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Cross-country differences in willingness to use conditionally automated driving systems: Impact of technology affinity, driving skills, and perceived traffic climate

İbrahim Öztürk [a,*], Esko Lehtonen [b], Ruth Madigan [a], Yee Mun Lee [a], Elina Aittoniemi [b], Natasha Merat [a]

[a] Institute for Transport Studies, University of Leeds, LS2 9JT, Leeds, United Kingdom
[b] VTT Technical Research Centre of Finland Ltd., Tekniikantie 21, 02150, Espoo, Finland

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ABSTRACT

The importance of public acceptance of automated driving systems (ADS) has grown as these systems have advanced. Previous research has acknowledged the existence of individual and cross-cultural differences in drivers' willingness to use these systems. This study aimed to further investigate cross-country differences in willingness to use conditionally automated driving systems, and the factors that influence it, such as technology affinity, driving skills, and traffic climate, across eight countries with varying road safety profiles. A large-scale survey was conducted as part of the Hi-Drive project, involving 7896 participants from eight countries (UK, USA, Germany, Sweden, Poland, Greece, China, and Japan). The findings revealed significant cross-country differences in willingness to use ADS, with China having the highest and the United Kingdom having the lowest scores. A mixed-effects model showed that willingness to use ADS was positively associated with technology affinity, driving skills, and external affective demands, and functionality dimensions of Traffic Climate Scale, and negatively associated with internal requirements factor of traffic climate. The results indicate that technology affinity plays a crucial role in influencing willingness to use ADS across countries, while perceptions of driving skills and traffic climate may provide insights into some country and individual-level differences in acceptance of these systems. These findings contribute to our understanding of the acceptance of ADS and the role of individual differences and transport-specific factors.

1. Introduction

The technical capabilities and reliability of automated driving systems (ADS) are improving, bringing us ever closer to the implementation of fully automated vehicles on our roads. While technological advancements in automated driving systems are progressing, users expect more imminent realisation of fully automated vehicles in the near future (Bazilinskyy et al., 2019). For this reason, measurements of user experiences and attitudes serve as important indicators of who will use the vehicles, and provide information on the expectations or meanings that users attribute to these new technologies. This information allows vehicle manufacturers, policymakers, and road safety researchers to understand the reasons for the acceptance or scepticism of road users towards these vehicles. These factors also reflect public perception, and are crucial in avoiding future unintended consequences such as over-reliance (Charness et al., 2018; Hardman, Berliner, & Tal, 2019; Kaye et al., 2021; Liljamo et al., 2018; Piao et al., 2016; Zoellick et al., 2019) or misuse of these technologies (Bainbridge, 1983; Parasuraman & Riley, 1997). This research primarily concentrates on conditionally automated driving systems for privately owned personal vehicles (see Section 2.2.4 for further descriptions of the system).

Research indicates that the acceptance of ADS is a complex issue, and numerous models and theories have been proposed to explain it (e.g., Golbabaei et al., 2020; Kaye et al., 2021; Madigan et al., 2017; Nordhoff et al., 2016). Several models and theories, such as the Theory of Planned Behaviour (Ajzen, 1991), the Technology Acceptance Model (Venkatesh & Davis, 2000), and the Unified Theory of Acceptance and Use of Technology (Venkatesh et al., 2003) have been used to examine individuals' behavioural intention to use technology. These models tend to focus on individual-level determinants of user acceptance (e.g., Jing

* Corresponding author.
E-mail address: i.ozturk@leeds.ac.uk (İ. Öztürk).

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et al., 2020). However, a comprehensive review by Nordhoff et al. (2016) revealed that multiple individual and contextual factors are relevant when considering acceptance. These include system-specific characteristics, individual differences, and contextual aspects (Nordhoff et al., 2016). When evaluating individual differences, it is evident that both trait-like (consistent factors, such as personality) and state-like (factors related to the context, such as performance expectancy) characteristics of individuals affect the acceptance of ADS (Nordhoff et al., 2016). For example, Nordhoff et al. (2016) highlighted the importance of sociodemographic factors, such as age and gender; mobility factors such as daily travel behaviours that address diverse mobility patterns; and psychological characteristics, including personality factors.

1.1. Sociodemographic factors

While age and gender differences in acceptance appear to be one of the primary determinants of willingness to use ADS in many studies, the effects have been found to vary across studies (e.g., Anania et al., 2018; Hőgye-Nagy et al., 2023; Louw et al., 2021; Madigan et al., 2017; Nordhoff et al., 2020; Öztürk et al., 2023; Payre et al., 2014; Schoettle & Sivak, 2014). For example, a study by Nordhoff et al. (2020) found that age and gender had small effects on behavioural intention across 17 countries, with young people and males found to be more likely to intend to use conditionally automated vehicles (Louw et al., 2021; Nordhoff et al., 2020). In another study examining the gender gap in the acceptance of automated vehicles by Torrao et al. (2024), it was found that the gender gap varies with the Gross Domestic Product level of countries. While no general pattern was found, it was discovered that in some countries, females were less willing to use, whereas in other countries, the overall willingness to use was generally high and similar for females and males. These findings demonstrate the importance of demographic factors in accounting for discrepancies in individual differences across countries.

1.2. Technology affinity

One of the personality traits associated with the acceptance of ADS is technology affinity, which is also referred to as technology adoption or technology aptitude. According to this trait, individuals who embrace technological advancements tend to have more positive attitudes towards ADS (e.g., Hardman, Berliner, & Tal, 2019; Thurner et al., 2022), exhibit higher levels of trust in automation (e.g., Kraus et al., 2020), and demonstrate greater acceptance of the systems (e.g., Kraus et al., 2020). This may be due to the fact that these individuals possess a greater understanding and knowledge of these systems (Öztürk, Wallén Warner, & Özkan, 2024). It is essential to recognise and consider the aspect of technology affinity as a trait characteristic when addressing individual differences in the acceptance of technological advancements such as ADS.

