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Acceptability of connected automated vehicles: Attributes, perceived behavioural control, and perceived adoption norm

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ABSTRACT

Connected Automated Vehicles (CAVs) could be dominating the roads in the near future. CAVs are fully automated vehicles equipped to communicate and share data with other devices both inside and outside the vehicles, and can increase traffic safety and decrease greenhouse emissions from traffic, as they can ensure a more efficient traffic flow and reduce traffic jams. However, CAVs can only achieve this potential when they are accepted and widely adopted by the public. In this paper, we propose a model to explain the acceptability (i.e. evaluation before experience) of CAVs. We hypothesize that the acceptability of CAVs is higher when people evaluate its attributes more favourably, feel more able to use CAVs (i.e. higher perceived behavioural control), and think close others would consider adopting CAVs (i.e. the perceived adoption norm). We identified seven key attributes that could be important for the acceptability of CAVs, namely: safety, instrumental, hedonic, control, symbolic, environmental, and trustworthiness attributes. Results from a large-scale online questionnaire ($N = 3783$) showed that the proposed model explains acceptability well. Together, the evaluation of attributes of CAVs, perceived behavioural control, and perceived adoption norm explained 60 % of variance in acceptability. Positive evaluations of attributes were the strongest predictor of acceptability of CAVs, in particular safety, instrumental, and environmental attributes. Interestingly, we found that symbolic attributes predict acceptability better when the perceived adoption norm is low. The results suggest the acceptability of CAVs may be enhanced by improving the evaluations of its key attributes and by introducing it as a status product in the early adoption phase.

1. Introduction

Estimations indicate that in the near future connected automated vehicles (CAVs) could be dominating the roads (e.g. Talebian & Mishra, 2018), with several countries already allowing experiments on public roads and forming governmental regulations for either allowing or disallowing CAVs to drive on public roads in the future (Hansson, 2020). CAVs are fully automated vehicles equipped to

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communicate and share data with other devices both inside and outside the vehicles, including other vehicles and public transport systems (Shladover, 2018). For example, CAVs can communicate braking and speed status to other nearby vehicles. This makes the behaviour of CAVs more predictable to surrounding vehicles, thereby enhancing safety. CAVs may play an important role to reduce several societal problems, such as limiting climate change by emitting less CO_2 than manual cars, because of more fuel-efficient and economical driving, reducing traffic jams, and increasing traffic safety (Alessandrini et al., 2015). CAVs may also ensure transport equity, as they can enhance mobility levels for vulnerable road users and those currently unable to drive (Papa & Ferreira, 2018). In addition, CAVs may contribute to meeting the increased demands of goods transportation through more effective usage of existing infrastructure through truck platooning, for example. Major players in the automotive industry have invested heavily in designing vehicles with full (Level 4/5) automation and many started pilot testing these vehicles in designated areas (SAE International, 2016). Hence, a lot of resources and manpower are being allocated to promote the goal of the large scale use of fully automated vehicles. In the present paper we focus on CAVs as an individual mode of transportation, although CAVs could potentially also be employed as public transportation or as a shared ride service (see e.g. Zoellick et al., 2019).

CAVs will only be effective and provide their potential benefits when they are accepted by the general public and widely adopted by drivers, stressing the importance of examining public acceptability already in the development phase it is in right now (Dunphy & Herbig, 1995; Golbabaei et al., 2020). After all, interventions to enhance acceptability will be more effective if they target important determinants of acceptability. Acceptability reflects the extent to which people evaluate CAV favourably, before having any experience with it (Payre, Cestac, & Delhomme, 2014). Acceptance, on the other hand, reflects people's behavioural reactions after having experienced CAVs ((Schlag and Schade, 2000)), which is difficult to establish at present, as CAVs are not on the market yet. This means that acceptability is an attitude towards CAVs before having experienced the vehicle that may predict intention to adopt a CAV (Alexandre et al., 2018). Acceptability can be seen as a first step when considering adoption (see e.g. Bockarjova & Steg, 2014). Low acceptability of CAVs is likely to lead to low adoption rates, which in turn may result in the product being taken off the market, or not even entering it (Noppers et al., 2015).

Various psychological factors can affect the acceptability of mobility innovations, as for example seen when electric vehicles were reintroduced in the market (Coffman, Bernstein, & Wee, 2017). Although factors that influence acceptability of electric vehicles and partially automated vehicles have been examined before (e.g., Li et al., 2017), a thorough research of psychological factors that affect the acceptability of CAVs in particular is missing. The aim of the present study is to examine which psychological factors affect the acceptability of CAVs, which could provide valuable input on how to design interventions to enhance public acceptability before CAVs are introduced on the market.

Some level of automation has already been incorporated and is accepted in modern vehicles, such as parking assist and adaptive cruise control to assist the driver. However, CAVs will significantly change the driving experience, both for its passengers and for other road users, as it completely takes over the driving task. As such, different factors may be at play that influence its acceptability compared to vehicles with lower levels of automation. Research on vehicles with higher levels of automation has focused on the acceptability of Autonomous Vehicles (AV; e.g. Jing et al., 2020). Compared to AVs, CAVs include improved vehicle connectivity abilities to communicate with other vehicles and transportation networks, which can enhance the situational awareness of the vehicles. CAVs can share, for example, the vehicle's speed, heading, and brake status with other vehicles nearby. This could increase the road safety of CAVs compared to AVs (Eskandarian, Wu, & Sun, 2019). Moreover, CAVs' connectivity abilities could aid in improving the traffic flow and in planning the most efficient road, which could further enhance convenience for the user. Yet, the public may have concerns about the privacy of CAVs, as they share data with others, and as they could potentially get hacked through their connectivity abilities. In short, CAVs acceptability and the factors that influence it may differ from AVs and thus require additional research.

In the current paper, we aim to study which psychological factors influence the public acceptability of CAVs specifically. Below, we introduce a theoretical model that aims to explain which factors may influence the acceptability of sustainable innovations such as CAVs, namely the Instrumental Symbolic Environmental Model (ISE-model; Noppers et al., 2014). We will build upon this theoretical model by including additional factors that may be related to the acceptability of CAVs, and propose a new model that aims to explain the acceptability of CAVs specifically.

