Balancing Privacy and Acceptance: The Role of Anthropomorphism and Information Sensitivity in Autonomous Taxis

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***Abstract*—This study investigates how anthropomorphic interface design and information sensitivity influence users' acceptance of autonomous vehicles (AVS), and examines the underlying role of privacy concern and its boundary conditions in a commercial autonomous taxi context. Addressing prior research that has predominantly examined anthropomorphism or privacy concerns in isolation, this study employs a 2 × 2 experimental design to test the main interaction effects of anthropomorphism and information sensitivity on technology acceptance. The results demonstrate that both anthropomorphism and information sensitivity significantly affect users' acceptance of AV technology, with a significant interaction effect between the two. Specifically, when information sensitivity is high, lower levels of anthropomorphism lead to higher acceptance, whereas under low information sensitivity, anthropomorphic design enhances acceptance. Further analysis reveals that privacy concern mediates the relationship between anthropomorphism, information sensitivity, and technology acceptance. Moreover, cultural value orientation and technical familiarity moderate the effect of privacy concern on technology acceptance, such that the negative impact of privacy concern is attenuated among users with stronger collectivist orientations and higher levels of technical familiarity. By clarifying the sequential roles of design cues, privacy concern, and individual differences, this study reveals a dynamic balance mechanism between emotional engagement and perceived privacy risk in data-intensive mobility services. These findings advance understanding of privacy–acceptance dynamics and provide practical implications for the design and deployment of autonomous taxi interfaces.**

Keywords*—Anthropomorphism; information sensitivity; privacy concern; technology acceptance; individual cultural value; technical familiarity; autonomous taxis

I. INTRODUCTION

With the rapid development of smart cities, domains such as healthcare, smart parking, transportation, and public safety are becoming increasingly interconnected, allowing physical objects to provide intelligent services to citizens [1]. Among them, unmanned driving technology has become a vital part of modern transportation. Driverless taxis, exemplified by pilot projects in cities like Wuhan, China, are gaining global attention. Unlike traditional driving that relies on human control, autonomous driving depends on artificial intelligence and machine learning. For example, in Wuhan's "Radish Kuaipao" autonomous taxi service, safety officers monitor vehicles and intervene if necessary. Although such systems promise fewer accidents and higher efficiency, they raise concerns about privacy, security, and public acceptance [2].

Privacy is a particularly critical issue. As noted in [2], smart technologies often require large-scale personal data collection. In driverless taxis, this may involve continuous tracking and biometric data such as facial recognition.

Improper handling of such data can lead to misuse and privacy breaches. Moreover, users' perception of privacy risk strongly affects their acceptance. In [3], the authors found that greater privacy sensitivity reduces trust in autonomous vehicles, thereby lowering adoption willingness. Hence, balancing service efficiency and privacy protection remains a key challenge. Another important factor is anthropomorphism in driving behavior, which shapes user comfort and perception. In [4], the authors highlighted that vehicle behavior influences passengers' familiarity and perceived safety. In [5], the authors showed that intelligent in-vehicle voice agents using natural language processing can simulate human-like interaction, enhancing user experience. Similarly, [6] demonstrated that anthropomorphic driving increases trust and social acceptance. Technically, anthropomorphism does not involve data collection but rather evokes emotional and cognitive responses through perceived human-likeness. Thus, integrating anthropomorphic features effectively is essential for the broader acceptance of autonomous taxis. However, existing studies have largely examined privacy-related risks and anthropomorphic design cues as separate determinants of user acceptance, leaving their joint and potentially interactive effects insufficiently understood.

Despite the growing importance of autonomous taxis, most studies emphasize technical feasibility [7] rather than the socio-psychological mechanisms driving acceptance. Unlike privately owned autonomous vehicles, commercial autonomous taxi services involve transient usage, platform-based data governance, and limited user control, making privacy perceptions more salient and context-dependent. In particular, prior research has predominantly focused on privately owned autonomous vehicles, whereas commercial autonomous taxi services involve short-term use, platform-mediated data collection, and heightened information sensitivity, which may fundamentally alter users' privacy perceptions and acceptance mechanisms. While trust is central to understanding technology adoption [8], it cannot fully explain interactions involving privacy and anthropomorphism. Therefore, it is necessary to

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explore how these two dimensions jointly influence user acceptance.