1.3. Driving skills and traffic climate

Several studies have highlighted road users expectations regarding the potential of automated vehicles to enhance their driving experiences (e.g., Alessandrini et al., 2015; Chan, 2017; Gish et al., 2017). ADS are expected to bring positive impacts to both users and the broader traffic system and society (Chan, 2017). These expectations include a more relaxing and comfortable driving experience for individuals and a more efficient infrastructure and traffic system. However, these expectations may also be related to the drivers' perceptions of their *driving skills,* i.e. their confidence, or lack thereof, in their abilities in challenging driving situations, or the *traffic climate,* i.e. their perceptions about the challenges faced in the traffic system within which they are travelling.

Although the role of the driver is expected to change with the implementation of ADS, it is important to note that driving skills will still play a critical role, particularly during times when the ADS is not actively in operation (e.g., Kyriakidis et al., 2019; Trösterer et al., 2016). As such, it is highly likely that drivers' initial skill level will be a crucial factor in their expectations and experiences of ADS (Trösterer et al., 2016). Findings from an online cross-country study on driving skills revealed that individuals who perceived their technical driving abilities to be lacking, tended to prefer vehicles with greater capabilities and advanced driving features (i.e., vehicles with higher levels of automation) in Türkiye and Sweden (Öztürk et al., 2023).

Furthermore, the perception and attitudes of road users towards the traffic system in which they travel (often referred to as traffic culture or traffic climate) are also connected to their attitudes and behaviours in traffic (Gehlert et al., 2014; Öztürk, Tümer, & Öz, 2024; Xu et al., 2018). Traffic climate is influenced by personal experiences, attitudes and interactions within the traffic environment, which can vary significantly between individuals, even within the same country. This variability highlights the dynamic and subjective nature of traffic climate and emphasises its relevance as a psychological construct rather than a purely objective systemic descriptor.

Traffic climate has been conceptualised under three dimensions: external affective demands, functionality, and internal requirements. *External affective demands* pertain to the emotional engagement necessitated by the traffic system, such as perceiving the system as aggressive. *Functionality* encompasses perceptions of the traffic system's efficiency and safety, for example, viewing it as well-planned. *Internal requirements* relate to the perceived competencies and capabilities required of road users, including vigilance and alertness in navigating the traffic system (Gehlert et al., 2014). The perceived traffic climate has been used to assess road users' perception of a traffic system, and has been associated with intra- and inter-country differences (e.g., Gehlert et al., 2014; Kaçan-Bibican et al., 2025; Üzümcüoğlu et al., 2019). Although technological advancements in vehicles are expected to bring about significant changes in the traffic system and its perception, research in this area remains limited. For example, in a study examining the relationship between the perception of traffic climate and ADS benefits and concerns, Qu et al. (2019) found that individuals who perceived the traffic system *as functional* reported more usefulness-oriented benefits (e.g., believing that fully automated vehicles will lead to a reduction in time and resource consumption compared to manual vehicles), and system-related concerns (e.g., concerns about fully automated driving systems). Individuals who perceived the system as skill-demanding (*internal requirements*) reported more situational benefits (i.e., benefits of fully automated vehicles under different situations) and scenario-specific concerns (i.e., security risk scenarios). Moreover, individuals who perceived the traffic system as externally demanding in general (*external affective demands*) reported more system-related concerns. Both internal requirements and functionality were positively associated with willingness to use ADS. Another study conducted by Öztürk et al. (2023) found that perceiving the traffic environment as risky and stressful was positively associated with a preference for vehicles with higher levels of automation.

Although the trait and state characteristics mentioned above highlight general individual differences, the literature emphasises that these differences also vary across countries (e.g. Torrao et al., 2024). Many cross-cultural studies show significant country differences in acceptance and willingness to use ADS (e.g., Anania et al., 2018; Louw et al., 2021; Schottle & Sivak, 2014). To illustrate with a few examples, Anania et al. (2018) showed that Indians are more willing to use driverless vehicles than Americans. In another study, Schoettle and Sivak (2014) found that participants in the U.S. had higher concerns about fully automated driving systems than participants in the UK and Australia. These findings are in line with research by Louw et al. (2021), which showed that countries with lower Gross Domestic Product (GDP) and higher road fatality rates had higher intentions to use automated driving assistance systems than countries with higher GDP and lower road death rates. Consequently, there are some early indications that the perceived traffic climate in a country may influence the acceptability of automated driving systems, which could have implications for both vehicle manufacturers and policymakers. The relationship between perceived driving skills and traffic climate (*state-like variables*) is likely to influence this willingness to use ADS. However, to date, this has not been explored in cross-country settings.

1.4. Aim of the present study

It is widely acknowledged that significant discrepancies exist in potential users' acceptance of automated vehicles, and many of these can be attributed to individual differences. A multitude of factors, such as personality traits, demographic characteristics, and prior experience, have been found to contribute to these variations (Hardman, Berliner, & Tal, 2019; Kaye et al., 2021; Nordhoff et al., 2016; Zhang et al., 2021). Additionally, research has demonstrated that the relationship between individual characteristics and user acceptance varies between countries (Anania et al., 2018; Louw et al., 2021; Nordhoff et al., 2022; Öztürk, Wallén Warner, & Özkan, 2024; Zhang et al., 2021). The underlying reasons for these cross-country differences are complex and multifaceted, including income and geographical disparities. Thus, it is important to conduct detailed explorations of the factors which may influence these differences. The aforementioned models and theories, such as the Technology Acceptance Model (Venkatesh & Davis, 2000), primarily focus on individual and technology-related constructs, emphasising factors such as perceived usefulness, perceived ease of use, and social influence as predictors of behavioural intention and technology use (e.g., Li et al., 2024). While these models offer valuable insights into user acceptance, they are largely centred on individual-level determinants and technology-specific attributes. In contrast, this study aims to explore acceptance through a broader lens, incorporating contextual, social, and environmental factors that are not fully addressed by these frameworks (e.g., Zhu et al., 2024). This approach allows for the consideration of the complex interplay of factors influencing acceptance, particularly in dynamic or under-researched contexts where the definition of acceptance itself may vary.

