Getting in the path of the robot

Pedestrians acceptance of crossing roads near fully automated vehicles

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Getting in the path of the robot: Pedestrians acceptance of crossing roads near fully automated vehicles

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Abstract

Adoption of Automated Vehicles (AVs) within transport networks relies on the technology acceptance of not only AV users, but also other road users such as pedestrians. However, previous research has mostly focused on user acceptance of AVs and the receptivity of pedestrians towards AVs has been largely unexplored. This study aims to fill this gap by applying the Theory of Planned Behaviour (TPB), the Technology Acceptance Model (TAM), and the Unified Theory of Acceptance and Use of Technology (UTAUT) to investigate pedestrians' intentions to cross a road in front of a fully AV. To achieve this goal, a 20-minute online questionnaire was administered in Australia and data were collected for a total of 485 participants (average age = 35.35 years, 51.5% female). Bivariate correlation analysis and hierarchical regression models were then applied on the data to investigate the association between pedestrian attributes and their behavioural intentions. The findings revealed that the TPB and the UTAUT explained 46% and 43% of the variance in intentions to cross a road in front of a fully AV, respectively, with perceived behavioural control (PBC) and subjective/social norms the most significant unique predictors of intentions within the TPB and UTAUT, respectively. The TAM, however, only explained 35% of the variance in intentions to cross a road in front of a fully AV. When added into Step 2 of the hierarchical regression, age accounted for additional variance above the TAM predictors, indicating that younger participants reported higher intentions to cross a road in front of a fully AV than older participants. Age was not a significant predictor of intentions when entered with the predictors of the TPB and UTAUT. This study provides support for the use of these theoretical models to understand pedestrians' acceptance of AVs.

Keywords. Automated vehicles; pedestrians; technology acceptance; Theory of Planned Behaviour; Technology Acceptance Model; Unified Theory of Acceptance and Use of Technology.

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1. Introduction

Pedestrians are among the most vulnerable road users who account for more than one fifth of road fatalities around the world each year (World Health Organisation, [WHO] 2013). In Australia, pedestrians accounted for 13% (160 out of 1,195) of road deaths in 2019 (BITRE, 2020). The pedestrian injury statistics are even higher, highlighting the need to better understand factors influencing pedestrian safety across road networks in Australia. Previous studies have shown that factors contributing to pedestrian injuries and fatalities may arise from three major sources including engineering design of the road environment (e.g., lack of footpaths, inadequate visibility), driver behaviour and human error (e.g., speeding, alcohol impairment), and pedestrian behaviour (e.g., alcohol impairment, mobile phone distraction) (Nasar & Troyer, 2013; WHO, 2013). Among these factors, driver behaviour and human error have been reported to be the primary cause of roadway crashes in general (Afghari et al, 2016, 2018) and pedestrian crashes, in particular (Habibovic et al., 2013; Preusser et al., 2002; Sasidharan et al., 2015). Meanwhile, Automated Vehicles (AVs) have been proposed as a potential solution to reduce roadway crashes associated with human error and thus may contribute to pedestrian safety as well. However, successful adoption of AVs within transport networks heavily relies on road users' acceptance towards this new technology as well as application of relevant policy incentives, and mitigation of potential behavioural issues among all road users.

1.1. Pedestrian-AV interaction

Recently, there has been emergence of literature which has examined pedestrian-AV interaction (see Ezzati Amini et al., 2021), particularly studies which have investigated pedestrians' intentions to cross in front of AVs (e.g., Epke et al., 2021; Jayaraman et al., 2020; Nuñez Velasco et al., 2019; Palmeiro et al., 2018; Rad et al., 2020). For example, Nuñez Velasco et al (2019) examined 55 participants intentions to cross in-front of an automated passenger shuttle (WEpod). Using a mixed binomial logistic regression model, they found that the presence of a zebra crossing and larger gap size between the vehicle and pedestrian resulted in higher crossing intentions. Further, higher self-report ratings of perceived behavioural control (PBC; perceived ease or difficulty of performing a behaviour) and trust were also associated with higher crossing intentions. Similarly, Rad et al. (2020) reported that the presence of a zebra crossing and distance from the AV were significant predictors of crossing behaviour. Further, participants aged between 18-40 years crossed nearly twice as much more in front of the approaching AV than participated aged over 40 years. In Dey et al. (2019), speed and distance were also reported by participants in determining their willingness to cross in front of the approaching automated or manually driven vehicle.

