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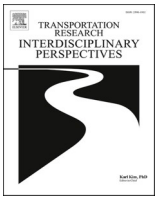

Acceptance of automated vehicles: Gender effects, but lack of meaningful association with desire for control in Germany and in the U.S.

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ABSTRACT

Although automated vehicles (AVs) come with many promises such as enabling the driver-passenger to perform non-driving-related-tasks or increased safety, the public's acceptance of AVs will have a crucial impact on whether or not AVs will be ultimately adopted. In particular, the personality trait desire for control may influence the acceptance of AVs, which has received scant research attention to date. Therefore, we independently carried out two questionnaire studies: Study 1 in Germany and Study 2 in the U.S. In both studies, we applied the self-driving car acceptance scale (SCAS) and the desirability of control scale (DoCS). In Study 1, we queried 114 participants (60 female) and in Study 2 we sampled data from 601 participants (322 female). In both studies, our findings consistently indicate that the overall DoCS factor was not associated with the overall SCAS factor. We only uncovered a weak positive correlation in Study 1, but only for a reduced overall acceptance factor with 10 items obtained by factor analyses instead of the 24 items of the SCAS. Furthermore, our results revealed that women assign significantly lower ratings to the overall acceptance factor of AVs as well as to the desirability for control factor than men, both in Germany and in the U.S., respectively. Despite the influence of gender on acceptance of AVs and DoCS, we conclude that there might be either no or only a weak association between desire for control and acceptance of AVs, which needs to be further investigated in future studies.

Introduction

Automated vehicles (AVs) are expected to have broad impacts on future mobility systems (Litman, 2020), with speculative potential benefits including reduced fuel consumption (Zhu et al., 2019), fewer driving fatalities (Kalra and Groves, 2017), greater access to transportation for older adults and people with disabilities (Dicianno et al., 2021), and a reduction in urban spaces devoted to parking Alessandrini et al., 2015; Fagnant and Kockelman, 2015). Realization of these benefits, however, will require drivers to adopt and use AVs instead of traditional vehicles. Adoption of new technology tends to occur in phases, whereby some potential users are more willing to use new technology than others (Rogers, 2003). Once beneficial safety margins are attained by AVs, resistance to adoption might result in problems including preventable deaths (Kalra and Groves, 2017; Xiao et al., 2021) and non-optimal traffic patterns (Chen et al., 2019). Since AVs represent a paradigm shift in driving, the extent to which drivers will accept AVs remains an open question, and acceptance (or lack thereof) will have important consequences for the impact of AVs in future mobility (Harb et al., 2021).

Acceptance of AVs

In the past decade, the pace of development of AVs has accelerated (Becker, 2020). Accordingly, researchers have shown increasing interest in studying acceptance of AVs. A general definition of *acceptance* is "… the degree to which an individual incorporates the system in [their] driving, or, if the system is not available, intends to use it" (Adell et al., 2014, p. 18). Scales for measuring acceptance of AVs have already been developed (e.g., the Self-driving Car Acceptance Scale (SCAS), Nees, 2016 or the Questionnaire on the Acceptance of Automated Driving (QAAD), Weigl et al., 2021). Researchers have deployed questionnaires and surveys to assess current levels of acceptance across many different contexts. Studies have reported on acceptance of AVs in numerous

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different countries (Edelmann et al., 2021; Kaye et al., 2020; Tennant et al., 2019) and across different potential application contexts, such as acceptance of privately-owned AVs (Wang et al., 2020) versus AVs for public transport (e.g., Acheampong et al., 2021; Nordhoff et al., 2018). Both simulator (e.g., Buckley et al., 2018) and field studies (e.g., Xu et al., 2018) have begun to examine how exposure to AVs affects acceptance. In the last few years, the accumulation of data on acceptance of AVs has begun to allow for evidence synthesis through *meta*-analysis and systematic reviews (e.g., Dicianno et al., 2021; Gkartzonikas and Gkritza, 2019; Kaye et al., 2021; Pigeon et al., 2021).

Through this research, some patterns have emerged in our understanding of acceptances of AVs. Research has tended to show that general attitudes toward AVs are perhaps best described as cautiously optimistic, with mean scores typically reflecting neutral to positive ratings on items measuring acceptance (e.g., Nees, 2016; Wintersberger et al., 2016; Zoellick et al., 2019). In reviewing research on acceptance of AVs, Hilgarter and Granig (2020) concluded that "most studies reported positive or conditionally positive attitudes towards AVs" (p. 227). Still, drivers have expressed concerns about safety and trust with AVs (see, e.g., Edmonds, 2018; Schoettle and Sivak, 2016; Zmud et al., 2016; also see Nees, 2019). One study (Nielsen and Haustein, 2018) categorized 38% of participants as skeptical of AVs, whereas only 25% were categorized as enthusiastic (for a similar analysis, also see Liu, 2020). In another study, data collected over several years showed that 25–30% of respondents would be unwilling to use a highly automated vehicle, with some evidence suggesting a decrease over time in comfort with higher levels of vehicle automation (Lee et al., 2021). As such, acceptance of AVs appears likely to remain a barrier, and difficulties for understanding and predicting acceptance of AVs have yet to be resolved.

AVs and desire for control

Given these challenges, researchers have begun to consider how psychological traits may impact acceptance of vehicle automation. Individual differences in personality, for example, may be helpful for predicting which drivers will tend to accept high automation. Charness et al. (2018) found some relationships between Big Five personality traits (Goldberg, 1993) and three sub-dimensions of acceptance of highly automated vehicles (concern, eagerness to adopt, and willingness to relinquish control). Conscientiousness, for example, was associated with greater concern and less eagerness to adopt, whereas openness to new experiences was associated with greater eagerness to adopt and greater willingness to relinquish control. None of their models, however, accounted for more than 10% of the variance in the acceptance variables examined, which suggested that Big Five traits may not be especially useful for predicting acceptance. Kyriakidis et al. (2015) also found weak to nonexistent correlations between acceptance and Big Five personality traits.