In view of these findings, the objectives of the current study are.

1) To analyse cross-country differences in willingness to use ADS
2) To investigate the impacts of demographic variables i.e. age and gender in a large scale cross-country study
3) To investigate how individuals' attitudes towards new technologies (*trait-like characteristic)* and perceptions of their driving skills and their daily driving environment (i.e., traffic climate, *state-like variables*) relate to their willingness to use ADS across different countries.

2. Methods

2.1. Participants

Data was collected from 7896 participants with valid driving licences from eight countries, namely, the UK, USA, Germany, Sweden, Poland, Greece, China and Japan (refer to Table 1 for descriptive information).

2.2. Measurements

2.2.1. Technology affinity

The Technology Readiness Survey's Innovativeness subscale (Parasuraman & Colby, 2015) was used to measure drivers' inclination towards using new technologies. The scale comprises of four items (e.g., "In general, I am among the first in my circle of friends to acquire new technology when it appears"), which are rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Positive scores indicate greater technology affinity. The Cronbach's alpha reliability for each country is depicted in Table 1.

2.2.2. Driving skills

Drivers' perceptions of their driving skills (or confidence) were measured using a nine-item scale. A number of challenging driving situations were described (e.g., driving in congested traffic, overtaking slower vehicles, or driving in adverse weather conditions), and participants were asked to rate their level of skill in each of these situations on a 5-point Likert scale, ranging from 1 (definitely weak) to 5 (definitely strong). Higher values indicate greater confidence in driving skills. The Cronbach's alpha reliability for each country is presented in Table 1.

2.2.3. Traffic climate

Participants were requested to evaluate the daily traffic environment using the 16-item Traffic Climate Scale (Üzümcüoğlu et al., 2020) on a 6-point Likert scale, ranging from 1 (does not describe it at all) to 6 (very much describes it). The scale has three factors: external affective demands (e.g., stressful), functionality (e.g., free flowing), and internal requirements (e.g., demands alertness). The scale has shown good psychometric properties, allowing cross-country comparison across eight countries (see Öztürk et al., 2025). The Cronbach's alpha reliability for each country is presented in Table 1.

2.2.4. Willingness to use conditionally ADS

ADS was defined as "*Future automated driving systems can handle various driving tasks. When activated, you will be allowed to take your hands off the wheel and eyes off the road. Consequently, you will have the option to use the travel time for other purposes than driving. However, you will need to take back control if the system asks you to do so. Automated driving systems do not need to be monitored by the driver while activated. This is the main difference compared with 'driving assistance systems' currently on the market. A car with an automated driving system can be called an automated car, even though it may not be able to drive in automated mode everywhere.*". Participants' willingness to use the systems was assessed using a three-items as follows: (1), "I would use an automated driving system if I had it in my car.", (2) "The next car I buy/lease/rent will have an automated driving system if it is available.", and (3) "I would use the automated driving system during my everyday trips.", which were rated on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). A higher score reflects a greater inclination towards using ADS. The Cronbach's alpha reliability for each country is illustrated in Table 1.

2.3. Procedure

The study is a part of the Global User Survey of the Hi-Drive project, which is supported by HORIZON Europe (Project No. 101006664). Survey methodology has been employed in this area of research (e.g., Edelmann et al., 2021; Maghrour Zefreh et al., 2023; Nordhoff et al., 2020; Payre et al., 2014; Zhu et al., 2024), providing valuable insights from larger samples with greater statistical power (e.g., Jones et al., 2013). Prior to commencing the study, participants provided informed consent. The study adheres to the guidelines provided by the Finnish National Board on Research Integrity TENK.[1] As the study involved adult participants who provided informed consent, it was deemed exempt from ethical approval, as it did not jeopardise the daily routines, physical well-being, or safety of individuals involved. The data collection was performed by a Finnish market research company, Taloustutkimus Oy. The questionnaire was developed in English and subsequently translated into other languages by the company. No feedback or translation ambiguities have been reported by the research company. The data were collected to represent each country's geographical distribution, and the online panel was structured to equally represent three age groups (18–38, 38–55, and 56–75; age data

[1] https://tenk.fi/sites/default/files/2021-01/Ethical_review_in_human_sciences_2020.pdf.

Table 1
Descriptive and reliability values of study variables across eight countries.

	UK	US	Germany	Sweden	Poland	Greece	China	Japan
n	954	1060	949	1000	967	937	1057	972
Age in years								
M (*SD*)	49.42 (14.64)	50.11 (15.54)	48.73 (14.54)	49.30 (15.61)	46.22 (13.87)	46.84 (13.38)	46.26 (12.51)	48.41 (13.50)
Min-Max	18–75	18–75	18–75	18–75	18–75	19–75	19–71	19–75
Gender								
Man	490	536	487	519	494	489	540	496
Woman	463	521	461	478	471	446	513	473
Other	0	1	1	2	0	1	4	1
Prefer not to say	1	2	0	1	2	1	0	2
Technology affinity (TeAf)								
M (*SD*)	3.04 (1.03)	3.15 (1.22)	3.21 (.95)	3.07 (1.01)	3.43 (.93)	3.49 (.83)	4.06 (.64)	2.94 (.90)
Cronbach's alpha	0.89	0.90	0.84	0.86	0.90	0.85	0.72	0.90
Driving skills (DrSk)								
M (*SD*)	3.80 (.69)	3.79 (.78)	3.58 (.75)	3.76 (.75)	3.76 (.70)	3.87 (.69)	3.94 (.52)	3.03 (.81)
Cronbach's alpha	0.91	0.92	0.93	0.92	0.92	0.89	0.80	0.94
External affective demands (EAD) – Traffic Climate Scale								
M (*SD*)	2.96 (1.06)	3.10 (1.15)	2.97 (1.04)	2.79 (1.06)	3.12 (1.00)	3.60 (1.20)	3.24 (1.11)	2.90 (.83)
Cronbach's alpha	0.91	0.91	0.89	0.91	0.90	0.93	0.90	0.87
Functionality (Fun) – Traffic Climate Scale								
M (*SD*)	3.66 (.88)	3.75 (.98)	3.84 (.95)	3.64 (.92)	3.92 (.90)	3.39 (.99)	4.48 (.90)	3.52 (.84)
Cronbach's alpha	0.77	0.81	0.82	0.79	0.84	0.80	0.83	0.85
Internal requirements (InRq) – Traffic Climate Scale								
M (*SD*)	4.15 (1.19)	4.18 (1.22)	4.38 (1.20)	4.00 (1.07)	4.15 (1.07)	4.55 (1.18)	4.22 (1.05)	3.43 (1.00)
Cronbach's alpha	0.86	0.83	0.88	0.73	0.85	0.86	0.78	0.79
Willingness to use conditionally automated driving systems (WtU)								
M (*SD*)	2.82 (1.25)	2.85 (1.35)	2.98 (1.35)	3.09 (1.25)	3.51 (1.05)	3.47 (1.02)	4.29 (.49)	3.54 (.98)
Cronbach's alpha	0.94	0.95	0.94	0.93	0.90	0.91	0.54	0.92