External human-machines interfaces (eHMIs) have also been reported to influence pedestrian crossing behaviour (e.g., Ackermann et al., 2019; Bazilinskyy et al., 2019; Dey et al., 2019; Wang et al., 2021). Wang et al. (2021) applied a Wizard of Oz (i.e., vehicle operator wearing a seat suit as a “ghost” driver) method to examine pedestrians’ interaction with an AV at an intersection with crossing. The study also examined the influence of eHMIs on individuals’ decision to cross the road, including text (e.g., using words such as stopping, stopped), symbols (e.g., hand, person), and animated eyes. They found that participants reported vehicle speed as the most important information source for deciding when to cross the road in front of an AV. In terms of eHMIs, participants rated text as most effective, followed by symbols, then aminated eyes. Bazilinskeyy et al. (2019) also found that compared to colour-only eHMIs, textual eHMIs were reported by pedestrians to be more persuasive. Further, Ackermann et al. (2019) reported that participants preferred direct advice from the vehicle (e.g., go ahead) than communication of the vehicle status. Overall, these studies highlight that factors including speed, distance, presence of a zebra crossing, eHMIs, trust, and age may influence whether a pedestrian will cross a road in front of an AV or not.

1.2. Psychosocial theories of acceptance and related research

To date, only a few published studies have applied psychosocial theories of acceptance to assess pedestrians' perceptions towards AVs (e.g., Deb et al., 2017; Penmetsa et al., 2019). The current study extends upon the previous research by applying three psychosocial models of acceptance (i.e., Theory of Planned Behaviour [TPB], Technology Acceptance Model [TAM], and Unified Theory of Acceptance and Use of Technology [UTAUT]) to examine pedestrians' intentions to cross the road in front of AVs. The TPB is a conceptual framework extended based on the Theory of Reasoned Action (Ajzen & Fishbein, 1980) to predict and understand human behaviours in specific contexts (Ajzen, 1991). The theory is described in a way that traces the causal links from beliefs through attitudes, subjective norm, perceived behavioural control (PBC) and intentions to the actual behaviour of interest. Individual's intention to perform a given behaviour is the central factor of the framework, and it indicates the extent of willingness and effort that people are planning to exert to perform the behaviour. According to TPB, there are three conceptually independent determinants of intentions, which are attitudes (favourable or unfavourable beliefs), subjective norms (perceptions that important others would approve or disapprove of you performing the behaviour) and PBC. Further, PBC, together with intentions, are direct predictors of behaviour. The focus of this study was on intentions given that fully AVs are not yet available in Australia.

The TAM was first proposed by Davis (1986) and is a widely used theoretical model in the field of information system to predict users' acceptance and usage of technology. The model contains two main determinants: perceived usefulness and perceived ease of use.

Perceived usefulness refers to "the extent to which a person believes that using a given system would enhance his/her job performance", and perceived ease of use is defined as "the extent to which a person believes that using a particular system would be free of effort" (Davis, 1986). According to the TAM, perceived ease of use has direct influence on perceived usefulness as it is believed that the easier the system is to use, the more useful it can be if other things remain equal (Davis, 1989).

Venkatesh et al. (2003) synthesized several prominent models that have been widely applied to explain and predict user acceptance and usage of information technology, including TPB and TAM, and proposed the UTAUT. The UTAUT identifies four main determinants, including performance expectancy (the extent to which the system will assist an individual), effort expectancy (ease of use), social influence (influence of important others on using the system), and facilitating conditions (existing support to use the system), and four moderators (i.e., age, gender, experience, and voluntariness of use) to predict users' intentions to use a technology. The UTAUT theorizes that user acceptance is influenced by both facilitating conditions and users' intentions to use and that intentions are determined by performance expectancy, effort expectancy, and social influence. The combinations of the four moderators were established to moderate the relationships among various UTAUT constructs.