Perhaps other traits more proximal to the driving task would account for more variance in acceptance. Charness et al. (2018) and others (e.g., Lee and Kolodge, 2018) have identified the desire for control of the vehicle and willingness to relinquish control to automated systems as potentially important aspects of acceptance of vehicle automation. Desire for control is a personality trait defined by "the motive to control the event's in one's life" (Burger and Cooper, 1979). Desire for control has received some attention concerning the acceptance of new products in general. Faraji-Rad and colleagues (2017) showed that higher desire for control might present a barrier to the willingness to adopt new products. There might be a passive resistance to adopting innovations which entail a fear of losing control (Heidenreich and Handrich, 2015).

A shift accompanying the advent of AVs will be the change from a driver's role to a passenger, which may be problematic for some drivers. In traditional driving, research has shown that people (sometimes unrealistically) perceive that they are more likely to be involved in an accident as a passenger as compared to when they are driving (McKenna, 1993). Survey research has shown that respondents express a strong preference to have the option to retake control of AVs (König and Neumayr, 2017; Kyriakidis et al., 2015; Nees, 2016; Schoettle and Sivak, 2016), and fear of loss of control appears to present a psychological barrier to support of AVs (Bazilinskyy et al., 2015; Benleulmi and Blecker, 2017; Fraedrich et al., 2016; Müller et al., 2017). Researchers have reported that the notion of handing over control caused feelings of distress (Pettigrew et al., 2019) and resulted in safety concerns and concerns of being held accountable for the AV's actions (Merfeld et al., 2019).

Adopting AVs will make it necessary for the driver to relinquish direct control over driving maneuvers. It is possible that people who are high in desire for control will be less willing than others to accept automation of driving—a task that involves high levels of individual control with simultaneous abandonment of direct control. Some evidence has suggested that drivers who score higher on measures of desire for control and illusion of control also tend to be risk-takers (Hammond and Horswill, 2001), which suggests that those drivers might benefit from advanced driver safety systems and automation.

To date, the evidence capable of directly linking desire for control to acceptance of AVs is sparse. In an interview study, Zmud, Sener, and colleagues (Sener et al., 2019; Zmud et al., 2016) found a small number of respondents who spontaneously reported desire for control as a reason they did not intend to use AVs, but a brief (4-item) measure of desire for control did not correlate with measures of acceptance in their quantitative survey study. Similarly, Brell et al. (2019) reported that participants voiced concerns about relinquishing control in an interview study, but no significant differences in acceptance as a function of the need for control (as measured by a 6-item scale created for their study) were observed in a subsequent survey. Lee and Kolodge (2018) found that desire for control was an emergent theme in responses to an open-ended question about trust in AVs, with a representative participant stating, "I want total control over my vehicle." Using items written to specifically measure desire for control over AVs, two studies (Herrenkind et al., 2019; Nastjuk et al., 2020) found no evidence of a relationship between desire for control and intention to use AVs, although, curiously, Herrekind et al. did find that desire for control predicted negative *attitudes* about AVs.

Of note, these quantitative studies used brief, ad hoc measures of desire for control with indeterminate psychometric properties. Burger and Cooper's (1979) Desirability of Control (DoC) scale is a widely-used 20-item scale with established reliability and validity (McCutcheon, 2000). Using a modified, 9-item version of the DoC, Syahrivar et al. (2021) found the predicted negative relationship between desire for control and attitudes toward AVs, but to our knowledge, no studies to date have used the validated version of the DoC to examine relationships with acceptance of AVs.

The present studies

In an instance of scientific co-discovery, two labs - independently and without the other's knowledge - examined the relationship between Desirability for Control as measured by the DoC scale (Burger and Cooper, 1979) and the acceptance of AVs as measured by the SCAS (Nees, 2016; Nees and Zhang, 2020). Upon discovering these similarities in our research approaches, new analyses were undertaken to align the presentation of the two studies as much as possible. Hitherto, there exists no questionnaire study which focuses jointly in a study in Europe and in a study in the U.S. on desire for control as a potential and essential parameter influencing the acceptance of AVs. Therefore, we have raised the following primary research question (RQ) in Germany and in the U. S., respectively:

RQ1: Are there any associations between the acceptance of AVs and desire for control?

Many studies also have considered possible gender differences in acceptance of AVs. Research collectively has provided relatively strong evidence to support that men are more accepting of AVs than women

(for reviews summarizing this literature, see Wintersberger et al., 2016; Becker and Axhausen, 2017; Harb et al., 2021; Kaye et al., 2021; Keszey, 2020; Pigeon et al., 2021). For example, a review of 80 studies of predictors of AV acceptance (Golbabaei et al., 2020) concluded that "… most studies found that males are likely to be more interested in AVs, have greater intention to use or own them than females, be more willing to pay for AVs, less worried about them, and feel confident to let fully AVs to perform all functions [sic]" (pp. 12). Thus, as a secondary analysis, we posed the following RQ:

RQ2: What is the impact of gender on the acceptance of AVs and desire for control?

Finally, our two studies incidentally allowed for cross-national comparisons to be made. Research increasingly has focused on acceptance of AVs with multi-national samples and comparisons across cultures (e.g., Kaye et al., 2020; Tennant et al., 2019). Edelmann et al. (2021) previously observed similar acceptance of decisions of AVs in German and North American participants. Our studies allowed us to examine whether these similarities were replicated in new samples.

Method

To investigate our research questions RQ1 and RQ2, we independently conducted a cross-sectional questionnaire study in Germany (Study 1) and a cross-sectional questionnaire study in the U.S. (Study 2).