were collected and used as a continuous variable during the analysis). All age groups consisted of approximately half women and half men. The sample size per country is deemed high enough for minimal effect size (e.g., Lakens, 2022; Vanbrabant et al., 2015) and cross-cultural studies (e.g., Zhao et al., 2024). Participants were incentivised to participate through either a small monetary compensation or the chance to win prizes through the online panel. Anonymity and confidentiality of responses were assured.

2.4. Analysis

Following the initial process of data cleaning, which involved the removal of participants who did not possess a valid driving license, bivariate correlation coefficients between the study variables were calculated for each country (see Section 3.1 and Appendix A) to explore the relationship between variables. Subsequently, an analysis of covariance (ANCOVA) was carried out to compare cross-country differences in willingness to use ADS. In this analysis, age and gender (dummy coded: 0: male, 1: female) were taken into account as control variables.

A mixed-effects model was conducted to investigate the effects of technology affinity, driving skills, external affective demands, functionality, and internal requirements on willingness to use ADS across eight countries. Given that one of the primary objectives of the current study is to investigate cross-country variations, a mixed-effects model was deemed the most appropriate methodological approach to capture country-level variability. To achieve this, the model included country as a random coefficient and fixed effects for the other variables. Taking into account that the age and gender distributions were similar across countries, the variables were not added to the mixed-effects model. After examining the overall model, separate hierarchical regression analyses were performed for each country to examine the predictive power of the study variables on willingness to use ADS. In the first step, age and gender (dummy coded: 0: male, 1: female) were included in the model to control for the effects of demographic variables. In the second step, technology affinity was included (*trait-like characteristic*). In the final step, transport-specific state-like variables (i.e. driving skills, external affective demands, functionality, and internal requirements) were entered (see Section 3.3). To account for multiple comparisons and minimise the risk of type I error, we applied the Bonferroni correction to adjust the significance threshold. The adjusted p-value threshold was calculated as α/m, where $\alpha = .05$ and m represents the number of comparisons. Considering the sample size and correlations between variables, a p-value of .001 was used to determine statistical significance (see Giner-Sorolla et al., 2024; Lakens, 2022, for further discussion). All statistical analyses were performed using SPSS version 29.0 and Jamovi 2.4.14.

3. Results

3.1. Bivariate correlations

The bivariate correlation coefficients indicated that, across all countries, technology affinity (r ranging from .256 in Greece to .569 in the United States) and driving skills (r ranging from .073 in the United Kingdom to .336 in China) demonstrated a positive relationship with willingness to use ADS. Moreover, external affective demands also showed a significant positive relationship with willingness to use ADS in all countries except Japan, Greece, and China (r ranging from .054 in Japan to .212 in the United States). Functionality was significantly positively related to willingness to use ADS in all countries except Germany, Sweden, and the United Kingdom (r ranging from .055 in Sweden/Germany to .275 in China). Lastly, internal requirements did not display any significant relationship with willingness to use ADS (r ranging from −.076 in the United Kingdom to .100 in Japan). Details of the correlations per country can be found in Appendix A.

3.2. Cross-country difference in willingness to use ADS

According to the results of the ANCOVA examining the cross-country comparison of willingness to use ADS (after accounting for age and gender), a significant difference among countries was observed ($F(7, 7867) = 187.90$, $p < .001$, $\eta_p^2 = .14$). The pairwise comparison between countries is presented in Fig. 1, where the highest willingness to use was observed in China, while the lowest was observed in the United Kingdom and the United States.

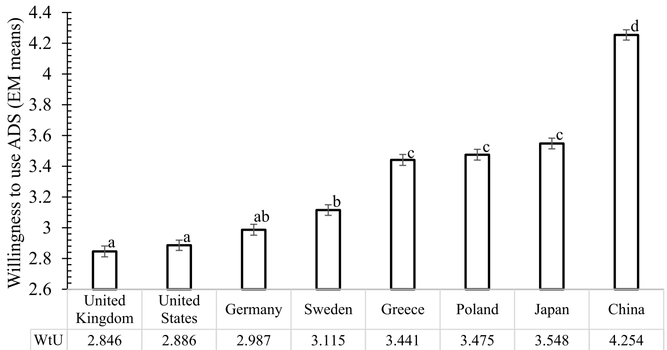

Fig. 1. Willingness to use ADS across eight countries (Error bars represent standard error). Different superscript letters over the means indicate significant differences (p < .001) between the countries. For example, the United Kingdom (referenced with a superscript "a") exhibits a significantly lower willingness to use score when contrasted with countries that do not possess the superscript "a", e.g., Sweden, Poland, Greece, China, and Japan.