In recent years, many pioneering research efforts have been made to apply the three models or their variant forms to understand individuals' acceptance and usage intention towards AVs. For example, Buckley et al. (2018) applied the TPB and TAM to assess drivers' intended use of AVs, and their study showed that all constructs of TPB were significant predictors of intentions to use a conditional (Level 3) private AV which explained 46% of variance in intentions. Further, the two predictors within the TAM explained 41% of variance in intentions. Moták et al. (2017) applied the TPB and TAM to assess individuals' intentions to use an automated passenger shuttle. They found that the predictors within the TPB and TAM accounted for 40% (study 1; undergraduate students) and 43% (study 2; individuals who had used the shuttle) of variance in intentions to use an automated passenger shuttle. Additional variables of group norms, pleasure, confidence, and environment values accounted for an additional 16% of the variance in intentions in study 1. Experience also accounted for additional variance in intentions for those who had used the shuttle in study 2.

Zhang et al. (2019) introduced new constructs which included initial trust, perceived safety risk, and perceived privacy risk to the TAM to explore the factors influencing users' acceptance of AVs. Their study suggested that initial trust was the most important factor of attitudes towards AVs, and it determined the intentions to use AVs together with perceived usefulness. Xu et al. (2018) recruited 300 undergraduate students to ride in a conditional AV on a test track. Consistent with the TAM, perceived usefulness and perceived ease of use were significant positive predictors of future intentions to use self-driving vehicles in the future. Trust and perceived safety were also identified as significant positive predictors of future intentions. Kaye et al. (2020) applied the TPB and UTAUT to explore drivers' a priori acceptance of highly (Level 4) AVs. Participants were recruited in Australia, France, and Sweden. Their study showed that drivers' intention to use highly AVs differed according to country of residence, and the factors within the TPB accounted for 57.9% to 74.1% of the variance in intentions, with the UTAUT accounting for an additional 3 to 6% of the variance more than the predictors within the TPB. Taken together, these studies provide some support for the utility of the TPB, TAM, and UTAUT in predicting users' future intentions to use AVs and provide insights into the critical factors that may influence the intended use of AVs.

To take into account individual difference in accepting new technologies, personal innovativeness has been identified as an important factor in addition to the basic demographic characteristics (e.g., age, gender). The construct helps identify individuals who are more likely to adopt technology innovations earlier than others, and the scale measures the extent to which individuals are willing to try out new technologies (Agarwal & Prasad, 1998). In the research related to AV acceptance, several studies have found that personal innovativeness has a positive influence on the behavioural intention to use automated vehicles (Benleulmi & Blecker, 2017; Hegner et al., 2019). Thus, this construct was included as an additional variable in the current study.

1.3. Current research

The focus of this study was on fully AVs as our motivation was to assess basic human behaviours towards purely machine-controlled vehicles. Conditional (Level 3) and highly (Level 4) vehicles were not focused upon as their control is shared between human driver/operator and the vehicle systems. Despite the existing support in the literature for the utility of applying psychosocial models to examine user acceptance of AVs (e.g., Buckley et al., 2018; Madigan et al., 2016, 2017; Zhang et al., 2019), limited research has assessed pedestrians' perceptions towards AVs. However, it is intuitive to postulate that the way in which pedestrians interact with fully AVs will be different from their current interactions with traditional vehicles. For instance, pedestrians will no longer be able to rely on the non-verbal cues from the driver and instead, will have to learn to detect the intention of fully AVs. While most recent research has examined how AVs should best communicate their intention to pedestrians (e.g., Fuest et al., 2020), there is lack of research on pedestrians' current acceptance of fully AVs. Therefore, this study aimed to address this research gap by comparing the explanatory values of the TPB, TAM, and UTAUT in predicting pedestrian intentions to cross a road in front of a fully AV.

2. Methods

To test the application of the three theoretical models of acceptance in predicting pedestrians' behaviour towards AVs, an online questionnaire was administered in

Queensland (Australia) following a cross-sectional design. The research was approved by the Ethics Review Committee of Queensland University of Technology (approval number: 1900000669). The characteristics of the participants, the details of the measures in the questionnaire and the questionnaire procedure are presented in the following.