Study 1 in Germany

Participants

In total, we queried 114 licensed car drivers of which 60 identified themselves as female and 54 identified themselves as male (diverse was selected from nobody). The average age of women was 51.4 years (SD = 18.8) and of men 55.6 years (SD = 18.3). The overall age range was between 21 and 85 years. All respondents were fluent in German, reported no diagnosis of a psychiatric or neurological disorder, and consumed no alcohol or drugs. They reported that the daily commute by car was on average 28 min (SD = 24; n = 60), 33 min (SD = 32; n = 19) by public transport, and 13 min (SD = 15; n = 42) by bicycle. Although all participants were licensed car drivers, who drove their car on a regular basis, which was an inclusion criterion, some of them used public transport or a bicycle as an additional or preferred mode of transport. A general qualification for university entrance possessed 51 participants, a university of applied sciences entrance qualification 17, a high-school diploma 25, a secondary modern school qualification 19, one person graduated from a professional academy, and one from a polytechnic school. A severe road traffic accident (RTA) was reported by 26 participants, a non-severe by 56, and 32 never experienced any RTA. The participants had no prior knowledge of AVs and no prior experience with AVs, but all of them received a comprehensive and standardized introduction to AVs.

An attention check was implemented where the participants had to fill a prescribed combination of letters, which was explained to all invited respondents. Hence, it was possible to exclude 29 fakers or non-serious participants from the survey.

Materials

In this section, we explain the self-rating scales for assessing the acceptance of AVs and desirability for control. We deployed the questionnaires on LimeSurvey, Version 3.12.1 + 180616 (Limesurvey Project Team and Schmitz, 2021), accompanied by demographic items and collected all data online and anonymously. In this regard, we want to mention that we also provided two more questionnaires that are beyond the scope of the present study and have been published in (Weigl, 2020). We computed Cronbach's Alpha (Cronbach's α) which is considered as a measure for internal consistency of a scale (Cronbach, 1951; Cronbach et al., 1963), whereas values above 0.7 are considered as acceptable and below 0.5 as unacceptable (Cortina, 1993; George and Mallery, 2003; Nunnally and Bernstein, 1994).

Self-Driving car acceptance scale 2016 (SCAS 2016)

The Self-driving Car Acceptance Scale (Nees, 2016) measures the acceptance of automated vehicles with 24 items comprising an 8-factor structure assessing the dimensions: (1) perceived reliability of automation/trust (e.g., "1. Self-driving cars will be safe."), (2) cost of automation (e.g., "5. The benefits of a self-driving car would outweigh the amount of money it would cost."), (3) appropriateness of automation/compatibility (e.g., "7. I do not think that computers should be driving cars."), (4) enjoyment of to-be-automated task (e.g., "10. I enjoy driving a car."), (5) perceived usefulness of automation (e.g., "15. Self-driving cars will reduce traffic problems."), (6) perceived ease of use of automation (e.g., "16. Self-driving cars will be easy to use."), (7) experience with automation (e.g., "19. I like to use technology to make tasks easier for me."), and (8) intention to use automation (e.g., "22. I would like to own a self-driving car."). Each of the 8 factors is assessed with 3 items on a 7-point rating scale ("strongly disagree = 1" to "strongly agree = 7). The SCAS also provides an overall factor across all 24 items, which was used by the developers of the SCAS for inferential statistical analyses. The 13 items 3, 6, 7, 8, 9, 10, 11, 12, 17, 18, 20, 23, and 24 are reverse-coded and have to be re-coded prior to calculating the overall mean score across all items. Higher scores indicate greater acceptance of AVs. We identified a Cronbach's α of 0.85 for the overall acceptance score with 24 items and of 0.90 for the overall acceptance score with 10 items. More details of the 10-item version of the SCAS 2016 is explained in the Statistical Analyses section (cf. 2.3).

Desirability of control scale (DoCS)

We assessed desire for control with the Desirability of Control Scale (Burger and Cooper, 1979). This scale measures "individual differences in the general level of motivation to control the events in one's life" (p. 381). The items 7, 10, 16, 19, and 20 are reversely coded which have to be recoded before they are aggregated to the overall sum score. All items are provided with a 7-point Likert scale (1 = "This statement doesn't apply to me at all" to 7 = "This statement always applies to me") constituting one overall factor summed as a total score ranging from 20 to 140, whereas higher scores indicate a greater desire for control. The DoCS assesses one general personality factor of *desire for control* including the traffic domain (e.g., "17. When driving, I try to avoid putting myself in a situation where I could be hurt by someone else's mistake."). Additionally, five factors were originally extracted: (1) general DC (e.g., "9. I enjoy having control over my own destiny."), (2) decisiveness (e.g., "19. There are many situations in which I would prefer only one choice rather than having to make a decision."), (3) preparation-prevention-control (e.g., "13. I like to get a good idea of what a job is all about before I begin."), (4) avoidance of dependence (e.g., "3. I try to avoid situations where someone else tells me what to do."), and (5) leadership (e.g., "4. I would prefer to be a leader rather than a follower."). However, Gebhardt and Brosschot (2002) extracted only three instead of five factors and labelled them: (1) 'control others' (desire to be in charge of and control others), (2) 'control self' (desire to control one's own life), and (3) 'relinquish control' (desire to leave others in control). Therefore, we decided to focus only on the overall DoCS score and how it relates to the acceptance of AVs assessed with the SCAS. The overall sum score yielded a Cronbach's α of 0.67.

Study design

We carried out a cross-sectional questionnaire study in Germany and pursued the two main goals: (1) performing correlational analyses to investigate any associations between the acceptance of AVs and the desire for control (RQ1) and (2) applying inferential statistical analyses to study whether or not there are any gender differences on the acceptance of AVs and on the desire for control (RQ2). Therefore, for RQ2 we adopted a two factorial (2 × 1) between-subjects design with the independent variable (IV) gender. Our dependent variables (DVs) were the

overall mean scores of the SCAS and the sum score of the DoCS.