3.3. *Factors affecting willingness to use ADS*

According to the mixed-effects model (Table 2, Marginal $R^2 = .21$, Conditional $R^2 = .29$, AIC = 22532.97, BIC = 22625.75, LogLikel = −11276.98, ICC = .10), increased technology affinity, driving skills, functionality and external affective demands and decreased internal requirements were associated with higher willingness to use. The model demonstrated convergence, and the ICC value was low.

Considering the significant cross-country differences in willingness to use and the low ICC value in the mixed-effects model, separate hierarchical regression analyses were run to examine the contribution of each variable after controlling for demographic variables and considering the trait-like characteristics first.

According to the hierarchical regression analysis, the final model (Table 3), including demographic variables (age and gender) in Step 1, technology affinity in Step 2, perceived driving skills and perception of traffic climate factors (external affective demands, functionality, and internal requirements) in Step 3, was significant for all countries; the United Kingdom ($R^2 = .251$, $F(7, 945) = 45.34$, $p < .001$), the United States ($R^2 = .389$, $F(7, 1049) = 95.50$, $p < .001$), Germany ($R^2 = .223$, $F(7, 940) = 38.63$, $p < .001$), Sweden ($R^2 = .263$, $F(7, 989) = 50.44$, $p < .001$), Poland ($R^2 = .145$, $F(7, 957) = 23.16$, $p < .001$), Greece ($R^2 = .100$, $F(7, 927) = 14.68$, $p < .001$), China ($R^2 = .332$, $F(7, 1045) = 74.09$, $p < .001$), and Japan ($R^2 = .119$, $F(7, 961) = 18.49$, $p < .001$).

With regard to demographic variables, the effects of age and gender varied widely between countries. While no significant effect of gender was observed in Greece, Poland, China, or Japan, men were more willing to use ADS in the United Kingdom, the United States, Germany, and Sweden. Regardless of the effect size, age was always negatively associated with the willingness to use ADS in the United Kingdom, United States, Germany, Sweden, and Poland, while there was no significant effect of age in Greece, China or Japan.

Across all countries, the strongest association was observed between technology affinity and willingness to use ADS. Participants with higher technology affinity scores demonstrated a greater inclination towards using ADS, with the variance explained ranging from 7.1 % in Greece to 31 % in China.

The contribution of the state-like characteristics included in the last block fluctuated between 1 and 3 %, after accounting for other variables. The United States was the only country where there was a significant relationship between driving skills and willingness to use ADS, with a positive relationship emerging. In the United Kingdom, United States, Germany, Sweden, and Poland, perceiving traffic systems as more demanding (i.e., higher external affective demands) was associated with a higher willingness to use ADS. Perceiving the transport system as more functional was associated with higher willingness to use ADS in the United Kingdom, the United States, Greece, and China. Finally, in the United Kingdom and the United States, the perception that the transport system requires lower skills (i.e., lower internal requirements) was associated with greater willingness to use ADS.

4. Discussion

The present study examined the willingness to use conditionally automated driving systems in eight countries, considering the effects of technology affinity, perceived driving skills, and perceptions of traffic climate. The findings provide information about the impact of factors related to individual differences on ADS acceptance, and highlight noteworthy variations between countries.

4.1. *Cross-country differences in willingness to use ADS*

The results indicated significant cross-country differences in ADS acceptance across countries, consistent with prior research (e.g., Edelmann et al., 2021; Etzioni et al., 2020; Nordoff et al., 2022; Öztürk et al., 2024). While all countries showed generally favourable attitudes towards ADS, China showed the highest acceptance rates, and the United Kingdom, the United States, Germany, and Sweden exhibited lower rates. This is in line with previous studies (Louw et al., 2021). This disparity could be ascribed to the overall technology affinity score. China has exhibited the highest technology affinity score and, this may indicate that participants from China are more inclined to believe in the influence of all technology.

Furthermore, the current level of societal and policy readiness may also influence the acceptance by the general public. For example, recent policy developments, such as the UK's Automated Vehicles Act (UK Government, 2025), aim to increase safe deployment of automated vehicles, which could potentially enhance willingness to use ADS in these regions. On the other hand, a lower willingness to use scores in countries like the United States, where road users have relatively higher familiarity with such systems through self-driving taxis, might be explained by personal values or the personal enjoyment of driving tasks (Hardman, Lee, & Tal, 2019).

One of the key points to emphasise is that the low ICC value outlined by mixed-effects model results suggests that the differences in willingness to use ADS are largely attributable to individual variations within countries rather than between countries. In other words, the factors that influence the willingness to use ADS are more uniform within countries.

Table 2
Fixed effects parameter estimates.

			95 % Confidence Interval				
Names	Estimate	SE	Lower	Upper	*df*	*t*	*p*
(Intercept)	3.322	0.120	3.087	3.558	6.99	27.70	<.001
Technology affinity	0.458	0.013	0.433	0.484	7889.89	35.44	<.001
Driving skills	0.056	0.017	0.022	0.089	7889.97	3.27	.001
External affective demands	0.160	0.012	0.137	0.184	7886.38	13.24	<.001
Functionality	0.121	0.013	0.095	0.148	7889.90	9.08	<.001
Internal requirements	−0.091	0.012	−0.114	−0.068	7889.05	−7.65	<.001

Table 3
Regression analysis predicting willingness to use ADS across eight countries.