This study proposes an integrative framework examining how anthropomorphism and information sensitivity influence technology acceptance, and investigates privacy concern as a mediating mechanism underlying this relationship. It further investigates whether anthropomorphic design can reduce perceived privacy risks and enhance willingness to use driverless taxis. Individual cultural value and technical familiarity are included as moderators to capture personal differences. These moderators are theoretically relevant because cultural orientation shapes how individuals weigh collective benefits against personal privacy risks, while technical familiarity influences users' perceived control and tolerance toward data-driven systems. To test these relationships, a 2×2 between-subjects experiment was conducted, manipulating anthropomorphism (high vs. low) and information sensitivity (high vs. low). Participants evaluated privacy concern and technology acceptance, and the moderating roles of culture and technical familiarity were analyzed using ANOVA and PROCESS procedures. This experimental approach enables a clear examination of both causal effects and interaction mechanisms between design cues and information characteristics, which are difficult to disentangle using survey-based or observational methods. By systematically manipulating anthropomorphism and information sensitivity, the study provides stronger internal validity in explaining users' acceptance of autonomous taxi services. Drawing upon the Privacy Calculus Framework, anthropomorphism theory, and the Technology Acceptance Model (TAM), this study bridges research on privacy protection and human-like design within autonomous mobility. It provides both theoretical insight and practical guidance for balancing efficiency, ethics, and psychological acceptance in the design and governance of driverless taxis in smart cities. While prior research has primarily addressed either privacy or anthropomorphism separately, little is known about their combined effect on user acceptance, especially in commercial AV contexts.

The remainder of this study is organized as follows: Section II reviews the relevant literature and develops the research questions. Section III shows the theoretical background of the research, research models and hypotheses. Section IV describes the experimental design, data collection procedures, measurement instruments, empirical results and hypothesis testing. Finally, Section V discusses the conclusions of the findings, acknowledges the limitations of the study, and outlines directions for future research.

II. Literature Review

A. Autonomous Driving Technology

AVs have evolved from early 20th-century visions into operational systems through decades of interdisciplinary research [9]. Early AVs operated in controlled environments, relying on infrastructure support, while advances in sensors, algorithms, and computation have enabled navigation in complex urban settings [10]. Pioneering projects, including Carnegie Mellon's Navlab and Germany's EUREKA initiative, laid the groundwork for partial automation, and Google's 2010 public-road tests accelerated global investment and research.

AV applications now span passenger transport and logistics, with companies such as Tesla and Waymo integrating automated driving assistance systems (ADAS) and partial self-driving features, while autonomous delivery vehicles undergo trials [11]. AV integration into intelligent transportation systems (ITS) leverages real-time data sharing and smart traffic infrastructure to improve efficiency and reduce congestion, prompting new considerations of human–machine interaction, privacy, and data governance [12].

Future AV development aims for full autonomy (SAE Level 5), yet technical challenges, including unpredictable traffic, adverse weather, and public trust, constrain adoption [13]. Progress relies on AI, deep learning, sensor fusion, and high-speed communication networks [14, 15, 16], alongside emerging ride-hailing platforms that may reshape transportation norms [17].

Privacy concerns are central, as AVs collect sensitive user data such as location, biometrics, and behavioral patterns [18]. Anthropomorphic AV interfaces—ranging from visual avatars to human-like behavioral cues—affect trust, emotional engagement, and privacy perception [19, 20]. User responses are moderated by individual cultural values (e.g., collectivism vs. individualism) and technical familiarity, influencing both privacy concern and technology acceptance.

In sum, successful AV adoption depends not only on technological advancement but also on human factors, including privacy perception, interface design, and cultural context. Integrating these considerations is essential for designing ethically responsible, user-centered autonomous mobility systems.