Procedure

Before the beginning of the study, it was approved by the ethics committee at the Department of Psychology at Catholic University Eichstätt-Ingolstadt. To obtain a diverse sample, the participants were invited from various venues at multiple places in Germany. All of them were recruited by personal invitation either at home (especially older people), or at Catholic University Eichstätt-Ingolstadt or Technische Hochschule Ingolstadt, or via phone or video call with remote assistance following the same standardized introduction as for the on-site recruitment.

At the beginning, each participant was introduced and invited to ask questions throughout the study. After the subjects provided written informed consent, they completed the SCAS and the DoCS self-rating scales and additional demographic questions (cf. 2.1). Upon completion of the study, each participant was thanked and received a sheet with a summary of the study as well as the contact details of the examiner, in case any questions may arise later. During the entire study duration, which ranged from 20 to 30 min, the examiner was either present or could be reached by phone or video-call. The subjects did not receive financial compensation. However, in case they were interested in the findings of the study, they were invited to provide their email addresses.

Study 2 in the U.S.

Study 2 reports a partial analysis of a larger data set that examined relationships between acceptance of high automation in vehicles, desire for control, and several other driving-related scales and variables. Analyses of questions unrelated to AVs from the same data set are reported elsewhere (see Nees et al., 2021). The approach was exploratory; relationships among all of the scales were examined.

Participants

Participants (N = 630) were recruited from Amazon Mechanical Turk (AMT; n = 500) and undergraduate psychology courses at Lafayette College (n = 130). These numbers do not include potential participants who started and abandoned the survey (n = 39 from AMT; n = 5 from Lafayette) or failed to complete the survey in time to receive compensation (n = 1 from AMT). Mechanical Turk workers were required to be located in the United States, to have a task approval rating of greater than 99%, and to have at least 1,000 previously approved tasks. The study description also indicated that the research was only open to licensed drivers.

Two attention checks were included in the study. The first instructed participants to select the option "5″ on a Likert response scale. For the second, participants responded to the prompt "I read and answered all questions in this survey to the best of my ability" on a scale from 1 ("strongly disagree") to 7 ("strongly agree"). Of the 630 participants, 29 were excluded for various reasons, including failing the first attention check (n = 14), failing the second attending check (i.e., by giving a response < 6 on the scale, n = 8), providing nonsensical responses in optional open-ended comments at the end of the study (n = 1), or meeting more than one of these criteria (n = 6). The final sample used in analyses was N = 601 (322 females, 277 males, 2 participants preferred not to respond).

The mean age in the sample was 35.27 years (SD = 13.57) and ranged between 18 and 75 years. Self-reported racial/ethnic backgrounds represented in the sample were white (n = 502), Asian (n = 45), black or African American (n = 37), Hispanic or Latino (n = 33), American Indian or Alaska Native (n = 8), Native Hawaiian or Pacific Islander (n = 4), other (n = 3), and prefer not to answer (n = 4). Participants were allowed to select more than one category, so these numbers sum to a number greater than the sample size. Participants' highest level of education attained included no high school diploma (n = 4), a high school diploma or GED (n = 103), some college with no degree (n = 189), an associate's or 2-year degree (n = 55), a bachelor's or 4-year degree (n = 189), a master's degree or post-bachelor's professional degree (n = 53), and a doctoral degree (n = 8). Participants reported M = 18.06 years of driving experience (SD = 13.60, minimum = 1.00, maximum = 58.00). Participants reported driving M = 7.19 h per week (SD = 7.89, mdn = 5.00, minimum = 0.00, maximum = 90.00). Participants reported the scenario that best described where they drive most often as urban/city driving (n = 287), rural/small town driving (n = 219), distance/interstate/freeway driving (n = 80), and other (n = 15). On a scale from 1 ("not familiar at all") to 7 ("extremely familiar"), participants rated their familiarity with the current state of technology related to AVs as M = 3.70 (SD = 1.52, mdn = 4.00). Participants reported having read M = 3.94 articles about self-driving cars in print or online (SD = 8.60, mdn = 2.00, minimum = 0.00, maximum = 100.00). Two-hundred-seventy-one participants reported owning or using a vehicle that had automated features including 243 instances of cruise control, 36 instances of adaptive cruise control, 33 instances of automatic braking, 40 instances of automatic lane keeping or lane keeping assist, 12 instances of Autopilot or Level 2 systems (see SAE_J3016, 2021), 2 instances of automatic headlights, and 2 responses for which the technology being described couldn't be determined.

Materials. Self-Driving car acceptance scale 2020 (SCAS 2020)

The SCAS 2020 (Nees and Zhang, 2020) is the newer version of the SCAS 2016 (Nees, 2016) and comprises only 20 items instead of the 24 items of the SCAS 2016. The 2020 version was formulated using exploratory factors analysis (EFA) applied to a much larger pool of items than the 2016 study. The 20 items used in Study 2 were selected as a result of having loaded on a general factor of acceptance that was extracted first in the 2020 EFA analysis, accounted for the most variance, and exhibited high internal consistency reliability. The relationship between the SCAS 2016 and 2020 in the current studies is explained in the section Statistical Analyses (cf. 2.3). We obtained a Cronbach's α for the overall mean score with the 20- and 19-item version of 0.92, respectively.

Desirability of control scale (DoCS)

In Study 2 the DoCS was applied in exactly the same way as in Study 1. Hence, we also computed the overall sum score of the DoCS score. We computed Cronbach's α, which was 0.85.

Study design

We carried out a cross-sectional questionnaire study in the U.S. and pursued exactly the same two main goals as in Study 1: (1) performing correlational analyses to investigate any associations between the acceptance of AVs and the desire for control (RQ1) and (2) applying inferential statistical analyses to study whether or not there are any gender differences on the acceptance of AVs and on the desire for control (RQ2; cf. more details in section 2.1.3).