2.1. Participants

Participants (N = 485) were aged between 18-85 years (average age = 35.3 and standard deviation 16.4) and 51.5% were female. All participants resided in Australia. According to the Australian Bureau of Statistics ([ABS], 2020), in 2019 the median age of Australian was 37 years with 76% of the population aging between 18-85 years, and females accounted for 50.4% of the national population. However, the age of the sample was not representative of the age distribution in Australia. For education, participants were asked to report the highest level of education that they had completed. Thirty-four (7.0%) reported completing less than year 12, 162 (33.4%) completed year 12, 133 (27.4%) completed a certificate or diploma, 109 (22.5%) completed a bachelors' degree, and 44 (9.1%) reported completing a Masters' degree or higher. Three participants (0.6%) did not provide a response to this question. Most of the sample (91.0%) reported hearing of the term 'automated vehicle' prior to completing the questionnaire. As an incentive strategy, participants received either partial course credit (0.5%) or entry into a prize draw to receive 1 of 10 $50 AUS shopping vouchers for their participation.

2.2. Measures[1]

2.2.1. Demographics and descriptive questions. Demographic information included age, gender, and education. Participants were also asked, "Before today, have you heard of the term automated vehicle?" (yes/no). To measure exposure, participants were asked, "How many hours do you spend walking on roads in the average week?"

[1] Only those measures relevant to this paper are reported.

2.2.2. Personal Innovativeness. Based on previous research (Deb et al., 2017), a 7-point Likert Scale (1 = *strongly disagree*, 7 = *strongly agree*) was used to assess personal innovativeness. The four items included, "If I heard about a new technology, I would look for ways to experiment with it", "Among my peers, I am usually the first to try our new technologies", "In general, I am hesitant to try out new technologies" (reverse scored), and "I like to experiment with new technologies". Higher scores reflect greater personal innovativeness and the scale was shown to have strong internal consistency in the current study ($\alpha = .87$).

2.2.3. Acceptance measures. A list of items which were used to measure the TPB, TAM, and UTAUT are presented in the Appendix. A 7-point semantic differential scale measured attitudes using the following word pairs; unpleasant/pleasant, unfavourable/favourable, unsafe/safe, and negative/positive. All other acceptance constructs were measured on a 7-point Likert Scale (1 = *strongly disagree*, 7 = *strongly agree*). For the TPB items, 2 items measured PBC ($r = .291$, $p < .01$), 2 items measured subjective norms ($r = .438$, $p < .01$), and 2 items measured intentions ($r = .928$, $p < .01$). For the TAM, 1 item measured perceived usefulness and 2 items measured perceived ease of use ($r = .537$, $p < .01$). For the UTAUT, 2 items each measured performance expectancy ($r = .697$, $p < .01$) and effort expectancy ($r = .551$, $p < .01$). The same item used to measure subjective norms in the TPB was used to measure social influence in the UTAUT. This construct will be referred to as subjective norms from this point forward. Higher scores on all measures indicated greater acceptance of fully AVs.

2.3. Procedure

The Qualtrics questionnaire platform was used to create the online questionnaire (http://www.qualtrics.com). A global online market search firm, Dynata (http://www.dynata.com), was invited to provide questionnaire administration and dissemination, and data collection and cleaning services. Meanwhile, the online questionnaire was also disseminated using social media (e.g., Facebook, Twitter) and electronic mail through Queensland University of Technology mailing lists. Respondents of the study were required to be living in Australia, over 18 years old. The questionnaire took about 20 minutes to complete, and the respondents were assured that participation was voluntary.

2.4. Data analysis

Bivariate correlations were first undertaken to assess the relationships between the demographic variables of age, gender, and education, personal innovativeness, and the constructs within the TPB, TAM, and UTAUT. Consistent with previous research which has applied psychosocial models to assess users' intentions to use AVs (e.g., Kaye et al., 2020; Madigan et al., 2017), hierarchical regression models were performed whereby the predictors were entered into Step 1, and demographic variables, exposure, and personal innovativeness were entered into Step 2 to check if these variables explained further variance in intentions. Hierarchical regression modelling is a useful way of evaluating whether an independent variable of interest explains a statistically significant amount of variance in the dependent variable of interest after accounting for all other independent variables (Hox, 1994). In doing so, several regression models are created one after another by adding independent variables to the previous regression model at each step. The statistical fit of the regression models are then evaluated to determine whether newly added independent variables result in a significant improvement in the statistical fit. R-squared (R^2) and F Statistic are common statistical measures that are used to evaluate the proportion of explained variance in the dependent variable within the hierarchical regression models (Recchia, 2010).