Factors	United Kingdom			United States			Germany			Sweden		
	β	p	95 % CI	β	p	95 % CI	β	p	95 % CI	β	p	95 % CI
1st Level	$R^2 = .120, F\triangle(2, 950) = 64.671, p < .001$			$R^2 = .195, F\triangle(2, 1054) = 127.469, p < .001$			$R^2 = .114, F\triangle(2, 945) = 60.682, p < .001$			$R^2 = .131, F\triangle(2, 994) = 75.133, p < .001$		
Age	**−.327**	**< .001**	**−.033, .023**	**−.401**	**< .001**	**−.040, -.030**	**−.299**	**<.001**	**−.033, -.022**	**−.325**	**<.001**	**−.031, -.021**
Gender (0: Man, 1: Women)	**−.128**	**< .001**	**−.470, -.172**	**−.184**	**< .001**	**−.646, -.352**	**−.165**	**<.001**	**−.606, -.282**	**−.156**	**<.001**	**−.533, -.244**
2nd Level	$R^2 = .225, F\triangle(1, 949) = 129.414, p < .001$			$R^2 = .354, F\triangle(1, 1053) = 260.311, p < .001$			$R^2 = .193, F\triangle(1, 944) = 92.562, p < .001$			$R^2 = .247, F\triangle(1, 993) = 152.35, p < .001$		
Technology affinity	**.363**	**< .001**	**.365, .518**	**.467**	**< .001**	**.495, .632**	**.300**	**<.001**	**.339, .512**	**.377**	**<.001**	**.393, .541**
3rd Level	$R^2 = .251, F\triangle(4, 945) = 8.192, p < .001$			$R^2 = .389, F\triangle(4, 1049) = 14.963, p < .001$			$R^2 = .223, F\triangle(4, 940) = 9.211, p < .001$			$R^2 = .263, F\triangle(4, 989) = 5.355, p < .001$		
Driving skills	−.013	.680	−.133, .087	**.123**	**< .001**	**.124, .304**	.072	.019	.022, .239	.013	.673	−.077, .119
External affective demands	**.163**	**< .001**	**.115, .269**	**.147**	**< .001**	**.104, .240**	**.164**	**<.001**	**.133, .291**	**.128**	**<.001**	**.078, .222**
Functionality	**.114**	**< .001**	**.077, .249**	**.095**	**< .001**	**.059, .203**	.081	.020	.018, .210	.064	.029	.009, .165
Internal requirements	**−.132**	**< .001**	**−.210, -.068**	**−.117**	**< .001**	**−.196, -.064**	−.078	.032	−.167, −.007	−.025	.427	−.103, .044

Factors	Poland			Greece			China			Japan		
	β	p	95 % CI	β	p	95 % CI	β	p	95 % CI	β	p	95 % CI
1st Level	$R^2 = .020, F\triangle(2, 962) = 9.626, p < .001$			$R^2 = .001, F\triangle(2, 932) = .342, p = .710$			$R^2 = .002, F\triangle(2, 1050) = 1.135, p = .322$			$R^2 = .010, F\triangle(2, 966) = 5.065, p = .006$		
Age	**−.115**	**< .001**	**−.013, -.004**	−.022	.507	−.007, .003	.042	.175	−.001, .004	**−.092**	**.004**	**−.011, -.002**
Gender (0: Man, 1: Women)	.077	.016	.030, .293	.015	.641	−.100, .163	−.023	.453	−.083, .037	−.045	.163	−.211, .035
2nd Level	$R^2 = .117, F\triangle(1, 961) = 109.867, p < .001$			$R^2 = .072, F\triangle(1, 931) = 71.287, p < .001$			$R^2 = .312, F\triangle(1, 1049) = 471.738, p < .001$			$R^2 = .108, F\triangle(1, 965) = 106.015, p < .001$		
Technology affinity	**.331**	**< .001**	**.303, .443**	**.276**	**< .001**	**.261, .420**	**.558**	**< .001**	**.392, .470**	**.327**	**< .001**	**.288, .424**
3rd Level	$R^2 = .145, F\triangle(4, 957) = 6.896, p < .001$			$R^2 = .100, F\triangle(4, 927) = 7.209, p < .001$			$R^2 = .332, F\triangle(4, 1045) = 7.820, p < .001$			$R^2 = .119, F\triangle(4, 961) = 2.824, p = .024$		
Driving skills	.070	.030	.010, .200	.091	.007	.037, .231	.081	.006	.022, .133	−.032	.376	−.125, .047
External affective demands	**.117**	**< .001**	**.053, .192**	.091	.028	.009, .146	.021	.448	−.015, .034	−.007	.865	−.097, .081
Functionality	.100	.005	.036, .196	**.139**	**< .001**	**.076, .210**	**.119**	**< .001**	**.035, .096**	.067	.049	.000, .157
Internal requirements	−.014	.715	−.085, .059	−.023	.572	−.087, .048	−.034	.245	−.043, .011	.062	.124	−.017, .140

Note. Significant variables are shown in bold.

There is still considerable variation between countries, particularly with regard to the strength of the relationships and the overall predictive power of the model. In general, factors like traffic conditions, road quality, geographical features, and transport infrastructure policies of each country are most likely to affect the perceived difficulty of driving and the perception of traffic climate. However, it is noteworthy that the impact of traffic climate variables becomes limited in countries such as Sweden, China, and Japan after accounting for technology affinity. This may suggest that ADS are currently perceived as a technological and innovative tool. Thus, the nature of the relationships might change with increasing exposure to ADS in the coming years.

4.2. Impact of trait and state-like characteristics

Consistent with previous research (e.g., Louw et al., 2021; Nordhoff et al., 2020; Torrao et al., 2024), age and gender exhibited significant variations across countries, with some significant associations with willingness to use ADS within countries. The findings indicated that younger participants and men demonstrated a higher propensity to use automated driving systems in the UK, US, Germany, and Sweden.

Technology affinity emerged as the most significant predictor of willingness to use ADS across all countries, consistent with previous studies (Kraus et al., 2020; Öztürk et al., 2024). Participants with higher technology affinity scores demonstrated a greater inclination towards using ADS, suggesting that a general affinity for new technologies and innovation plays a crucial role in ADS acceptance. This finding underscores the importance of fostering technological literacy and awareness to enhance ADS acceptance globally. While this establishes a strong correlation between technology affinity and acceptance, it does not ensure that users possess accurate information about the system in use, which may lead to overreliance or misplaced trust in the system. Achieving an appropriate level of trust is crucial for the safe deployment of automated driving systems and the realisation of societal benefits (e.g., Walker et al., 2023). Educational initiatives and public demonstrations of ADS technologies (e.g., Wang et al., 2024) can help bridge the knowledge gap and foster positive attitudes.