1.1. A model to explain the acceptability of CAVs

The Instrumental Symbolic Environmental model (ISE-model; Noppers et al., 2014), offers some insight on what one may consider to judge the acceptability of innovations such as CAVs. The ISE-model is a concise theory-based model that distinguishes between different types of motives that affect acceptability of innovations, and has been successfully used to explain acceptability and use of sustainable innovations, such as electric vehicles and local renewable energy systems. Specifically, the ISE-model posits that acceptability and adoption intentions of sustainable innovations are not only predicted by the evaluation of instrumental attributes (i.e. perceptions regarding functional outcomes of owning or using the product) as is most often assumed, but also and maybe even more so, by perceptions regarding symbolic attributes (i.e. perceptions regarding outcomes for one's self-identity or social status for owning or using the product) and environmental attributes (i.e. perceptions regarding outcomes for the environment for owning or using the product).

We propose that the acceptability of CAVs can be explained by the evaluation of four additional attributes that reflect the specific risks and benefits of CAVs due to their fully automated nature and connectivity abilities. More specifically, in the case of CAVs, where control is taken away from the driver, we reason that the following four other attributes may be relevant to explain the acceptability of CAVs: control attributes, safety attributes, trustworthiness attributes, and hedonic attributes. We will explain each of these below.

1.1.1. Control attributes

We define control attributes as the extent to which a person believes they are in control over a CAV's behaviour. The feeling of being in control of the vehicle is an important aspect of driving (Gardner & Abraham, 2007). However, as being driven by a CAV means that the traditional driver hands over control to the car, users may potentially experience a loss of autonomy ((Bongaerts et al., 2017)). This could reduce acceptability, as drivers generally indicate they value control over the vehicle (Brookhuis et al., 2001). Notably, the majority of drivers indicate they would still like to have some control over the pedals and steering wheel ((Schoettle and Sivak, 2014)), and prefer to be able to drive automated cars manually as well (Liljamo et al., 2018). Furthermore, lack of control is rated as the least attractive feature of automated vehicles (Howard & Dai, 2014), which may result in lower acceptability of autonomous vehicles (Waung, McAuslan, & Lakshmanan, 2021). We expect a similar finding for CAVs and we reason that control attributes associated with CAV may influence the acceptability of CAVs.

1.1.2. Safety attributes

As CAVs take over all driving tasks, CAVs are also responsible for the safety of their passengers and the safety of the other road users. This implies that perceptions of the extent to which CAVs will be successful in securing safety may affect acceptability of CAVs. We define safety attributes as the extent to which a person believes CAVs will not inflict harm upon its passengers and other road users. While some studies found that people are afraid of driving an automated car due to safety concerns, such as equipment failure and vehicle performance in unexpected situations (Schoettle & Sivak, 2014; Kyriakidis,Happee,& De Winter, 2015), other studies found that people associate automated vehicles with high safety and believe automated vehicles will improve road safety overall (Zmud et al., 2016; Howard & Dai, 2014). In a study where potential users experienced a highly automated vehicle, it was found that perceived safety and acceptability were strongly positively correlated, and that perceived safety is a solid predictor of intention to use automated vehicles (Zoellick et al., 2019). Hence, the evaluations of safety of CAVs may influence acceptability. As such, we include safety attributes to investigate their role in the acceptability of CAVs.

1.1.3. Trustworthiness attributes

It is possible that CAVs may not always behave as the passengers and other road users expect them to behave. However, CAVs can be seen as more acceptable when people believe they can count on the system that operates CAVs to function properly (Hoff & Bashir, 2015). Moreover, users may have doubts about data security, as CAVs share data with other vehicles and could potentially get hacked (Bongaerts et al., 2017), also indicating perceived trustworthiness may be related to acceptability of CAVs. We define trustworthiness attributes as the extent to which one believes CAVs will function properly as intended. Research has found that as trust in technology decreases, the perceived risk associated with using an automated vehicle increases, which may lower the acceptability of AVs (Choi & Ji, 2015). Moreover, higher trust in AVs is associated with a stronger intention to use AVs, which could be an indication that higher trust is linked to acceptability, as well. Interestingly, in a large-scale international survey 47% of the respondents indicated that a lack of trust (including the occurrence of system errors, and the potential of the vehicle getting hacked) was the largest barrier for the implementation of AVs (Jeon et al., 2018). Low trust in AVs can even lead to an increase in psychophysiological stress when driving in an AV (Morris et al., 2017). As such, trust in CAV technology can be a key predictor of acceptability.

1.1.4. Hedonic attributes

Lastly, we consider hedonic attributes, which we define as the extent to which a person believes driving in a CAV will be pleasurable. Drivers generally do not view driving as just a means of transportation, but find driving in itself thrilling, pleasurable, and adventurous (Steg, 2005). Fully automated driving could pose a threat to driving pleasure, as users no longer perform driving tasks. Research has found that expected fun of driving is lower for higher levels of vehicle automation (Rödel et al., 2014). On the other hand, automated driving may be pleasurable when engaging in situations in traffic that would normally be hasslesome manoeuvres, such as reverse parking and traffic jams (Bjørner, 2017). Hence, while findings on how perceived pleasure relates to one's (expected) experiences with automated driving is inconclusive (König & Neumayr, 2017), we hypothesise that greater perceived pleasure could be related to higher acceptability of CAVs (see e.g. Bernhard et al., 2020).

1.1.5. Perceived adoption norm and perceived behavioural control

Aside from evaluations of attributes, we include two other factors that could explain the acceptability of CAVs, namely the perceived adoption norm and perceived behavioural control. First of all, our behaviour may be guided by the perceived behaviour and expectations of others, especially of close others (Fishbein & Ajzen, 1975; Cialdini, Kallgren, & Reno, 1991). Indeed, an extended version of the ISE-model included the direct and indirect effects of the perception of the extent to which significant others will adopt a sustainable innovation (i.e. adoption norms; Noppers et al., 2019) as a predictor of acceptability of innovations. A stronger perceived adoption norm indeed increased adoption likelihood of electric cars (Noppers et al., 2019). Additionally, adoption norms may also affect the adoption of sustainable innovations in an indirect way, as weak adoption norms may strengthen the effect of symbolic attributes on adoption likelihood: symbolic attributes may in particular predict acceptability and adoption of sustainable innovations when people believe only few others consider adopting it. Hence, adoption may signal one's identity to others and the self more strongly if adoption norms are weak, as adoption is more likely to be attributed to personal characteristics when adoption norms are weak (Noppers et al., 2019). There is some initial evidence to suggest that indeed the evaluation of symbolic attributes particularly predicted interest in using an electric car when the perceived adoption norm was weak (Noppers et al., 2019). We will test whether the evaluation of symbolic attributes is more strongly related to the acceptability of CAVs when the adoption norm is weak.