B. Information Sensitivity in Autonomous Vehicle Systems

Information sensitivity has become a critical concern in digital ecosystems, particularly in ITS and AVs, which rely on continuous data collection through sensors, GPS, and vehicle-to-infrastructure communications [21, 22]. Data ranges from geolocation and routing information to more sensitive types such as biometric identifiers and real-time behavioral patterns, elevating privacy risks beyond traditional transportation. Perceived sensitivity directly influences users' privacy concern and willingness to adopt AVs [23]. Regulatory and policy interventions, including GDPR and AV-specific strategies, emphasize user rights, informed consent, and data minimization [24, 25, 26].

Technological mechanisms, such as encryption, anonymization, and limited data collection, complement regulatory measures to mitigate privacy risks [27]. Transparency and user control—allowing data access, correction, or deletion—further enhance perceived safety [28]. Nonetheless, AV innovations continue to outpace existing protections, making perceived information sensitivity a key determinant of privacy concern and technology acceptance. User responses are also shaped by interface design, particularly anthropomorphic cues, which can mediate how sensitive data is perceived.

C. Anthropomorphism in Human-AV Interaction

Anthropomorphism involves attributing human-like traits to non-human agents, including AVs, via visual cues, language, or behavioral feedback, aiming to enhance user engagement, trust, and comprehension [29, 30]. Such designs can reduce psychological distance and influence perceptions of data practices, though effects are context-dependent [31]. Emotional connection, transparency, and human-like responsiveness can increase perceived trust, safety, and enjoyment, fostering user acceptance [32, 33].

Privacy Concern (PC) reflects perceived vulnerability from personal data collection, which is crucial in AVs due to pervasive data capture [34]. Factors influencing PC include individual characteristics (age, education), socio-cultural background, prior privacy experiences, information sensitivity, perceived transparency, and technical familiarity [35, 36]. Elevated PC can reduce trust and perceived usefulness, thereby limiting Technology Acceptance (TA) [37].

Empirical evidence indicates that information sensitivity increases PC, which lowers TA [2, 18]. Anthropomorphic design can enhance trust and acceptance, but may also raise privacy concerns when systems appear highly human-like [19, 20]. Interaction effects show that high anthropomorphism combined with sensitive data amplifies privacy concerns, whereas low-sensitivity contexts allow anthropomorphism to primarily boost user satisfaction and adoption [38, 19]. This underscores the importance of balancing interface design with data sensitivity to optimize AV acceptance.

D. Moderating Effects of Individual Cultural Value and Technical Familiarity

The effects of information sensitivity and anthropomorphic design on PC and TA are moderated by Individual Cultural Value (ICV) and Technical Familiarity (TF). ICV dimensions, such as individualism–collectivism, influence privacy norms and risk tolerance: sensitivity to data is higher in individualistic cultures, while anthropomorphic cues may be perceived differently across cultures [39, 40]. TF shapes user evaluation of privacy and system functionality: higher TF can reduce PC by improving understanding of mitigation mechanisms, whereas low TF users rely more on human-like signals to assess unfamiliar systems [23]. Evidence suggests that these moderators interact, with cultural norms and technical knowledge jointly shaping trust, privacy perception, and acceptance [41, 42].

Despite progress, research gaps remain, particularly in commercial AV contexts such as autonomous taxis. Most studies focus on private vehicles, neglecting transactional, short-term interactions where data sensitivity and anthropomorphic design may fluctuate across service stages—from navigation to payment. The dynamic interplay of anthropomorphism and information sensitivity, and their amplification of PC, is underexplored. Additionally, the moderating roles of ICV and TF in such service-based environments require empirical validation to inform culturally adaptive and user-specific design principles [39] [40].

Future research should adopt integrated, mediated-moderated frameworks that examine combined effects of anthropomorphism and information sensitivity in commercial AV adoption, ensuring that system design balances usability, trust, and ethical data practices.

Basic the privacy theory and anthropomorphism theory, aiming to clarify the psychological processes through which human-like design cues and varying levels of sensitive data shape user perceptions in data-intensive AV systems. Three research questions guide this investigation:

RQ1: How do anthropomorphic design and information sensitivity, individually and interactively, affect users' privacy concerns?