Procedure

The study was approved by the Lafayette College Institutional Review Board. The survey was hosted on Qualtrics, and AMT participants were recruited from using the CloudResearch service (formerly called TurkPrime, see Litman et al., 2017) to block duplicate IP addresses and suspicious geocodes, and also to verify the country location. Undergraduate participants were recruited using an online research participant sign-up system. Participants were told, "The purpose of this research is to learn more about peoples' driving histories, how people feel about their driving abilities and habits, peoples' preferences for doing things themselves, and peoples' opinions about self-driving cars." Following informed consent, instruments were presented in a random order to each participant (including the SCAS, the DoCS, and additional scales beyond the scope of this report), with the exception of the demographics questionnaire, which was always presented last. For the DoCS, participants were instructed "Please read each statement carefully and respond to it by expressing the extent to which it applies to you" (see Burger and Cooper, 1979). For the SCAS, participants were instructed,

"The next questions ask you to make ratings about vehicles that are self-driving or are in self-driving modes. For the purposes of this research, 'self-driving' is defined as a vehicle in which computers and automated systems perform driving tasks including steering, accelerating/braking, and monitoring the driving scenario without help from the human driver." The presentation of questions within a given instrument was randomized except for the demographics questionnaire. The median completion time was around 16 min. AMT participants were paid $1.00 for their time. Lafayette College participants were compensated with course extra credit.

Statistical analyses of Study 1 and Study 2

We set the significance level to $\alpha = 0.05$. Therefore, all results with $p < \alpha$ are reported as statistically significant. Initially, we computed the overall mean score of the SCAS and the sum score of the DoCS.

We consecutively analyzed all data of Study 1 and 2 and reported all results together for RQ1 and RQ2, respectively. Prior to the main analyses (cf. 3.1 and 3.2), we performed exploratory and confirmatory factor analyses on the SCAS to critically investigate whether or not the overall factor mean scores would replicate for the SCAS of 2016 with 24 items and the SCAS of 2020 with 20 items. When applying the confirmatory factor analysis (CFA), we set the number of extracted factors to "1". Since the DoCS scale is already well-established we did not apply any factor analyses on the DoCS overall sum scores.

In Study 1 conducted in Germany, it turned out that for the SCAS of 2016, in total 14 items did not load on the overall acceptance factor and indicated too low item communalities (all were below < 0.22, which was the highest communality of those items) when performing CFA (i.e., the items 3, 6, 9, 10, 11, 12, 17, 18, 19, 20, 21, 23 and 24 were removed). Given the rather small sample size of N = 114, those low communalities would be even more problematic than for a larger sample as, for example, collected in Study 2 with N = 601. However, after the removal of those 14 items, which would load on 5 different factors, the remaining 10 items indicated acceptable item communalities and clearly loaded on the extracted and only overall acceptance factor score (i.e., 1, 2, 4, 5, 7 (reverse coded), 13, 14, 15, 16 and 22). Since the newer version of the SCAS of 2020 also removed 12 of the excluded 14 items and included 8 new items (summing up to 20 items) which were developed to contribute and load on the overall acceptance factor, we decided to only focus on this overall acceptance factor, also for comparison reasons with Study 2.

In Study 2 carried out in the U.S., in which the newer SCAS of 2020 was applied, the results revealed that 19 of those 21 items had acceptable item communalities and clearly loaded on the extracted overall acceptance factor. It has to be noted that the item with ID 19 ("Even if I had a self-driving car, I would still want to drive myself most of the time.") was accidentally included in the data collection process, which was not intended because it was already known prior to the beginning of the study that this item was not loading on the overall acceptance factor. Hence, it was excluded resulting in the SCAS with 20 items. The item with the ID 16 was also excluded ("I would be more likely to use self-driving cars after my friends or family have tried them."; all 20 items are listed in Nees and Zhang, 2020), because it revealed ambiguous loadings and was the only item (out the 20 items), which opened another factor. Moreover, it is interesting that the remaining 10 items of Study 1 were also extracted among the 19 items of Study 2 although in the SCAS of 2020 only 12 items were kept from the original 24-item version of 2016. However, items 9 (=item 15 in the SCAS 2020) and 20 (=item 17 in the SCAS 2020) were not selected in the 10-item version of the SCAS 2016 in Study 1 when performing EFA and CFA.

After reverse coding of items 7 (=item number 7 in the SCAS 2020), 9 (=item number 15 in the SCAS 2020) and 20 (=was positively reformulated in the SCAS 2020), we computed the mean scores for the overall acceptance factors. Note that items 9 and 20 were not included in the reduced 10-item version of the SCAS 2016, but only in the long 24-item version. For completeness and comparison reasons, we decided to report both the extracted factor mean scores with 10 and 19 items of the SCAS 2016 and 2020, respectively, and the originally recommended overall acceptance score with all 24 and 20 items of both SCAS versions. Hence, in the following, we report two mean scores for the SCAS 2016 and 2020, respectively (cf. Table 1 and 2).

For all statistical analyses, we applied IBM® SPSS® Statistics, Version 25, (IBM Corp., 2017). We share our two data sets on the Open Science Framework (OSF). The data set of Study 1 and 2 can be downloaded here: https://osf.io/8q2wb/.

Results

Associations of acceptance of AVs and desirability of control (RQ1)

First, we studied whether or not there exist any associations between the overall factor scores of the SCAS and the DoCS. Therefore, we performed exploratory correlational analyses while controlling for the familywise error rate (Type I error rate) because of multiple testing by applying the Bonferroni-Holm correction (Holm, 1979), which also accounts for the Type II error rate and is less conservative than the Bonferroni correction. The data were normally distributed and variance homogeneity was met (also in section 3.2). Hence, we computed the Pearson product-moment correlation between the overall mean score of the SCAS and the overall sum score of the DoCS. Additionally, we calculated the bootstrapped confidence intervals (cf. Table 1) to provide additional measures of accuracy accompanying the *p* values of the correlation coefficients.