The final factor we consider is perceived behavioural control, reflecting the perception of how easy or difficult using CAVs will be

(Ajzen, 1991). Potential barriers of CAVs could be the current lack of a legal framework or relevant policy to support the implementation of CAVs, as well as the unclarity about liability in case of an accident (Fagnant & Kockelman, 2015). Additionally, as CAVs are a new type of technology, some people may expect to have trouble with understanding how to operate the vehicle (Bennett et al., 2019). Especially people who are currently unable to drive and those who feel anxious about technology may be concerned about being able to use CAVs, and in turn may tend to be less likely to adopt CAVs (Dicianno et al., 2021). We hypothesise that these barriers could influence the extent to which one believes they will be able to use CAVs (i.e. perceived behavioural control), and in turn decrease the acceptability.

1.2. The current study

The aim of the current study is to test the proposed Acceptability of Connected Automated Vehicles model (ACAV-model) to predict the acceptability of CAVs specifically (see Figure 1). More concretely, we expect that the acceptability of CAVs depends on the evaluation of the attributes of CAVs and the perceived adoption norm, as is proposed by the extended ISE-model (Noppers et al., 2019). We further extend the ISE-model by including four additional attributes that may be relevant for acceptability of CAVs: control, safety, trustworthiness, and hedonic attributes. Moreover, we include perceived behavioural control as a predictor of the acceptability of CAVs.

We first test the ACAV-model by examining to what extent the three main predictors are related to acceptability of CAVs: the overall evaluation of CAV's attributes, perceived behavioural control, and perceived adoption norm. We expect that acceptability of CAVs will be higher if one evaluates the attributes of CAVs more positively, when people feel more able to use CAVs, (i.e., have higher perceived behavioural control), and when people perceive a stronger adoption norm, that is, when people expect many close others would consider adopting CAVs (Hypothesis 1, see Figure 1).

Aside from testing the ACAV-model, we test two other hypotheses. First, we will examine the relative strength of the separate attributes of CAVs in predicting acceptability, to determine which aspects of CAVs are relatively more important for acceptability, regardless of the perceived adoption norm and perceived behavioural control. This could be useful information for developing interventions aimed at enhancing public acceptability. Second, we test whether the effect of symbolic attributes on acceptability of CAVs is stronger when people believe only few others consider adopting CAVs, regardless of their evaluation of the other attributes. If it is, then interventions could take this into account at the early deployment stage, when the adoption norms are most likely weak. For example, CAVs could initially be marketed as a status product to possibly enhance acceptability.

2. Method

2.1. Participants

To test the ACAV-model, we conducted an online questionnaire study in six different European countries: the United Kingdom, the Netherlands, Germany, France, Spain, and Italy.[1] Respondents ($N = 5156$) were recruited via the online panel company Dynata, a company which has its own participant platform. Participants were selected on the basis of the following criteria: (1) respondents had to be aged 18 or older, (2) at least 80% of the sample had to possess a valid driving license, and (3) the sample needed to be balanced in terms of age and gender. A professional translator from Dynata translated the original English version of the questionnaire to all other languages, and the translations were checked and adapted when appropriate by native speakers before the questionnaire was distributed. Participants received money as compensation for their time. Ethical approval to conduct the research was obtained from the ethical committee of Psychology from the University of Groningen beforehand.

Respondents were excluded from the sample[2] if: (1) they completed less than 80% of the survey ($N = 332$; 6.4%), (2) they completed the survey in under 3 min (as estimated time of completion was 10–15 min; $N = 774$; 15%), (3) they clicked the same answer on a large proportion of questions (straight lining) or clicked the same answer on reverse-coded questions as on non reverse-coded questions ($N = 250$; 4.8%), (4) they left random words or numbers, or comments that clearly indicated they did not fill out the survey seriously in the comment box in combination with signs of straight lining ($N = 17$; 0.3%).

The final sample consisted of 3783 participants, of which 50.9% was female. Participants' age ranged from 18 to 72, with an average of 43 ($SD = 12.84$); age was distributed relatively evenly with roughly 20% younger than 30 and roughly 20% older than 55. The sample was equally distributed across countries, ranging from 625 participants to 637 participants per country. About 7.4% of the respondents did not have a driving license, 72.7% owned a car, 32.2% drove every day, while 13% drove rarely (i.e. a couple of times a month or less).

2.2. Procedure

Participants first received information about the study aims and what was expected of them, and they were asked to fill in an informed consent form. After giving consent, participants first were given a short description of what a CAV is, followed by questions

[1] We compared the sample characteristics per country with Chi^2-tests, and found no differences for gender and age distribution between countries.

[2] Exclusion criteria were determined before data collection. Visual inspection does not reveal systematic differences in age, gender, or country between included and excluded participants.

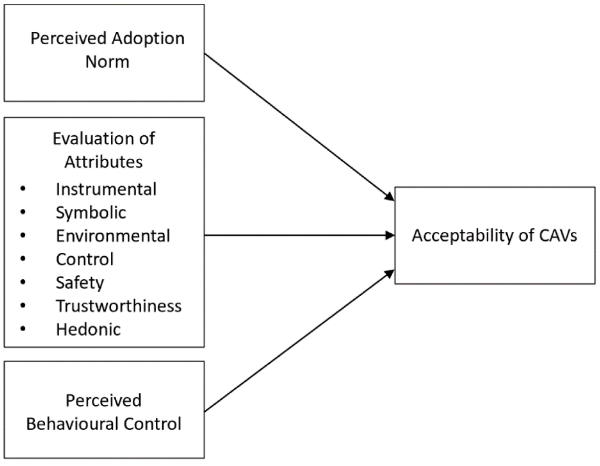

Fig. 1. Conceptual View of the Acceptability of Connected Automated Vehicles (ACAV) Model.

assessing their evaluations of the attributes of CAVs. Next, participants were asked about their perceived behavioural control, perceived adoption norm, acceptability of CAVs, and demographics. Participants were asked some other questions (e.g. personal values). However, as these are not at the focus of the present study, we will not discuss them further.