RQ2: Does privacy concern mediate the relationship between anthropomorphism, information sensitivity, and technology acceptance?

RQ3: Do individual cultural value and technical familiarity moderate the effect of privacy concern on technology acceptance?

III. Methodology

A. Theoretical Background

Privacy has long been central to understanding individuals' decisions about data disclosure and technology use. In [43], the authors defined privacy as control over one's personal information—deciding when, how, and to what extent data are shared. In digital contexts such as autonomous driving, this control becomes complex and psychologically salient. Users weigh perceived risks and benefits of sharing data, consistent with the Privacy Calculus Framework. In this study, information sensitivity represents varying privacy costs, allowing examination of how perceived data risk influences emotional responses (privacy concern) and behavioral intentions (technology acceptance).

Anthropomorphism theory provides a complementary perspective. In [44], the authors suggest that human-like cues enhance engagement and trust by evoking social connection. In autonomous vehicles, anthropomorphic interfaces may improve approachability and trustworthiness, thereby increasing perceived usefulness and lowering adoption barriers. However, from a privacy calculus viewpoint, heightened human-likeness can also increase perceived monitoring or judgment, amplifying privacy concern under high information sensitivity. Thus, anthropomorphism may simultaneously increase trust and privacy risk, creating a psychological trade-off that shapes user acceptance.

To integrate these mechanisms, this study extends the Technology Acceptance Model [45] by incorporating privacy concern as a mediating variable derived from the privacy calculus. Privacy concern reflects the outcome of users' cost–benefit evaluations and connects design characteristics (anthropomorphism, information sensitivity) to behavioral intentions. Furthermore, consistent with extended TAM frameworks, individual factors—cultural value orientation and technical familiarity—are introduced as moderators. Together, these theories form a comprehensive model explaining how emotional engagement and privacy risk jointly determine users' adoption of autonomous driving technologies.

B. Research Model and Hypotheses

Most prior studies on autonomous driving have focused on private self-driving vehicles. This study instead situates its research in the commercial driverless taxi context, emphasizing differences between private ownership and service-based use. This perspective aligns with real-world shared mobility applications while retaining theoretical generalizability across contexts.

The model of this study is constructed based on the relationship between autonomous driving and privacy, anthropomorphism and technology acceptance. However, unlike most studies that focus on "private self-driving vehicles" and ordinary human-machine interaction, this study clearly sets the research scenario as "unmanned taxis for business use". This setting not only highlights the differences from previous literature but also ensures that the research conclusions are closer to the context of shared mobility and commercial applications. Therefore, the research model proposed in this study should be understood as its applicability in the scenario of driverless taxis. Meanwhile, since the core variables and relationship mechanisms of this study have cross-scenario applicability, it is only necessary to emphasize the limitations of the research context (autonomous taxi) on the basis of the existing research framework, rather than introducing brand-new variables separately.

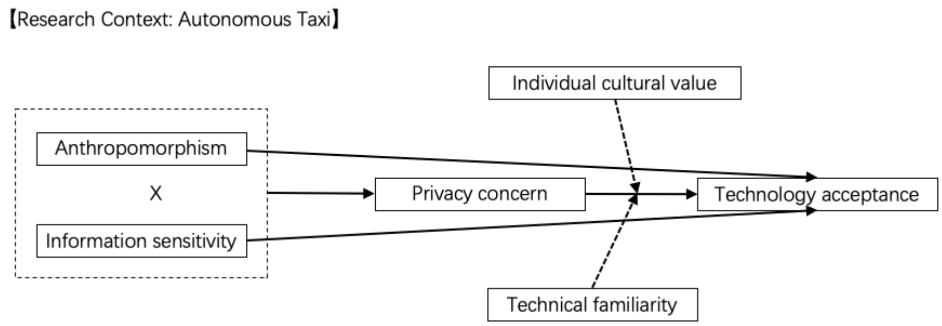

Fig. 1. Research framework.