Interestingly, in both Study 1 in Germany and Study 2 in the U.S., we identified no significant associations between the overall factor scores of the SCAS and the DoCS when computing the correlation coefficients using the recommended overall factor with all items (e.g., 24 items of the SCAS 2016 and 20 items of the SCAS 2020). However, in Study 1, we uncovered a significant, but only small to medium effect (Cohen, 1992; 1988), between the overall factor score of the SCAS with 10 items, obtained by exploratory and confirmatory factor analyses and the DoCS factor (cf. Table 1). Nevertheless, in Study 2, there was no significant association between the reduced 19-item factor of the SCAS and the DoCS.

Gender differences in acceptance of AVs and desire for control (RQ2)

Second, we applied six independent two samples t-Tests on the overall mean score of the acceptance of self-driving cars scale (SCAS) and the overall sum score of the desirability of control scale (DoCS) as DVs and gender as IV. Gender was categorized in *female* vs. *male* vs. *diverse* (Study 1) and female vs. male vs. *prefer not to respond* (Study 2). Although diverse was not selected in Study 1, prefer not to respond was only chosen by two respondents. Those two participants perhaps might have considered themselves as diverse or simply did not want to specify their gender. In either way, unfortunately, they could not be included, especially not as a separate group because it would have yielded highly unequal group sample sizes (i.e., 2 vs. 322 females vs. 277 males). Again, as in section 3.1, we applied the Bonferroni-Holm correction to account for multiple testing. Additionally, we computed the bootstrapped confidence intervals (CI) using the *bias-corrected and accelerated* (BCa) CIs, which have been proven as more robust and more reliable in many parametric and nonparametric data constellations (Efron, 1987).

Consistently in Study 1 in Germany and in Study 2 in the U.S., we found that women assign significantly lower self-ratings to acceptance of AVs for both overall acceptance scores of the SCAS 2016 and 2020, respectively than men (cf. Table 2). Similarly, we observed in Study 1 and 2 that women also reported significantly lower self-ratings of desire for control than men in Germany and in the U.S. (cf. Table 2).

Table 1
Pearson product-moment correlation of the overall mean score of the acceptance of self-driving cars scale (SCAS) and the overall sum score of the desirability of control scale (DoCS) and the bootstrapped confidence intervals.

					1			2		
	–	Factor Score	*M*	*SD*	*r*	CI_{lower}	CI_{upper}	*r*	CI_{lower}	CI_{upper}
Study 1	1	SCAS 2016: 24 items[a]	3.84	0.87	—	—	—			
Germany	2	SCAS 2016: 10 items[b]	3.94	1.30	0.90**	0.85	0.93	—	—	—
	3	DoCS	95.89	11.88	0.13	-0.05	0.31	0.21*	0.04	0.38
Study 2	1	SCAS 2020: 20 items[a]	4.05	1.52	—	—	—			
U. S.	2	SCAS 2020: 19 items[b]	4.03	1.56	0.99**	0.998	0.999	—	—	—
	3	DoCS	100.70	15.36	−0.07	−0.16	0.02	−0.06	−0.15	0.03

Note. Study 1: N = 114, using the SCAS of 2016 in Germany; Study 2: N = 601, using the newer SCAS of 2020 in the U. S. $CI_{lower/upper}$ = lower and upper *bias-corrected and accelerated* (BCa) confidence interval based on 1000 drawn bootstrap samples. [a]Overall acceptance mean score as recommended in the literature. [b]Overall acceptance mean score obtained by exploratory and confirmatory factor analyses.
*$p < 0.05$; **$p < 0.01$.

Table 2
Independent two samples t-Tests and bootstrapped confidence intervals on the overall mean score of the acceptance of self-driving cars scale (SCAS) and the overall sum score of the desirability of control scale (DoCS) as a function of gender.

		Women		Men						*BCa*	
	Factor Score	*M*	*SD*	*M*	*SD*	*t*	*p*	*Cohen's d*	*Power*	CI_{lower}	CI_{upper}
Study 1	SCAS 2016: 24 items[a]	3.64	0.76	4.06	0.94	−2.63	0.010	0.49	0.74	−0.72	−0.09
Germany	SCAS 2016: 10 items[b]	3.58	1.11	4.33	1.40	−3.21	0.002	0.60	0.88	−1.22	−0.26
	DoCS	92.95	11.46	99.15	11.59	−2.87	0.005	0.54	0.81	−10.10	−2.40
Study 2	SCAS 2020: 20 items[a]	3.67	1.51	4.49	1.41	−6.87	0.000	0.56	0.99	−1.06	−0.58
U. S.	SCAS 2020: 19 items[b]	3.63	1.53	4.50	1.45	−7.15	0.000	0.58	0.99	−1.12	−0.63
	DoCS	99.46	14.73	102.17	16.02	−2.16	0.031	0.18	0.58	−5.26	−0.32

Note. Study 1: N = 114 (60 female, 54 male), df = 112, using the SCAS of 2016 in Germany; Study 2: N = 599 (322 female, 277 male), df = 597, using the newer SCAS of 2020 in the U. S. *Power = achieved power;* $CI_{lower/upper}$ = lower and upper *bias-corrected and accelerated* (BCa) confidence interval based on 1000 drawn bootstrap samples. [a]Overall acceptance mean score as recommended in the literature. [b]Overall acceptance mean score obtained by exploratory and confirmatory factor analyses.
*$p < 0.05$; **$p < 0.01$.

Discussion

The present questionnaire study was designed to investigate how acceptance of AVs is related to desire for control and whether or not there might be any gender effect.