2.3. Materials

2.3.1. Evaluation of attributes of CAVs

Respondents were asked to evaluate 21 items that reflected the seven attributes of CAVs, on a 7-point Likert scale ranging from 1 'completely disagree' to 7 'completely agree'. The attributes reflected (1) control attributes, (2) hedonic attributes, (3) safety attributes, (4) trustworthiness attributes, (5) instrumental attributes, (6) symbolic attributes, and (7) environmental attributes. The statements were adapted from literature or created for this survey. Some items were formulated negatively, and thus reverse-coded. We recoded the reverse-coded items for the analyses, so that a lower score reflected a more negative view. Please refer to Table 1 below for an overview of the items and their origins.

2.3.2. Perceived adoption norm

Respondents were asked to indicate what percentage of close others (for example family, friends, and co-workers) they thought would adopt a CAV if it became available on a 11-point Likert scale ranging from 0 (0%) to 10 (100%), with increments of 10%.

2.3.3. Perceived behavioural control

Respondents were asked if they thought they would be able to use CAVs if they became available. Responses were given on a 7-point Likert scale, ranging from 1 (definitely not) to 7 (definitely). Higher means reflect a stronger perceived behavioural control.

2.3.4. Acceptability of CAVs

The acceptability of CAVs was measured by asking respondents to what extent they thought it the use of CAVs is acceptable, their country investing in CAVs is acceptable, a part of the traffic in their country consisting of CAVs is acceptable, and the use of CAVs within their country is acceptable (adapted from De Groot & Steg, 2007). All four questions were asked on a 7-point Likert scale, ranging from 1 (completely disagree) to 7 (completely agree; see Table 1). Higher means indicate higher acceptability of CAVs.

2.4. Data preparation

2.4.1. Confirmatory factor analysis

As we proposed a new model to explain acceptability and measured the included factors with modified or new items, we first conducted a confirmatory factor analysis (CFA) to test the factor structures and to obtain the factor weights that can be used to calculate the scales. The CFA was conducted using the lavaan package for R (Rosseel, 2012).

As can be seen in Figure 2, we entered a latent factor for the overall evaluation of attributes, which loaded onto separate latent factors for each attribute. The separate attribute latent factors loaded onto the specific items for each attribute. We also included a latent factor for acceptability, which loaded onto the items for acceptability. Factors were allowed to correlate, as we expected them to be related to some extent. We constrained every first item to 1 to be able to fit the model. Lastly, we included a latent factor called "method", which loaded on the reverse-coded items. Some participants may miss the presence of a negative particle in reverse-coded items, or they may have more difficulty to judge their agreement with a negatively-worded item. This can lead to inconsistent

Table 1
Items per Subscale with Source.

Subscale	Item	Source
Safety attributes	A connected automated car would be safe.	Created for questionnaire
	Driving in a connected automated car would not be safe. (R)	Created for questionnaire
	Connected automated vehicles would pose minimal risk to its driver, passengers, and other road users.	Created for questionnaire
Instrumental attributes	Connected automated vehicles would meet my driving needs.	Modified from Zmud, Sener, & Wagner (2016)
	Driving in a connected automated car would be convenient, since it would allow me to spend my time on other things than driving.	Modified from Ledger et al., 2018
	Driving a connected automated vehicle would be convenient, since it would make my journeys more efficient.	Modified from Montoro et al. (2019)
Hedonic attributes	Driving a connected automated vehicle would be less pleasurable than driving manually. (R)	Created for questionnaire
	Driving in a connected automated vehicle would be pleasurable.	Created for questionnaire
	Connected automated driving would be enjoyable.	Modified from Kyriakidis, Happee, & de Winter (2015)
Control attributes	I would be in control when driving in a connected automated vehicle.	Created for questionnaire
	I would have little control when driving in a connected automated vehicle. (R)	Created for questionnaire
	How a connected automated vehicle behaves is beyond the control of the driver/ passenger. (R)	Created for questionnaire
Symbolic attributes	A connected automated vehicle would enhance my social status.	Modified from Noppers et al. (2014)
	I can show who I am when driving a connected automated vehicle.	Modified from Noppers et al. (2014)
	A connected automated vehicle would give me the possibility to distinguish myself from others.	Modified from Noppers et al. (2014)
Environmental attributes	Connected automated cars would be more environmentally friendly than conventional cars.	Modified from Ledger et al., 2018
	Connected automated vehicles would reduce carbon emissions and pollution caused by car traffic.	Modified from Liu, Yang, & Xu (2019)
	A connected automated vehicle would emit less particulates and greenhouse gasses than conventional cars.	Modified from Noppers et al. (2014)
Trustworthiness attributes	I would trust a connected automated vehicle to behave as intended.	Created for questionnaire
	I trust that connected automated vehicles would correctly detect other road users.	Modified from Deb et al., 2017
	I trust the computer systems of connected automated vehicles cannot get hacked.	Modified from Liu, Yang, & Xu (2019)
Acceptability	The use of connected automated vehicles is acceptable.	Modified from De Groot and Steg (2007)
	It is acceptable that [country] invests in connected automated vehicles.	Modified from De Groot and Steg (2007); [country] reflected participant's country
	It is acceptable that a part of the [country]'s traffic will consist of connected automated vehicles.	Modified from De Groot and Steg (2007); [country] reflected the participant's country
	It is acceptable that people will use connected automated vehicles in [country].	Modified from De Groot and Steg (2007); [country] reflected the participant's country
Perceived adoption norm	According to you, what percentage of significant others (for example your family, friends, and coworkers) would drive a connected automated vehicle when they become available?	Modified from Noppers et al. (2014)
Perceived behavioural control	I will be able to drive a connected automated vehicle when they become available.	Modified from De Groot and Steg (2007)

Note. (R) reflects a reverse-coded item.

responses and affect model fit of a CFA (see e.g. Zhang, Noor, & Savalei, 2016; Lindwall et al., 2012). By including a "method" factor we can mitigate these negative effects. As estimator we used robust maximum likelihood. The model converged after 67 iterations.