It is somewhat surprising that although the relationship between perceived driving skills and willingness to use ADS was positive in the overall model, this effect disappeared once control variables and technology affinity were introduced, suggesting that technology affinity may overshadow the impact of perceived driving skills on ADS acceptance. This may be due to the fact that the driving skill measurement structure employed in the study focused on different challenging driving conditions, whereas previous studies (Öztürk et al., 2023) assessed driving skills through questions about general driving abilities. The measure used in the current study captures drivers' confidence in facing the challenges encountered in specific situations, but our knowledge of the extent to which they are exposed to these circumstances is limited. Consequently, the non-significant relationship between driving skills and willingness to use ADS in this context might be ascribed to drivers' potentially limited exposure to challenging circumstances or their propensity to avoid such situations through self-regulation. Additionally, it may stem from a lack of awareness regarding the potential advantages of ADS in circumstances where an automated driving system can effectively assist a human driver. Furthermore, the attenuation of this effect may be attributed to the application of statistical tests wherein small effects might have been deemed significant due to the large sample size. As additional predictors were incorporated into the final models and the statistical effects of other variables were controlled for, the unique contribution of weaker effects may have diminished owing to reduced statistical power in more complex models (see Lakens, 2022, for a discussion on sample size justification and power).

Among the dimensions of traffic climate, external affective demands exhibited a robust and consistent effect across countries. Perceiving the traffic system as more demanding was associated with a greater willingness to use ADS. This finding substantiates the notion that individuals who view the traffic environment as stressful or challenging may perceive greater advantages from ADS (Öztürk et al., 2023). Functionality demonstrated a positive relationship with willingness to use ADS, suggesting that a reliable functioning traffic system enhances acceptance. This is consistent with the positive relationships that exist between the functionality and perceived benefits of fully automated vehicles (Qu et al., 2019). Participants who perceive the traffic system as less functional demonstrated lower willingness to use conditionally automated driving systems. This perception may reflect participants' anticipation that the traffic system is also not adequately prepared for such systems. This finding aligns with the required changes to infrastructure and the traffic system in general, necessary for the integration of automated vehicle systems (Manivasakan et al., 2021; Tengilimoglu et al., 2023).

The negative relationship between internal requirements and willingness to use, implies that drivers who perceive the traffic system as demanding greater alertness may be less inclined to adopt ADS. High internal requirements suggest that drivers perceive the traffic system as demanding greater alertness (Gehlert et al., 2014). In this context, drivers who perceive high internal requirements from the traffic system may have some apprehensions about the ADS's competence in such difficult situations (traffic climate in their region). While this contradicts the positive correlation between internal requirements and willingness to use fully automated vehicles (Qu et al., 2019), this might be due to the differences in capabilities of automated driving systems and fully automated vehicles. Moreover, in the same study (Qu et al., 2019), internal requirements were positively related to security and system concerns. These concerns, along with other negative feelings towards automated vehicle technologies such challenges relating to mixed traffic (e.g., Swain et al., 2023), may lead to a reduced propensity to use ADS. Two practical outcomes can be inferred from this. Firstly, manufacturers and system developers must ensure that the automated driving system is capable of handling demanding driving environments. Secondly, the message regarding the capabilities of the automated driving system must be clear to the users by delineating the capabilities and limitations of the system, explicitly acknowledging its constraints. If there is a mismatch between the perceived capabilities of the driving system and the perceived traffic climate, this may result in some scepticism and lower intentions to use ADS.

4.3. Practical recommendations

Overall, this research presents practical recommendations for policymakers and manufacturers. To improve the adoption of ADS, it is crucial to concentrate on increasing technological knowledge and familiarity, particularly in countries with lower levels of acceptance. Customised communication strategies that highlight the advantages and capabilities of ADS in challenging traffic scenarios can assist in overcoming users' concerns and enhancing their readiness to utilise these systems. Furthermore, understanding the cultural and contextual factors affecting the acceptance of ADS is of paramount importance. In countries with high levels of driving stress, emphasising the driving comfort-related benefits of ADS may be effective. Conversely, in regions where driving is culturally valued, promoting the integration of ADS with enjoyable driving experiences may be more advantageous.

4.4. Limitations and future suggestions

While the study provides valuable insights into the predictors of ADS acceptance, there are certain limitations. One limitation of the study is the use of an online panel for data collection. This approach has been subject to criticism due to issues such as participant attentiveness (e.g., Albert & Smilek, 2023; Callegaro et al., 2014; Douglas et al., 2023). Despite this, the panel used in the study provided preliminary screening measures, such as checking the time taken to complete the study and additional controls to enhance the quality of the sampling (see Albert & Smilek, 2023 for further discussion on different panels). This comprehensive approach ensures that the data collected is of high quality.

Previous studies have demonstrated that constructs such as social norms and facilitating conditions play a role in acceptance (Nordhoff et al., 2020). These factors were not included, given the length of the study and the quality of the data. In future research, it may be beneficial to examine how these factors may help to explain cross-cultural differences in the acceptance of ADS, together with the findings from this study. Furthermore, the availability of various modes of transport and individual travel behaviors (e.g., Etzioni et al., 2020) may also influence users' acceptance of conditionally automated driving systems and account for some of the differences observed at the country level. Future research could also investigate the impact of these factors at both the individual level, such as personal transport mode preferences, and at the regional or national level, including car dependency and quality of public transportation services.