The great strength of the present study is that we independently identified the same findings in Study 1 in Germany and in Study 2 in the U.S. Although it seems that Study 2 was planned and initiated as a replication study of Study 1, in fact, it was planned and conducted entirely independently without knowing from each other, which was discovered by the authors at a later stage, when all data were already sampled in Germany and the U.S. This is the reason why both studies were carried out with a slightly different methodological approach (cf. sections 2.1 and 2.2). Despite applying exactly the same DoC scale, in Study 1 the SCAS of 2016 with 24 items and in Study 2 the newer and further developed SCAS of 2020 with 20 items was applied (cf. 2.1.2.1, 2.2.2.1, and 2.3). In the SCAS of 2020, 12 items were the same as in the former SCAS from 2016 and 8 new items were included that all loaded on a general overall factor constituting an overall mean score of acceptance of AVs.

However, we independently were interested in the relationship between the DoCS and the SCAS in Germany and in the U.S. with a special emphasis on a gender-differentiated approach. In the following, we discuss the results to emerge from both independently conducted studies in Germany and in the U.S.

Associations of acceptance of AVs and desire for control (RQ1)

Our investigation of RQ1 and the exploratory correlational analyses revealed a better insight into the patterns of our two data sets from Germany and the U.S. In doing so, we studied the correlations of both the recommended (non-reduced) overall factor scores as well as the reduced versions extracted by the factor analyses of the SCAS. Hence, we observed the correlations of the DoCS sum score with the mean scores of the general acceptance factors of the SCAS with 24 and 10 items of the SCAS 2016 applied in Study 1 in Germany and of the newer SCAS 2020 with 20 and 19 items provided in Study 2 in the U.S.

The most striking result which was consistently observed in Study 1 and in Study 2, was that desire for control was not correlated with the general non-reduced acceptance factors of the SCAS 2016 and 2020. This finding was confirmed for the correlation of the DoCS sum score with the mean score of the reduced acceptance factor in the larger Study 2 (N = 601) in which the newer version of the SCAS 2020 was applied. Although we identified a significant positive correlation of the DoCS sum score with the mean score of the reduced acceptance factor in Study 1, it was only associated with a small to medium effect and it has to be noted that the sample size (N = 114) was more than five times smaller than in Study 2. Hence, we consider the findings in Study 2 as more reliable than in Study 1. However, taking together those findings it is remarkable that there might be no or perhaps not more than a small association between the self-reported desire for control and the self-reported acceptance of AVs.

This is highly interesting because AVs at SAE level 3 to 5 (SAE_J3016, 2021) require the driver-passenger to relinquish control over driving maneuvers (Rödel et al., 2014). Therefore, our results obtained in Study 1 and 2 are surprising because it is known that individuals may differ highly in the personality trait desire for control in which they are "motivated to feel as if they are in control of the events in their lives" (Burger, 1992, p. 148), whereas persons who report high values on desire for control try to avoid to relinquish control.

Additionally, our findings are not directly in line with previous research in the context of AVs, where it was found that perceived control decreases with higher automation (Rödel et al., 2014) and that the fear of loss of control and safety concerns were observed (Merfeld et al.,

2019; Müller et al., 2017; Planing, 2014), as well as feelings of distress (Kyriakidis et al., 2015; Pettigrew et al., 2019), when handing over control to an automated driving system. Moreover, many participants preferred to be able to take over control anytime (Bazilinskyy et al., 2015; Benleulmi and Blecker, 2017; Fraedrich et al., 2016; Josten et al., 2018) and avoided handing over control completely (Wolf, 2016), which was especially pronounced in older participants (Abraham et al., 2017). Furthermore, it was concluded that those persons, whose biggest concern is handing over control to the AV, might show the least acceptance (Howard and Dai, 2014), which was also observed in a similar study in the late nineties, in which the evidence pointed to a lower likelihood of acceptance of automated systems that intervene in control over driving maneuvers (Van Der Laan et al., 1997). However, in none of these studies acceptance of AVs and desire for control were jointly assessed with the SCAS and the DoCS.

Moreover, previous general findings that higher desire for control might present a barrier to the willingness to adopt new products (Faraji-Rad et al., 2017) as well as that there might be a passive resistance to adopting innovations which entail a fear of losing control (Heidenreich and Handrich, 2015) have to be seriously reconsidered and further studied in the context of the acceptance of AVs.

Nevertheless, it cannot be ruled out that the self-reported acceptance of AVs is not or at least not strongly associated with the self-reported desire for control. Hence, we want to outline that despite the need for further research on this topic, it may be either possible that the encountered barriers to the acceptance of AVs might not be associated to the high extent as suggested by others or that the DoC scale may not be appropriate enough to assess desire for control in the context of AVs.

Gender differences in acceptance of AVs and desire for control (RQ2)

We observed consistent gender differences in both studies. Women reported a significantly lower acceptance of AVs as well as lower desire for control. Regarding acceptance, our findings integrate into the growing body of evidence that supports that women are overall less accepting of AVs than men are. Lower acceptance in women has been identified in several studies covering different operational concepts (private ownership, car sharing, and public transport), perspectives (the driver-passengers' as well as vulnerable road users' perspective), and methodological approaches (quantitative as well as qualitative research; Bansal et al., 2016; Charness et al., 2018; Dong et al., 2019; Esterwood et al., 2021; Hilgarter and Granig, 2020; Hohenberger et al., 2016; Hulse et al., 2018; Nielsen and Haustein, 2018; Nordhoff et al., 2018; Pakusch and Bossauer, 2017; Penmetsa et al., 2019; Rödel et al., 2014; Zhang et al., 2021). Although this study did not aim to conduct a cross-cultural comparison between the two sampled populations, it is worth noting that the self-reported acceptance of AVs was similar in both. This might suggest a similar overall acceptance of AVs in the U. S. and Germany. Such a notion is in line with the findings in Edelmann and colleagues' (2021) cross-cultural study, in which they observed similar acceptance of decisions of AVs in their German and North American participants. The similarity between these two cultures was illustrated by the contrasting self-reports by their Chinese participants.