We first inspected the model fit indices. The *CFI* (0.964; a desirable score is higher than 0.95), *RMSEA* (0.044, 95% $CI = 0.043 – 0.046$; a desirable score is below 0.05), and *SRMR* (0.036; a desirable score is below 0.08) all indicated that the model was a good fit. Next, we examined the factor loadings. Table 2 shows that the items correlated strongly with the subscale they belong to, and that the evaluation of all attributes forms a coherent overall scale.

2.5. Scale construction

We conducted a missing data analysis and found that across all items required for our analyses and demographics only 15 observations were missing (0.01 % of total observations). Considering this low amount of missing data, we decided to use listwise exclusion for missing data in all analyses.

The scales for each attribute, the overall evaluation of attributes, and acceptability were calculated using the factor loadings from the CFA as weights. For example, the scale of control attributes was calculated as ((score item 1 * 1) + (score item 2 * 0.85) + (score item 3 * 0.69)) / (1 + 0.85 + 0.69). The result was that for all scales of attributes and acceptability participants scored between 1 (very negative evaluation) to 7 (very positive evaluation). We additionally checked the skewness of the scales, which ranged from −0.63 to 0.36. The scales were nearly all approximately symmetric (skewness between −0.5 and 0.5), and all were within the acceptable range (skewness between −1 and 1) for analysis (Bulmer, 1979, p. 63). Please refer to Table 2 above for all factor loadings used to calculate the scales and refer to Table 3 below for the means, standard deviations, and skewness of all factors. In Table 4 in the Appendix we

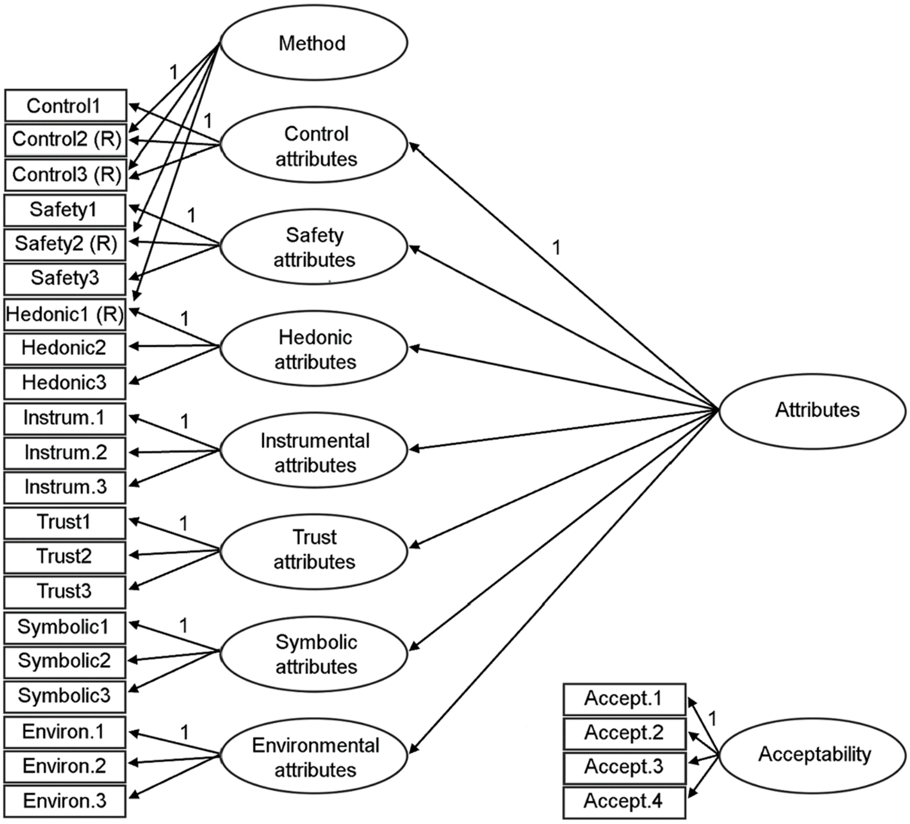

Fig. 2. Path Diagram of Confirmatory Factor Analysis. Note. Each item has an individual error. Factors were allowed to correlate. (R) represents a reverse-coded item. The first item of each scale is restricted to 1.

provide an overview of the correlations between all factors.

3. Results

3.1. Testing the ACAV model to explain acceptability of CAVs

All hypothesis testing was done using SPSS version 26. To test our first hypothesis – that acceptability of CAVs is higher when people evaluate the seven attributes more favourably, and when the perceived adoption norm and the perceived behavioural control is higher – we ran a linear regression where we included the three general predictors (i.e., overall evaluation of attributes, perceived adoption norm, and perceived behavioural control) in the model and acceptability as the outcome variable. Together, the three predictors explained 60.1% of the variance in acceptability (see Figure 3), indicating that the ACAV-model predicts a substantial portion of the variance in acceptability of CAVs. In line with our expectations, all three predictors uniquely contributed to the explanation of acceptability of CAVs in the expected direction. Evaluations of the attributes of CAVs was the strongest predictor, with more positive evaluations being related to higher acceptability of CAVs, $B = 0.873$, $SD = 0.018$, 95% CI [0.838 – 0.907], $t\,(3, 3764) = 49.585$, $p < .001$. Greater perceived behavioural control was also related to higher acceptability, $B = 0.115$, $SD = 0.011$, 95% CI [0.094 – 0.136], $t\,(3, 3764) = 10.607$, $p < .001$. Finally, as expected, the more people expected others to adopt CAVs (i.e., a higher perceived adoption norm), the higher the acceptability of CAVs, $B = 0.017$, $SD = 0.018$, 95% CI [0.003 – 0.031], $t\,(3, 3764) = 2.381$, $p = .017$.

Next, we tested which of the attributes is most strongly and uniquely related to acceptability of CAVs. For this purpose, we ran a linear regression with acceptability as the outcome variable, and all seven separate attributes (instrumental, symbolic, environmental, control, safety, trustworthiness, and hedonic attributes) as predictors. Together, the seven predictors explained 61.5% of the variance in acceptability (see Table 5). With the exception of symbolic attributes, the evaluation of all types of attributes were significantly and positively related with acceptability, with safety attributes, instrumental attributes, and environmental attributes being the strongest predictors.[3]

[3] Safety, instrumental, and environmental attributes always remained the strongest predictors of acceptability, regardless of which effect was taken as the main relationship by the model.