The proposed research model (Fig. 1) employs a 2×2 experimental design manipulating Anthropomorphism (high vs. low) and Information Sensitivity (high vs. low). These factors jointly influence privacy concern, which mediates their effect on technology acceptance. Two moderators—Individual Cultural Value and Technical Familiarity—are included to test individual differences in this relationship. The model extends the Privacy Calculus Framework by linking design and data characteristics to perceived risk, and reconceptualizes anthropomorphism within privacy-sensitive environments, testing whether human-likeness enhances or hinders trust.

Prior studies indicate that anthropomorphism affects responses to sensitive information [46], while information sensitivity directly influences privacy concern [47, 48]. Accordingly, this study examines how these two factors shape users' privacy perception and acceptance.

H1: Anthropomorphic design positively influences technology acceptance when information sensitivity is low.

H2: High information sensitivity significantly reduces technology acceptance.

In addition, anthropomorphism and information sensitivity are expected to interact. High anthropomorphism under high sensitivity conditions may elicit the highest privacy concern [46, 49], with privacy concern mediating this relationship [50].

H3: Anthropomorphism and information sensitivity interact such that the positive effect of anthropomorphism on technology acceptance weakens under high information sensitivity.

H4: Privacy concern mediates the relationship among anthropomorphism, information sensitivity, and technology acceptance.

Cross-cultural studies suggest that cultural orientation moderates the effect of privacy concern on acceptance [51, 52]. Technical familiarity also moderates users' evaluation of privacy and system reliability [53, 54].

H5: Individual cultural value moderates the relationship between privacy concern and technology acceptance, such that under a high collectivist orientation, the negative effect of privacy concern is weaker.

H6: Technical familiarity moderates the relationship between privacy concern and technology acceptance, such that at high familiarity levels, the negative effect of privacy concern is weaker.

IV. Experiments and Results

Previous research has consistently demonstrated that anthropomorphic design shapes user experience and trust in human–computer interaction (HCI). For example, [55] showed that human-like facial expressions combined with anthropomorphic language elicited more positive user responses than mechanical dialogue, while [56] confirmed that anthropomorphic visual design enhances user perception and engagement. Extending this line of inquiry, [29] found that augmented reality (AR) agents equipped with environmental sensing (e.g., motion tracking) may implicitly signal sensitive data collection, yet users' privacy perceptions remain insufficiently examined. Similarly, [6] demonstrated, respectively, that physically anthropomorphic vehicle features and virtual agents can shape privacy-related responses in AV contexts.

Building on these findings, the present research conducted experiments to empirically test the proposed model. Firstly, examined the main and interaction effects of anthropomorphism and information sensitivity on privacy concern and technology acceptance, whereas it further explored the moderating roles of individual cultural value and technical familiarity. Both studies adopted a 2 × 2 between-subjects design manipulating anthropomorphism (high vs. low) and information sensitivity (high vs. low).

A. Experiments

Participants were randomly assigned to one of four simulated AV interfaces (Fig. 2). Anthropomorphism manipulation: The high-anthropomorphism condition featured a human-like avatar with expressive facial features and conversational dialogue, while the low condition used a minimalistic, non-human-like interface [57, 58]. Information sensitivity manipulation: High-sensitivity interfaces indicated the collection of biometric and emotional data, whereas low-sensitivity interfaces collected only basic trip information [59, 60]. Data-use prompts clarified scope and storage—for example, "Facial information verified for risk control" versus "Only current location obtained; data stored locally" [61].

Fig. 2. Screenshot of the experimental video.

After exposure to an AV scenario like Fig. 2, participants completed 7-point Likert questionnaires measuring perceived anthropomorphism, information sensitivity, privacy concern, and technology acceptance. In addition, the study also included an Individual Cultural Value Scale adapted from Hofstede's cultural dimensions (e.g., [62]) and a Technical Familiarity Scale, which assessed participants' self-reported familiarity and experience with digital technologies. Data were collected via Wenjuanxing with attention checks for quality.