The first hierarchical regression model aimed to test the predictive value of the TPB. As such, the TPB constructs of attitudes, subjective norms, and PBC were employed in step 1 of the regression and personal innovativeness and demographic variables were employed in step 2 of the regression. The second hierarchical regression model aimed to test the TAM and so perceived usefulness and perceived ease of use were employed in the first step and personal innovativeness and demographic variables were employed in the second step of this regression. Finally, the last hierarchical regression model aimed to test the predictive value of the UTAUT and thus performance expectancy, effect expectancy, and subjective norms were entered into the first step and the demographic variables and personal innovativeness were entered into the second step of this regression model.

3. Results

3.1. Data screening

Initial screening of the data illustrated that there were a few missing records in the dataset. However, the Little's MCAR test revealed that missing data were less than 5% and that data were missing completely at random, χ^2 (41) = 43.43, p = .368. As such, the missing data were dealt with by case-wise deletion of the records with missing values (Afghari et al., 2019). All assumptions were met, and significance testing was assessed at $p < .05$.

3.2. Descriptives and Bivariate correlations

The mean values of the psychosocial constructs ranged from 3 to 5 on a 7-point Likert Scale (1 = *strongly disagree*, 7 = *strongly agree*; see Table 1). The mean scores for subjective norms (M = 3.53) and perceived usefulness (M = 3.87) suggest that participants slightly disagreed that important others would approve of their behaviour and that sharing the roads will fully AVs would improve their walking performance. The mean scores for attitudes, perceived ease of use, performance expectancy, effort expectancy, and intentions ranged from 4.26 to 4.66, equating to neutral (i.e., participants neither agreed nor disagreed that these factors would influence their interactions with fully AVs or crossing intentions). For PBC, and on average, participants slightly agreed that they were confident, and it was mostly up to them if they were to cross the road in the presence of fully AVs.

There were significant weak negative correlations between age and the factors of personal innovativeness, attitudes, subjective norms, perceived usefulness, performance expectancy and intentions (see Table 1). Further, there were significant weak negative correlations between gender and the factors of personal innovativeness, PBC, perceived ease of use, and effort expectancy, suggesting that male participants and younger participants had higher scores on these constructs. There were also significant weak positive correlations between personal innovativeness and the measures of acceptance, suggesting higher personal innovative scores were associated with higher acceptance of fully AVs. As expected, there were significant weak to strong positive correlations between all constructs within the TPB, TAM, and UTAUT (see Table 1).

Table 1 about here

3.3. Hierarchical regressions

The TPB constructs of attitudes, subjective norms, and PBC significantly accounted for 46.4% of variance in intentions to cross roads in front of fully AVs, ($F(3,468)$ 134.41, $p <$ .001). Attitudes, subjective norms, and PBC were all shown to be significant predictors of intentions, with PBC shown to be the strongest unique predictor of intentions (see Table 2). When entered into Step 2, the sociodemographic factors of age, gender, and education, exposure, and personal innovativeness did not significantly add variance to intentions to crossing a road in front of fully AVs, ($\Delta R^2 = .010$, ΔF (5,460) = 1.71, $p = .131$).

The TAM constructs of perceived usefulness and perceived ease of use significantly accounted for 36.0% of variance in intentions to cross roads in front of fully AVs, ($F(2,479)$ = 134.12, $p < .001$). When added into Step 2, age, gender, education, exposure, and personal innovativeness significantly accounted for additional variance in intentions to crossing a road in front of fully AVs, ($\Delta R^2 = .022$, ΔF (5,472) = 3.38, $p = .005$). Table 3 shows that along with the TAM constructs, age was the only significant unique predictor of intentions. Gender, education, exposure, and personal innovativeness were not significant predictors of intentions.

The UTAUT constructs of performance expectancy, effort expectancy, and subjective norms accounted for 43.6% of variance in intentions to cross roads in front of fully AVs, ($F(3, 479) = 122.44$, $p < .001$). Performance expectancy, effort expectancy, and subjective norms were all significant predictors of intentions, with subjective norms shown to be the strongest unique predictor of intentions (see Table 4). When entered into Step 2, age, gender, education, exposure, and personal innovativeness did not significantly add variance to intentions to crossing a road in front of fully AVs, ($\Delta R^2 = .011$, $\Delta F\ (5,471) = 1.89$, $p = .094$).