Table 2
Factor Loadings for all Latent Variables Based on Confirmatory Factor Analysis.

Latent variable		Factor loading	SD	Z-score	p
Control attributes	Item 1	1.00 [a]			
	Item 2 (R)	0.85	0.05	18.23	<0.001***
	Item 3 (R)	0.69	0.05	14.22	<0.001***
Hedonic attributes	Item 1 (R)	1.00 [a]			
	Item 2	1.22	0.06	19.91	<0.001***
	Item 3	1.19	0.06	19.48	<0.001***
Safety attributes	Item 1	1.00 [a]			
	Item 2 (R)	0.93	0.05	19.24	<0.001***
	Item 3	0.72	0.02	33.64	<0.001***
Instrumental attributes	Item 1	1.00			
	Item 2	0.98	0.02	63.78	<0.001***
	Item 3	0.95	0.02	61.98	<0.001***
Trustworthiness attributes	Item 1	1.00 [a]			<0.001***
	Item 2	1.05	0.02	55.88	<0.001***
	Item 3	1.00	0.02	45.31	<0.001***
Symbolic attributes	Item 1	1.00 [a]			
	Item 2	1.05	0.01	76.85	<0.001***
	Item 3	1.03	0.01	74.81	<0.001***
Environmental attributes	Item 1	1.00 [a]			
	Item 2	1.08	0.01	84.33	<0.001***
	Item 3	1.05	0.01	75.28	<0.001***
Method	Control attributes item 2	1.00 [a]			
	Control attributes item 3	0.99	0.04	22.90	<0.001***
	Hedonic attributes item 1	1.11	0.05	23.02	<0.001***
	Safety attributes item 2	1.14	0.05	21.04	<0.001***
Attributes	Control	1.00 [a]			
	Hedonic	1.18	0.07	17.60	<0.001***
	Safety	1.30	0.04	29.38	<0.001***
	Instrumental	1.48	0.05	29.49	<0.001***
	Trust	1.18	0.05	22.76	<0.001***
	Symbolic	1.16	0.04	27.82	<0.001***
	Environmental	1.01	0.04	24.78	<0.001***
Acceptability	Item 1	1.00[a]			
	Item 2	1.08	0.01	90.62	<0.001***
	Item 3	1.09	0.01	87.91	<0.001***
	Item 4	1.08	0.01	90.65	<0.001***

Note. [a] = item is constrained to 1, *** = significant at the 0.001 level.

Table 3
Descriptives of all Factors.

Factor	Number of items	Mean	SD	Skewness	Range
Control attributes	3	3.70	1.30	0.04	1–7
Hedonic attributes	3	3.94	1.37	−0.25	1–7
Safety attributes	3	4.13	1.22	−0.30	1–7
Instrumental attributes	3	4.24	1.51	−0.36	1–7
Trustworthiness attributes	3	4.38	1.55	−0.44	1–7
Symbolic attributes	3	3.41	1.63	0.10	1–7
Environmental attributes	3	4.48	1.43	−0.47	1–7
Attributes (total evaluation)	21	4.05	1.10	−0.37	1–7
Acceptability	4	4.71	1.46	−0.63	1–7
Perceived adoption norm	1	3.70	2.69	0.36	0–10
Perceived behavioural control	1	4.17	1.90	−0.22	1–7

3.2. Moderating effect of perceived adoption norm

The last hypothesis was that the effect of symbolic attributes on the acceptability of CAVs would be stronger when people believe that only few close others would consider adopting CAVs. To test this, we ran a two-step linear regression. In the first step, perceived adoption norm and symbolic attributes were entered in the model as predictors, and acceptability as the outcome variable. In the second step, the interaction term between perceived adoption norm and symbolic attributes was added. The model including the interaction term was significant. Perceived adoption norm and symbolic attributes together explained 30.2% of the variance in acceptability. The interaction term was also significant, and explained an additional 2.4% of the variance in acceptability on top of the main effects of perceived adoption norm and symbolic attributes. In line with Hypothesis 2, Figure 4 reveals that the effect of symbolic attributes of CAVs on acceptability was stronger for lower levels of perceived adoption norm, suggesting that symbolic attributes are

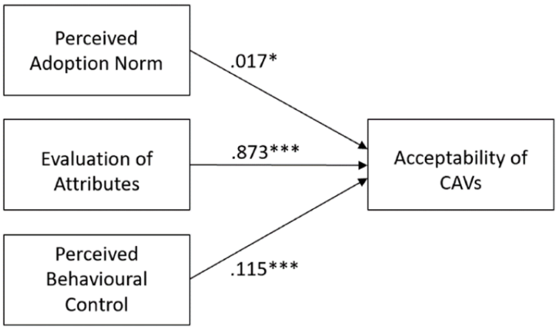

Fig. 3. Test of the ACAV-Model: Relationships between Evaluations of Attributes, Perceived Adoption Norm, and Perceived Behavioural Control and the Acceptability of Connected Automated Vehicles (Standardized Beta-Coefficients) Note. * = p <.05, *** = p <.001; $R^2 = 0.60$.

Table 5
Acceptability Predicted by the Evaluation of the Attributes Separately.

Predictor	B	SD	t	p	95% CI
Instrumental attributes	0.250	0.018	13.648	<0.001***	[0.214–0.286]
Symbolic attributes	-0.015	0.012	−1.259	0.208	[−0.039–0.008]
Environmental attributes	0.200	0.014	14.383	<0.001***	[0.172–0.227]
Safety attributes	0.305	0.018	16.535	<0.001***	[0.269–0.341]
Control attributes	0.030	0.013	2.324	0.020*	[0.005–0.055]
Hedonic attributes	0.128	0.012	7.316	<0.001***	[0.094–0.162]
Trustworthiness attributes	0.103	0.013	7.857	<0.001***	[0.077–0.128]

Note. * = significant at the 0.05 level, *** = significant at the 0.001 level; $R^2 = 0.62$.

more important for the acceptability of CAVs when one thinks fewer close others will consider adopting a CAV. Please refer to Table 6 for a full overview of the analysis.