B. Results

To examine the proposed mediation and moderated mediation relationships, this study employed the PROCESS macro for SPSS [63]. The PROCESS procedure is a regression-based analytical approach that allows for direct estimation of mediation, moderation, and conditional process (moderated mediation) effects using bootstrapping. Unlike structural equation modeling (SEM), which requires a relatively large sample size and focuses on latent constructs and overall model fit, PROCESS is particularly suitable for experimental data with observed variables and clear causal directions. Its main advantage lies in its ability to test indirect and conditional effects efficiently without imposing stringent distributional assumptions. Previous studies have employed the PROCESS macro to examine mediation and moderation effects in the context of privacy concern and technology acceptance. For instance, [64] examined the relationships between attitude, privacy concern, and behavioral intention using PROCESS to estimate mediation and moderation effects. Similarly, [65] applied PROCESS to test the moderating role of personality traits in technology acceptance. In this research, PROCESS Model 4 was used to test the mediation of privacy concern, and Model 14 was applied to examine the moderated mediation effects of individual cultural value and technical familiarity. This analytical strategy ensured a robust and transparent examination of the hypothesized causal mechanisms.

TABLE I. DESCRIPTIVE STATISTICS AND CORRELATION ANALYSIS

Variable	M	SD	PC	TA	ICV	TF
PC	3.284	1.466	—	-.237**	-.001	-.024
TA	4.576	1.640	-.237**	—	.775**	.764**
ICV	4.469	1.743	-.001	.775**	—	.894**
TF	4.670	1.946	-.024	.764**	.894**	—

Note: M and SD are used to represent mean and standard deviation, respectively. Values in parentheses are Pearson correlation coefficients. *p < .05, **p< .01.

Before hypothesis testing, preliminary analysis were conducted to ensure the validity of the manipulations and reliability of the measures. Table I presents the descriptive statistics and Pearson correlation coefficients among the main variables. PC showed a significant negative correlation with TA (r = –.237, p < .01), indicating that higher PC is associated with lower acceptance of autonomous taxis. ICV and TF were both strongly and positively correlated with TA (r = .775, p < .01; r = .764, p < .01, respectively), suggesting that individuals with higher collectivist tendencies and greater technical familiarity tend to show higher levels of acceptance. Moreover, ICV and TF were highly correlated with each other (r = .894, p < .01), implying potential conceptual overlap or shared variance between these two moderators. No significant correlations were found between Privacy Concern and either ICV or TF.

TABLE II. MANIPULATION TEST RESULTS (INDEPENDENT SAMPLE T-TEST)

Manipulate variable	Condition	M	SD	t	df	p
Anthropomorphism	Low (n=100)	2.415	1.062	-19.713	198	< .001
	High (n=100)	5.435	1.105			
Information Sensitivity	Low (n=100)	2.540	1.259	-15.231	198	< .001
	High (n=100)	5.390	1.385			

Note: M and SD are used to represent mean and standard deviation, respectively.

Table II presents the results of the manipulation checks for anthropomorphism and information sensitivity. An independent-sample t-test confirmed that the manipulation of anthropomorphism was successful. Participants in the high-anthropomorphism condition (M = 5.435, SD = 1.105) perceived significantly higher levels of anthropomorphism than those in the low-anthropomorphism condition (M = 2.415, SD = 1.062), t (198) = –19.713, p < .001.

Similarly, the manipulation of information sensitivity was effective. Participants in the high-sensitivity condition (M = 5.390, SD = 1.385) perceived significantly higher information sensitivity than those in the low-sensitivity condition (M = 2.540, SD = 1.259), t (198) = –15.231, p < .001. These results indicate that both experimental manipulations were successful, validating the subsequent hypothesis testing.

TABLE III. ANALYSIS OF VARIANCE RESULTS OF ANTHROPOMORPHISM AND INFORMATION SENSITIVITY ON TECHNOLOGY ACCEPTANCE

Source	Sum of Squares	df	Mean Square	F	p
Anthro (A)	16.965	1	16.965	7.255	.008
InfoSens (B)	41.633	1	41.633	17.803	< .001
A × B	18.453	1	18.453	7.891	.005
Error	458.349	196	2.339		
Total	4723.813	200			

Note: Anthro = Anthropomorphism, InfoSens = Information Sensitivity.