Tables 2-4 about here

4. Discussion

Utilising a cross-sectional design, this study aimed to assess the explanatory value of the TPB, TAM, and UTAUT in predicting pedestrian intentions to cross a road in front of a fully AV. Overall, the findings showed that the three theoretical acceptance models were able to predict pedestrians' intentions to cross a road in front of a fully AV. The predictors of both the TPB and UTAUT explained more variance in intentions to cross a road in front of a fully AV (46% and 43%, respectively) compared to the predictors within the TAM, which explained 35% of the variance in intentions. For the TPB, PBC was shown to be the most unique positive predictor of intentions to cross a road in front of fully AVs and for the UTAUT, subjective norms were the most unique positive predictor of intentions. These findings highlight the importance of pedestrians' perceived confidence in their ability to cross in front of fully AVs as well as the influence that important others will have on their intentions to cross in front of fully AVs. Further, personal innovativeness did not add to the variance in intentions above and beyond the predictors included in the three psychosocial models. This finding is inconsistent with previous research (e.g., Benleulmi & Blecker, 2017;

Deb et al., 2017) and may suggest that more research is required to investigate the effect of personal innovativeness on pedestrians' intentions to cross in front of AVs.

4.1. Pedestrian-AV interaction

As outlined in the introduction, variables including environment and vehicle factors (e.g., presence of a zebra crossing, the distance between pedestrian and vehicle, speed of vehicle), demographic factors (e.g., age), and external human-machine interfaces (e.g., textual, visual eHMIs) may also influence pedestrian crossing intentions (e.g., Bazilinskyy et al., 2019; Nuñez Velasco et al., 2019; Rad et al., 2020; Wang et al., 2021). eHMIs are designed to communicate the intentions of the AV to those outside of the vehicle (e.g., pedestrians, bicyclists). Previous research has found that eHMIs may improve pedestrians' sense of safety (Faas et al., 2020) and that pedestrians are more likely to cross in-front of an AV with eHMI than without eHMI (Kooijman et al., 2019). Further, a recent study which interviewed 16 experts in human factors found that most experts reported that eHMIs would enhance the interaction between AVs and vulnerable road users (Tabone et al., 2021). Relating back to the current findings, factors including PBC (confidence in crossing in-front of AVs) and performance expectancy (e.g., reducing risk of being involved in a crash) were significant positive predictors of participants intentions to cross in front of a fully AV. These current findings may provide some support for eHMIs, suggesting that pedestrians may be more willing to cross in front of a fully AV if they are aware of the intentions of the vehicle.

In the current study, and for demographic factors, age was also a statistically significant predictor of intentions when entered with perceived usefulness and perceived ease of use. The negative parameter of age suggested that younger pedestrians reported higher intentions to cross a road in front of a fully AV than older pedestrians. Previous research has shown that compared to those aged 31 years and older, younger adults (aged 18-30 years) reported greater confidence to cross a road in front of an AV (Deb et al., 2017). Further, Rad et al. (2020) reported that participants aged between 18-40 years were more likely to cross in-front of an approaching vehicle than those aged over 40 years. For gender and education, and similar to Rad et al. (2020) who reported that gender and education were not significant factors of crossing behaviour, gender and education were not significant predictors of crossing intentions in the current study. Overall, the current findings support previous research which has found that younger pedestrians have higher intentions to cross a road in front of a fully AV than older pedestrians.

4.2. Practice and policy implications

Acceptance of fully AVs among vulnerable road users such as pedestrians is important to guarantee uptake of this technology, smooth implementation of relevant policy, and mitigate potential behavioural issues among other road users. This is even more critical when considering that fully AVs are anticipated to have benefits for safety when fully implemented (US Department of Transportation, 2017). In this regard, some practice and policy implications can be drawn from the present study. Primarily, this investigation showed that the TPB and UTAUT explain to a larger extent the formation of acceptance among pedestrians compared to the TAM. Therefore, future evaluations of acceptance among pedestrians should prioritise the use of the TPB or UTAUT over the TAM. Additionally, statistical models with superior explanatory power (TPB and UTAUT) suggest that demographics may only have a minor role in the formation of acceptance. Thus, the technology itself appears to be a stronger determinant of acceptance than the individual differences such as age and gender. This is probably a consequence of the growing presence of automated driving in public discourse and pop culture (Cohen et al. 2020; Kröger, 2016), which make the idea of fully AVs to be more ubiquitous and accessible. It also means that public attitudes towards fully AVs are starting to shift, which highlights the need for on-going research aiming at monitoring changes in public and community acceptance of fully