4. Discussion

The introduction of CAVs may bring positive changes, such as improved safety and improved traffic flow compared to manual or non-connected vehicles (Alessandrini et al., 2015). Yet, CAVs are expected to change the driving experience for both its passengers and other road users, as they completely take over all driving tasks. However, their fully automated nature may raise concerns of trust and control, and their connective capabilities may raise concerns of privacy and security, potentially lowering acceptability. It is, therefore, important to understand which factors affect acceptability of CAVs, as this reveals which factors would have to be targeted to promote the acceptability, and possibly in turn, the adoption of CAVs. This research extends the literature on the acceptability of AVs by providing and testing the ACAV-model; a model to explain the acceptability for CAVs, that includes a wider range of factors than included in initial studies on the acceptability of CAVs. Specifically, the ACAV-model proposes that acceptability of CAVs is higher when people evaluate different attributes of CAVs more favourably, when they more strongly believe they will be able to use CAVs (i.e. higher perceived behavioural control), and when they believe that many close others consider using CAVs (i.e. stronger perceived adoption norm). We additionally examined which attributes are most important for acceptability of CAVs. Furthermore, we tested whether a positive evaluation of the symbolic attributes of CAVs is more strongly related to a higher acceptability of CAVs when people

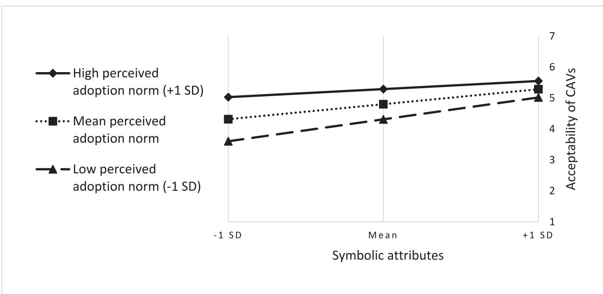

Fig. 4. Perceived Adoption Norm Moderates the Effect of Symbolic Attributes on Acceptability.

Table 6
Moderation Effect of Perceived Adoption Norm on the Effect of Symbolic Attributes on Acceptability.

Model	Predictor	B	SD	t	p	95% CI
Main effects only	Symbolic attributes	0.300	0.14	22.034	<0.001***	[0.273–0.327]
	Perceived adoption norm	0.170	0.008	20.589	<0.001***	[0.154–0.186]
Main effects and moderation effect	Symbolic attributes	0.489	0.021	23.198	<0.001***	[0.448–0.531]
	Perceived adoption norm	0.354	0.018	19.883	<0.001***	[0.319–0.389]
	Interaction	−0.051	0.004	−11.607	<0.001***	[−80.059 – −0.042]

Note. *** = significant at the 0.001 level; $R^2 = 0.30$ for the main effects only model, $R^2 = 0.33$ for the moderation and main effects model.

believe only few close others would consider adopting CAVs.

First, the proposed ACAV-model was able to explain acceptability of CAVs well. As expected, we found that the acceptability of CAVs is higher if people evaluate the attributes of CAVs more positively, if they believe they will be able to use CAVs, and if they expect many close others will adopt CAVs. The evaluation of the attributes of CAVs was most strongly related with acceptability, which is in line with other research investigating the acceptability and adoption of other sustainable innovations (e.g. Noppers et al., 2014; Zhang et al., 2017; De Groot & Steg, 2007).

As expected, we found a positive effect of perceived behavioural control on the acceptability of CAVs. The effects of perceived behavioural control on acceptability of CAVs or even AVs has not been widely studied. However, studies have found that higher perceived behavioural control is related to a stronger adoption intention of, for example, hybrid electric vehicles (Wang et al., 2016), and AVs (Golbabaei et al., 2020), as well as a more positive attitude towards privately owned AVs (Kaye et al., 2021). Similarly, studies have found that facilitating conditions, which is the degree to which one believes factors in the environment make an act easy to accomplish, may explain the intention to use a type of technology in general or AVs specifically (Venkatesh et al., 2003; Nordhoff et al., 2019; Madigan et al., 2017). The results of the present study show that perceived behavioural control could be an important factor to increase the acceptability of CAVs as well, even when controlling for the evaluation of attributes of CAVs. More research is needed on which internal and external barriers people perceive for CAVs, and which of them influence the acceptability of CAVs the most.

Next, we found that six of the seven attributes we included were uniquely and positively related to acceptability of CAVs, namely instrumental, environmental, safety, control, hedonic, and trustworthiness attributes. Yet, the evaluation of symbolic attributes was not significantly related to acceptability of CAVs when the other attributes were controlled for. Out of the seven attributes, safety, instrumental, and environmental attributes proved to be the most important for acceptability of CAVs. The relatively high importance of instrumental and environmental attributes is in line with earlier research testing the ISE-model to explain adoption of sustainable innovations (Noppers et al., 2014). The relatively high importance of safety and environmental attributes is also in line with research examining the acceptability of electric vehicles (e.g. Schmalfuß et al., 2017). In line with previous research, the results highlight that acceptability of CAVs is not only driven by the instrumental attributes of CAVs.

Interestingly, the positive effect of control attributes on acceptability, although significant, was relatively small, despite being an often-mentioned aspect of AVs that is important to understand acceptability (e.g. Schoettle and Sivak, 2014; Bongaerts et al., 2017). This indicates that other attributes are more important for acceptability of CAVs than control attributes. Perhaps having control over the vehicle is less important if the passengers trust the vehicle to drive safely in automated mode. People who believe, for example, that AVs have external control of the road situation, also tend to believe that AVs are capable of driving safely, and are more accepting of AVs (Dixon et al., 2020). Currently, there are people who are capable of driving manually (drivers), and people who are unable to drive manually (non-drivers). However, in a L5 CAV, they would all be passengers, but with different levels of driving experience. For non-drivers the only difference of being driven in a CAV would be that the vehicle would be driven by a computer instead of another person. For these non-drivers, the inability to control the driving tasks may be less of a loss, as they are not used to having this type of control. Additionally, as current drivers are often already familiar with handing over some of the driving tasks to their vehicle with Advanced Driver Assistance Systems (ADAS), handing over full control to a CAV as a passenger may be a relatively smaller step for them (see e.g. Sener et al., 2019). If this is the case, then future research could examine if the acceptability of CAVs is higher for current drivers who are familiar with ADAS compared to drivers who are not familiar with them. In short, more research is needed to investigate if the relatively weak effect of control attributes on acceptability differs among different user groups (people with no driving experience, people with driving experience without ADAS, and people with driving experience with ADAS).