Regarding desire for control, our findings are consistent with a tendency of lower scores in women, which has been reported for a long time in the psychological literature (Burger, 2013; Gebhardt and Brosschot, 2002). Although this difference is assumed to be especially pronounced in younger females (Burger and Solano, 1994), we also encountered it in Study 1, where the sample was balanced for age. The fact that a lower acceptance of AVs as well as a lower desire for control in women was not only consistent in our two studies but has repeatedly been observed by different authors is indicative of the high external validity of these findings. This implies that female gender currently can be considered a higher barrier to the adoption of AVs as compared to male gender. Stakeholders who are interested in increasing the receptiveness of AVs should be sensitive to this gender difference. Insights into the causes and mechanisms underlying this difference are desirable but beyond the scope of this study. Addressing these causes may prove useful in future campaigns that aim to increase acceptance in the female population specifically, in order to facilitate a successful adoption and integration of AVs into existing traffic. Future research should therefore expand on prior efforts to understand the reasons for differences in acceptance between certain target groups (like those undertaken by Hilgarter and Granig, 2020 or Pettigrew et al., 2019).

Limitations and future work

Future studies in multiple countries should be planned and conducted with exactly the same scales by applying the same methodology in each country (if feasible and applicable). This professional standardization would contribute to an even better and more reliable comparison of the results obtained across different countries. Nevertheless, in our case with the independently conducted studies in Germany and in the U.S., it is remarkable that even slightly different methodological approaches (cf. 3.1 and 3.2) yielded the same consistent findings, which put them together in a larger and more cohesive big picture. Of course, it cannot be excluded that our similar findings may not be found in new replication studies in Germany and in the U.S., but at least in our different areas where we collected the data from our participants, we obtained similar results with the same conclusions.

Another avenue for future research on the relationship of desire for control and acceptance of AVs could be to incorporate the three dimensions of the DoCS and to only apply the newer version of the SCAS of 2020 in each country with the overall acceptance factor. In this regard, it could be interesting to obtain a more diverse picture of the interrelations of those four dimensions.

Moreover, it would be interesting to incorporate prior knowledge of AVs and whether or not this might influence the self-ratings of acceptance of AVs, which may shed even more light on this complex topic. Additionally, it might be interesting to investigate the research questions specifically in the domain of public transportation, which, however, was beyond the scope of the present study.

Conclusion

In two independent samples collected with similar methods, we found weak or nonexistent relationships between the personality trait desire for control and the acceptance of AVs. We used a measure of desire for control–the DoCS–that has demonstrated reliability and validity (McCutcheon, 2000) and a measure of acceptance of AVs–the SCAS–that has seen on-going refinement and a consistent record of high internal consistency reliability (Nees, 2016; Nees and Zhang, 2020). The useful psychometric properties of both instruments were confirmed in this study. Thus, our data would seem to offer one of the more rigorous tests to date of the hypothesized relationship between desire for control and acceptance of AVs. The paradigm shift to AVs and the accompanying loss of control intuitively suggest that desire for control should have a considerable effect on acceptance. Yet our studies and others (Brell et al., 2019; Herrenkind et al., 2019; Nastjuk et al., 2020; Sener et al., 2019; Zmud et al., 2016) have produced data consistent with a weak to non-existent relationship (but for an exception, see Syahrivar et al., 2021). As numerous manufacturers and policymakers are paving the way for AVs on our roads, predicting acceptance of AVs will remain a major challenge for widespread deployment (Harb et al., 2021).

Interestingly, as our studies demonstrate, some of the personality traits–such as desire for control–that seemingly ought to correlate with acceptance have shown little evidence of usefulness. Research has continued to suggest that trust and safety concerns are major determinants of acceptance. A recent *meta*-analysis concluded that "trust was unanimously identified as the most important determinant of AV acceptance" (Zhang et al., 2021), and increased safety relative to the status quo or changes in personal mobility status appear to be factors

that are likely to have major impacts on acceptance rates (Lee et al., 2021). Since respondents have no experience with high levels of vehicle automation and limited experience with partial automation, studies of acceptance to date have invited participants to evaluate hypothetical AVs. Perhaps not surprisingly, research has shown that some of the theoretical sub-dimensions to differentiate dimensions of acceptance have been difficult to validate empirically De Winter and Nordhoff, 2021; Nees and Zhang, 2020). It appears that many people currently simply have generally positive or negative regard for the potential of AVs which perhaps is driven by a small number of variables. It will be interesting to observe whether personality correlates take on more predictive value as AVs are deployed and users gain more firsthand experience.

CRediT authorship contribution statement

Klemens Weigl: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft. **Michael A. Nees:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Writing – original draft. **Daniel Eisele:** Writing – original draft. **Andreas Riener:** Funding acquisition, Resources, Project administration, Supervision, Writing – review & editing.

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.

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This manuscript arose from an instance of scientific co-discovery. We became aware of our similar studies during the peer review process for Study 1. The approximately parallel procedures with different sampling methods and converging patterns of results led us to merge the manuscript for Study 1 with an unpublished preprint of Study 2 to produce the current manuscript. We applied the SDC approach for the sequence of authors. This project was funded by the “Innovative Hochschule” program of the German Federal Ministry of Education and Research (BMBF) under Grant No. 03IHS109A (MenschINBewegung). We are grateful to Eva Quednau, who collected the data from Study 1. Parts of Study 2 were supported by an R.K. Mellon Summer Research Fellowship awarded to the second author by the Lafayette College Academic Research Committee. We are thankful to Karli Herwig and Lindsey Quigley for their assistance in collecting the data and providing valuable input on preliminary drafts for Study 2. An earlier draft of Study 2 appeared as an unpublished preprint analysis of the same data reported in this manuscript (available at https://psyarxiv.com/kz94x/).

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