A two-way ANOVA (Table III) was conducted to examine the effects of anthropomorphism and information sensitivity on technology acceptance. Results indicated that anthropomorphism had a significant main effect [F (1,196) = 7.255, p = .008], and information sensitivity also had a significant main effect [F (1,196) = 17.803, p < .001]. Moreover, the interaction effect between anthropomorphism and information sensitivity was significant [F (1,196) = 7.891, p = .005].

As illustrated in Fig. 3, when information sensitivity was low (blue line), the level of technology acceptance remained relatively high regardless of anthropomorphism. However, under high information sensitivity (red line), technology acceptance decreased sharply as anthropomorphism increased. This suggests that the positive influence of anthropomorphic design is dampened under conditions of high information sensitivity, supporting the hypothesized interaction effect.

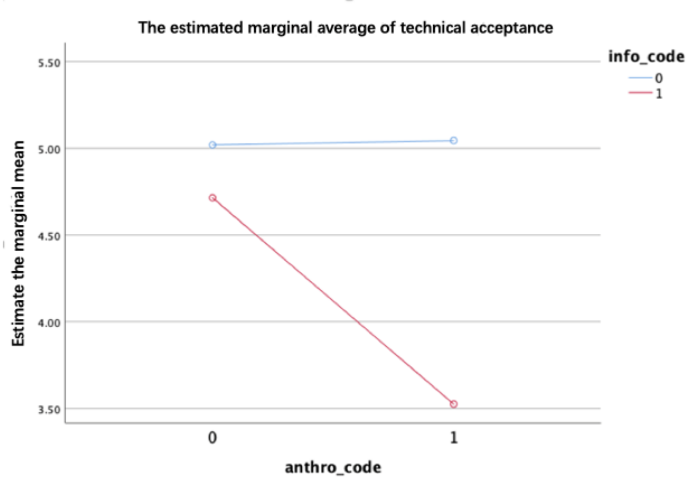

Fig. 3. The interaction graph of anthropomorphism and information sensitivity on technology acceptance.

TABLE IV. SIMPLE MEDIATION ANALYSIS (PROCESS MODEL 4)

Path	Coefficient	SE	t	p	95%CI
Interaction → PC	2.8617	0.1273	22.4757	< .0001	[2.6106, 3.1127]
PC → TA	0.3066	0.1378	2.2244	.0273	[0.0348, 0.5784]
Direct Effect					
Interaction → TA	-2.2790	0.4653	-4.8977	< .0001	[-3.1966, -1.3613]
Indirect Effect					
Interaction → PC → TA	0.8773	0.3709	-	-	[0.1053, 1.5707]

Note: N = [200]. Bootstrapping sample size = 5000. CI = confidence interval. Interaction = Anthropomorphism × Information Sensitivity interaction.

To further examine whether privacy concern mediates the effect of the interaction between anthropomorphism and information sensitivity on technology acceptance, a simple mediation analysis was conducted using PROCESS Model 4 [63]. As shown in Table IV, the interaction between anthropomorphism and information sensitivity had a significant positive effect on privacy concern ($\beta = 2.8617$, $t = 22.4757$, $p < .001$, 95% CI [2.6106, 3.1127]). In turn, privacy concern had a significant negative effect on technology acceptance ($\beta = 0.3066$, $t = 2.2244$, $p = .0273$, 95% CI [0.0348, 0.5784]). The direct effect of the interaction on technology acceptance remained significant ($\beta = -2.2790$, $t = -4.8977$, $p < .001$, 95% CI [−3.1966, −1.3613]), indicating a partial mediation effect. Moreover, the bootstrapped indirect effect through privacy concern was significant ($\beta = 0.8773$, 95% CI [0.1053, 1.5707]), as the confidence interval did not include zero. This finding suggests that the interaction between anthropomorphism and information sensitivity influences technology acceptance partly via increased privacy concern, supporting H4.