AVs. Finally, the constructs related to the capacity expected during interactions with fully AVs and the perceptions of other people are the ones that have a larger influence on acceptance. This contains an important lesson to fully AV's stakeholders: if pedestrians perceived that they have confidence in their ability to cross in front of fully AVs and that important others would approve of this behaviour then they will have greater intentions to cross in front of fully AVs. Stakeholders should consider these factors for public education initiatives among pedestrians.

4.3. Study limitations

This study is not without limitations. First, this study focused on pedestrians a priori acceptance of AVs as fully AVs are not yet available in Australia. Therefore, more research is required to examine pedestrian's acceptance and subsequent behaviour when crossing a road in front of fully AVs when these vehicles are introduced onto our roads. Second, the age of the sample was not representative of the age distribution within Australia. Therefore, more research is required to examine pedestrian's acceptance of fully AVs using a more representative sample. Third, the study did not assess participants prior knowledge or previous experience with AVs. Given that previous research has reported that pedestrians who had previously interacted with AVs reported more favourable attitudes towards AVs (Penmetsa et al., 2019), future studies should control for prior knowledge/experience when assessing pedestrians' acceptance of AVs. Finally, the study only controlled for the demographic factors of age, gender, and education. Future research should consider controlling for additional demographic factors such as occupation, income, and possession of a driver's licence to see if these factors influence crossing intentions.

4.4. Conclusion

Overall, the current findings extend upon previous research which has applied theoretical models to understand users' acceptance of AVs and provides support for the use of these models to understand pedestrians' acceptance of AVs. The current findings show that having confidence over one's ability to cross a road in front of an AV as well as the perception that important others would approve of this behaviour, were important in determining a pedestrians intention to cross a road in front of an AV. Applying well validated theoretical models of acceptance may assist in increasing our understanding of the factors that influence vulnerable road users acceptance of AVs, and intentions to interact with these vehicles once they are introduced onto our roads.

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Appendix

Acceptance items

Theory of Planned Behaviour (TPB)

Attitudes (adapted from Buckley et al., 2018; Elliott & Armitage, 2009; Gauld et al., 2017)
As a pedestrian, I would consider that crossing roads in the presence of fully AV would be: unpleasant/pleasant, unfavourable/favourable, unsafe/safe, negative/positive.

PBC (adapted from Buckley et al., 2018)
I am confident I will be able to cross roads in front of fully AVs.
It's mostly up to me whether or not I will cross roads in the presence of fully AVs.

Subjective norms (items from Deb et al., 2017 social norm scale) [2]
People who influence my behaviour would think that I should cross roads in front of fully AVs.
People who are important to me and/or influence my behaviour have a positive attitude towards fully AVs.

Technology Acceptance Model (TAM)

Perceived usefulness (adapted from Rahman et al., 2017)
Sharing roads with fully AVs would improve my walking performance.

Perceived ease of use (adapted from Rahman et al., 2017)
My interaction with fully AVs while crossing the road would be clear and understandable.
I would find fully AVs difficult to interact with while crossing the road (reverse score).

Unified Theory of Acceptance and Use of Technology (UTAUT)

Performance expectancy (adapted from Rahman et al., 2017)
Crossing roads in front of fully AVs would enable me to react to unsafe walking conditions more quickly.
Crossing roads in front of fully AVs would decrease my risk of being involved in an accident.

Effort expectancy (adapted from Rahman et al., 2017)
Learning to interact with fully AVs while crossing the road would be easy for me.
I would find it difficult to cross roads in front of fully AVs (reverse score).

Intentions (adapted from Buckley et al., 2018)
I intend to cross roads in front of fully AVs.
I plan to cross roads in front of fully AVs.

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[2] Item, "People who are not important to me would not think that I should cross the roads in front of FAVs" (reversed score) was removed as Cronbach's Alpha was a = .44 for the original 3-item scale.