To maintain a clear focus on the primary research question and to avoid undue complexity in the model, only a limited number of explanatory variables were included in our model. While age and gender were collected and analysed, other potentially influential factors, such as income, willingness to pay, enjoyment of driving or trust, were not included. These variables could provide additional insights into the nuanced factors influencing the willingness to use automated driving systems. Future research could address this limitation by incorporating a broader range of demographic and other-relevant variables and exploring their interactions with predictors of ADS acceptance. Moreover, studies could explore how gender-specific socio-economic factors, such as income inequality or access to resources, interact with cultural and contextual variables to influence ADS acceptance. Such an approach would provide a more comprehensive understanding of the factors shaping attitudes towards ADS and facilitate more targeted policy and design recommendations. As a result, caution is advised when interpreting the results, and future research should take into account factors such as experience and exposure.

Finally, while our approach aligns with the nature of the relations tested and ensures cross-national comparability, alternative approaches, such as structural equation modelling (e.g., Maghrour Zefreh et al., 2023) or other methodologies such as qualitative analysis (e.g., Swain et al., 2023), could allow for a deeper exploration of the factors and relationships between latent constructs. Constructing separate SEM models for each country or integrating these relationships into a single framework would help to develop theoretical models, which was beyond the scope of this study. With regard to the variations between countries, it is noteworthy that the variables examined in the present investigation account for only a limited degree of variance in WTU. The mixed effects model indicates that additional factors beyond the scope of the present study are necessary to fully understand the disparities observed.

5. Conclusion

The present study delved into the willingness to use conditionally automated driving systems across eight countries, providing insights into trait and transport-specific state-like factors which may influence this relationship. Significant cross-country differences in willingness to use ADS were observed, with China exhibiting the highest levels and Western countries like the United Kingdom, the United States, Germany, and Sweden showing comparatively lower values. The study highlights the pivotal role of technology affinity in promoting ADS acceptance globally, and emphasises the need for concerted efforts to enhance technological literacy and awareness. Additionally, transport-specific state-like variables, including perception of driving skills and traffic climate, played a variable role in willingness to use ADS, with the degree of effect varying across countries. This research contributes to the extant literature by elucidating the interplay between individual traits, perceptions of traffic systems, and cultural differences in shaping acceptance of ADS. By examining willingness to use ADS through both trait and state perspectives, the study extends existing theoretical frameworks and offers practical recommendations for policymakers and manufacturers. Future studies should focus on developing and testing further theories and models, tailoring interventions to address cultural nuances, enhancing exposure to ADS technologies, and bridging the gap between perceived and actual ADS capabilities. Subsequent research could expand on the findings by integrating additional socio-cultural and contextual factors and employing advanced analytical frameworks. As ADS technologies evolve, longitudinal and experimental studies will be essential to explore how increasing exposure influences user perceptions and acceptance over time. This would offer more robust and causal relationships for user research, thereby providing stronger evidence for the effects of experience and exposure to systems with different levels of reliability.

CRediT authorship contribution statement

İbrahim Öztürk: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Esko Lehtonen:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Data curation, Conceptualization. **Ruth Madigan:** Writing – review & editing, Methodology, Conceptualization. **Yee Mun Lee:** Writing – review & editing, Methodology, Conceptualization. **Elina Aittoniemi:** Writing – review & editing, Methodology, Conceptualization. **Natasha Merat:** Writing – review & editing, Supervision, Funding acquisition.

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Appendix A. Correlation coefficients between the variables across countries

Each table shows the correlation coefficients for the two countries. The countries are selected according to their order in the dataset. $^*p < .001$.

Table A.1
Correlation coefficients between study variables for the United Kingdom in bold and for the United States in italics.

Variables	1	2	3	4	5	6
1. Technology affinity	1	_.290*_	_.176*_	_.144*_	_.017_	_.569*_
2. Driving skills	**.273***	1	_.028_	_.294*_	_.161*_	_.275*_
3. External affective demands	**.158***	**−.063**	1	_.058_	_.480*_	_.212*_
4. Functionality	**.053**	**.225***	**−.106**	1	_.320*_	_.164*_
5. Internal requirements	**−.032**	**.179***	**.369***	**.290***	1	_−.003_
6. Willingness to use	**.442***	**.073**	**.188***	**.070**	**−.076**	1

Table A.2
Correlation coefficients between study variables for Germany in bold and for Sweden in italics.

Variables	1	2	3	4	5	6
1. Technology affinity	1	_.284*_	_.088_	_.045_	_−.060_	_.460*_
2. Driving skills	**.285***	1	_−.115*_	_.233*_	_.139*_	_.122*_
3. External affective demands	**.036**	**.006**	1	_−.080_	_.314*_	_.183*_
4. Functionality	**.039**	**.173***	**.016**	1	_.280*_	_.055_
5. Internal requirements	**−.092**	**.094**	**.233***	**.520***	1	_−.024_
6. Willingness to use	**.382***	**.182***	**.196***	**.055**	**−.048**	1

Table A.3
Correlation coefficients between study variables for Poland in bold and for Greece in italics.

Variables	1	2	3	4	5	6
1. Technology affinity	1	_.284*_	_.086_	_.044_	_.074_	_.256*_
2. Driving skills	**.321***	1	_.063_	_.103_	_.160*_	_.163*_
3. External affective demands	**.082**	**−.074**	1	_−.307*_	_.595*_	_.064_
4. Functionality	**.110**	**.196***	**−.046**	1	_−.093_	_.128*_
5. Internal requirements	**.047**	**.122***	**.354***	**.457***	1	_.056_
6. Willingness to use	**.322***	**.161***	**.130***	**.132***	**.095**	1

Table A.4
Correlation coefficients between study variables for China in bold and for Japan in italics.

Variables	1	2	3	4	5	6
1. Technology affinity	1	*.429**	*.031*	*.193**	*.043*	*.323**
2. Driving skills	**.468***	1	*−.112**	*.268**	*−.052*	*.108*
3. External affective demands	**.127***	**.163**	1	*.093*	*.600**	*.054*
4. Functionality	**.283***	**.282***	**−.077**	1	*.321**	*.138**
5. Internal requirements	**.141***	**.027**	**.391***	**.252***	1	*.100*
6. Willingness to use	**.556***	**.336***	**.062**	**.275***	**.074**	1

Data availability

Data will be made available on request.

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