org/10.1177/0013164413495237.