In line with the extended ISE-model (Noppers et al., 2014), we found that the perceived adoption norm both had a direct and indirect effect on acceptability. More specifically, if many close others are expected to adopt CAVs, CAVs are evaluated as more acceptable. Additionally, in line with our expectation, when few close others are expected to adopt CAVs, symbolic attributes become a more important predictor for the acceptability of CAVs. This indicates that a lower perceived adoption norm is likely to enhance the signalling function of CAVs for one's identity (see also Noppers et al., 2015). However, in contrast to earlier research testing the ISE-model, we found that the direct effect of symbolic attributes on acceptability was non-significant when the other six attributes were controlled for. It seems that other aspects of CAVs, such as the safety, may be so important for the acceptability of CAVs that symbolic attributes have a lower priority. The ISE-model controlled for fewer other attributes than the ACAV-model, which may have led to a significant positive effect of symbolic attributes in the ISE-model, but not in the ACAV-model. Additionally, the ISE-model was tested with EVs, which may be generally thought of to be more similar to manual vehicles using traditional fuel in terms of safety. After all, both are operated by a human. Moreover, it may be possible that people are not certain yet whether CAVs will be status symbols or not, as they are not available on the market right now. EVs have been on the market for some time, are quite visible as they often have logos or stickers indicating their electric nature, and are linked to the owner having a “green identity” (e.g. Schuitema et al., 2013). For CAVs no clear image has been established yet, which might explain why symbolic attributes did not directly predict acceptability of CAVs.

4.1. Theoretical and practical implications

The ACAV-model shows a good fit and can be used to explain acceptability of CAVs specifically, which was lacking in the literature. We found that the ACAV-model was very successful in explaining the acceptability of CAVs, indicating that a wide range of factors, including the evaluation of different attributes, as well as perceived adoption norm and perceived behavioural control are important to understand the acceptability of CAVs. Future studies could examine whether the ACAV-model, with some modifications, can also explain acceptability of other similar innovative transportation methods that are fully automated or have connective capabilities, such as the hyperloop. Future research should shed some light on the predictive power of the ACAV-model for these other innovations in transport.

The present research employed a correlational design, meaning we are unable to draw firm conclusions about the causal directions of the relationships found. Future research could use an experimental design, in which for example attributes of CAVs, the perceived behavioural control, or the perceived adoption norm are manipulated, to more clearly investigate the causal directions.

It should be noted that participants in the present research had not experienced a CAV, as it currently has not been fully developed. Hence, we could only measure the acceptability of CAVs, i.e. the attitude towards CAVs before having experienced the vehicle, and not the acceptance or actual adoption. Future research should examine to what extent the acceptability of CAVs and acceptance are related, as well as their link to the adoption intention of CAVs. In a similar vein, it is possible that once CAVs are introduced they may have different functions or performance levels, or otherwise may not fit the expectations that people have right now. All these factors, as well as the pricing, could influence how people evaluate CAVs’ attributes, which could in turn affect their decision to adopt a CAV or not. Future research could examine to what extent these factors influence acceptance once CAVs enter the market.

Our results show that people generally evaluate acceptability of CAVs slightly positive, and most attributes as somewhat favourably. To enhance the acceptability of CAVs, highlighting that CAVs have many positive attributes may be an effective strategy. Our results suggest that the main focus could be on how safe and environmentally friendly CAVs are, and what positive functions (instrumentality) CAVs have, as the evaluation of these attributes appeared to be the most strongly related to acceptability. At the deployment stage, enhancing symbolic attributes, by for example underlining the positive outcomes of using or owning a CAV for one’s status and identity, may also be effective, as long as the perceived adoption norm is relatively low. Symbolic attributes in particular are also important to people who are inclined to adopt innovations (such as CAVs) at earlier stages rather than later stages (Noppers et al., 2015).

4.2. Conclusion

To conclude, the proposed ACAV-model was able to explain the acceptability of CAVs well. The evaluations of the attributes of CAVs are the most important predictor of acceptability of CAVs, followed by a greater belief that many close others will adopt CAVs, and a greater belief that they will be able to use CAVs. Evaluations of safety, instrumental, and environmental attributes had relatively the strongest impact on acceptability. Additionally, evaluations of symbolic attributes are more important for the acceptability of CAVs when the perceived adoption norm is low rather than high.

CRediT authorship contribution statement

Jorick M.M. Post: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Visualization, Writing – review & editing. **Ayça Berfu Ünal:** Conceptualization, Validation, Writing – review & editing, Supervision, Funding acquisition. **Janet L. Veldstra:** Conceptualization, Validation, Writing – review & editing, Supervision, Funding acquisition. **Dick de Waard:** Validation, Writing – review & editing, Supervision. **Linda Steg:** Validation, Writing – review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

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Appendix A

Table 4
Correlation Table of Scales, Subscales, Perceived Adoption Norm, and Perceived Behavioural Control.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1. Acceptability										
2. Attributes (full scale)	0.76									
3. Perceived adoption norm	0.46	0.52								
4. Perceived behavioural control	0.56	0.60	0.59							
5. Safety attributes	0.68	0.80	0.39	0.47						
6. Instrumental attributes	0.70	0.89	0.47	0.55	0.68					
7. Hedonic attributes	0.64	0.83	0.41	0.45	0.64	0.76				
8. Control attributes	0.35	0.54	0.28	0.34	0.42	0.35	0.41			
9. Symbolic attributes	0.47	0.74	0.44	0.46	0.43	0.62	0.52	0.30		
10. Environmental attributes	0.60	0.74	0.40	0.44	0.54	0.61	0.51	0.28	0.52	
11. Trustworthiness attributes	0.59	0.77	0.35	0.45	0.60	0.61	0.54	0.28	0.46	0.53

Note. All correlations are significant at the 0.001 level.

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