Table 1

Descriptives and Bivariate correlations

	M(*SD*)	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Age	39.41 (16.22)	-												
2. Gender	1.47 (0.52)	-.195**	-											
3. Education	2.93 (1.10)	.168**	-.091*	-										
4. Exposure (hours walking)	4.04 (4.19)	-.053	.018	-.121**	-									
5. Personal innovativeness	4.78 (1.36)	-.178**	-.224	.142**	.075	-								
6. Attitudes	4.44 (1.65)	-.149**	-.053	-.033	-.027	.272**	-							
7. Subjective norms	3.53 (1.53)	-.210**	.017	-.010	-.009	.255**	.461**	-						
8. PBC	5.01 (1.27)	-.082	-.102*	.023	-.042	.317**	.458**	.439**	-					
9. Perceived usefulness	3.87 (1.65)	-.141**	-.082	.024	-.053	.337**	.484**	.514**	.499**	-				
10. Perceived ease of use	4.36 (1.37)	-.066	-.099*	.040	-.007	.349**	.529**	.483**	.572**	.588**	-			
11. Performance expectancy	4.13 (1.45)	-.152**	-.039	.012	-.078	.287**	.561**	.568**	.534**	.681**	.651**	-		
12. Effort expectancy	4.66 (1.34)	-.097*	-.119**	.085	-.038	.377**	.499**	.441**	.606**	.521**	.735**	.594**	-	
13. Intentions	4.26 (1.79)	-.206**	-.052	-.038	-.031	.286**	.460**	.550**	.586**	.510**	.548**	.511**	.555**	-

Notes. PBC = perceived behavioural control. All acceptance items were measured on a 1-7 scale.

** p <.01; * p < .05

Table 2

Regression analysis of TPB predictors of intentions to cross in front of FAVs

	B	SE B	β	*p*	sr^2
Step 1 (R^2 = .464)					
Attitudes	.142	.043	.133	.001	.01
Subjective norms	.472	.060	.317	<.001	.07
PBC	.539	.055	.388	<.001	.11
Step 2 (ΔR^2 = .010)					
Attitudes	.128	.043	.120	.003	.01
Subjective norms	.445	.061	.299	<.001	.06
PBC	.531	.057	.383	<.001	.10
Age	-.009	.004	-.088	.017	.00
Gender	-.034	.122	-.010	.780	.00
Education	-.044	.057	.033	.391	.00
Exposure	-.003	.015	-.006	.861	.00
Personal innovativeness	.043	.051	.033	.391	.00

Note. PBC = perceived behavioural control. Step 2 was not significant (*p* = .131) and the statistics in Step 2 are only presented for completeness.

Table 3

Regression analysis of TAM predictors of intentions to cross in front of FAVs

	B	SE B	β	*p*	sr^2
Step 1 (R^2 = .360)					
Perceived usefulness	.298	.049	.279	<.001	.05
Perceived ease of use	.502	.059	.390	<.001	.10
Step 2 (ΔR^2 = .022)					
Perceived usefulness	.269	.049	.251	<.001	.04
Perceived ease of use	.489	.059	.380	<.001	.09
Age	-.014	.004	-.126	.001	.00
Gender	-.012	.130	-.003	.929	.00
Education	-.070	.060	-.043	.248	.00
Exposure	-.007	.016	-.016	.673	.00
Personal innovativeness	.066	.054	.050	.225	.00

Table 4

Regression analysis of UTAUT predictors of intentions to cross in front of FAVs

	B	SE B	β	*p*	sr^2
Step 1 (R^2 = .436)					
Performance expectancy	.141	.057	.116	.014	.01
Effort expectancy	.445	.057	.338	<.001	.07
Subjective norms	.499	.063	.338	<.001	.07
Step 2 (ΔR^2 = .011)					
Performance expectancy	.132	.057	.108	.022	.01
Effort expectancy	.436	.059	.331	<.001	.06
Subjective norms	.475	.063	.321	<.001	.07
Age	-.008	.004	-.076	.041	.00
Gender	-.069	.124	-.020	.579	.00
Education	-.092	.057	-.052	.106	.00
Exposure	-.001	.015	-.003	.922	.00
Personal innovativeness	.045	.051	.035	.377	.00

Note. Step 2 was not significant (*p* = .094) and the statistics in Step 2 are only presented for completeness.