TABLE V. MODERATED MEDIATION ANALYSIS (PROCESS MODEL 14)

Moderator	Effect	Coeff.	SE	t	p	95%CI
ICV	Interaction → PC	2.8617	0.1273	22.48	< .001	[2.6106, 3.1127]
	PC → TA	0.3425	0.1419	2.41	.0167	[0.0627, 0.6224]
	ICV → TA	0.9729	0.0893	10.89	< .001	[0.7967, 1.1491]
	PC × ICV	-0.0857	0.0251	-3.42	.0008	[-0.1351, -0.0363]
	Direct Effect					
	Interaction → TA	-0.9985	0.2965	-3.37	.0009	[-1.5832, -0.4137]
		Effect	BootSE			BootCI
	Index of Moderated Mediation	-0.2452	0.0747			[-0.3948, -0.1053]
TF	Interaction → PC	2.8617	0.1273	22.48	< .001	[2.6106, 3.1127]
	PC → TA	0.4426	0.1403	3.16	.0019	[0.1660, 0.7192]
	TF → TA	0.8865	0.0836	10.61	< .001	[0.7217, 1.0514]
	PC × TF	-0.0852	0.0234	-3.64	.0003	[-0.1313, -0.0391]
	Direct Effect					
	Interaction → TA	-1.2785	0.2986	-4.28	< .001	[-1.8674, -0.6897]
		Effect	BootSE			BootCI
	Index of Moderated Mediation	-0.2437	0.0744			[-0.3979, -0.1032]

Note: N = [200]. Bootstrapping sample size = 5000.

To further test whether ICV and TF moderate the indirect effect of the interaction between anthropomorphism and information sensitivity on technology acceptance through privacy concern, two moderated mediation analyses were conducted using PROCESS Model 14 [63].

As shown in Table V, for ICV, the interaction between anthropomorphism and information sensitivity significantly predicted privacy concern ($\beta = 2.8617$, $t = 22.48$, $p < .001$, 95% CI [2.6106, 3.1127]). Privacy concern had a significant negative effect on technology acceptance ($\beta = 0.3425$, $t = 2.41$, $p = .0167$, 95% CI [0.0627, 0.6224]), and the interaction between privacy concern and ICV was also significant ($\beta = -0.0857$, $t = -3.42$, $p = .0008$, 95% CI [−0.1351, −0.0363]). The index of moderated mediation was significant ($\beta = -0.2452$, BootSE = 0.0747, 95% CI [−0.3948, −0.1053]), indicating that the indirect effect of the interaction on technology acceptance through privacy concern was contingent on individual cultural value. Specifically, the negative impact of privacy concern on technology acceptance was weaker among individuals with higher collectivist cultural values, supporting H5.

Similarly, for TF, the interaction term significantly predicted privacy concern ($\beta = 2.8617$, $t = 22.48$, $p < .001$), and the effect of privacy concern on technology acceptance was significant ($\beta = 0.4426$, $t = 3.16$, $p = .0019$, 95% CI [0.1660, 0.7192]). The interaction between privacy concern and TF was significant ($\beta = -0.0852$, $t = -3.64$, $p = .0003$, 95% CI [−0.1313, −0.0391]), and the index of moderated mediation was also significant ($\beta = -0.2437$, BootSE = 0.0744, 95% CI [−0.3979, −0.1032]). This pattern indicates that the negative influence of privacy concern on technology acceptance diminishes as users' technical familiarity increases, supporting H6.

C. Discussion

This study examined how anthropomorphic interface design and information sensitivity jointly shape users' acceptance of AVs, emphasizing the mediating role of privacy concern and the moderating effects of individual cultural value and technical familiarity. Drawing upon the Privacy Calculus Framework and the TAM, the findings reveal that user acceptance of AVs results from a dynamic balance between emotional engagement and perceived data risk.

Consistent with expectations, both anthropomorphism and information sensitivity significantly influenced technology acceptance. High anthropomorphism enhanced acceptance only when information sensitivity was low, whereas under high information sensitivity, anthropomorphic designs reduced acceptance by intensifying privacy concerns. This interaction indicates that anthropomorphism does not universally promote positive user attitudes but instead functions as a context-dependent cue that can either facilitate or hinder acceptance depending on the perceived privacy risk. The results highlight a privacy–affect trade-off: while human-like design enhances social connection and trust, it simultaneously heightens users' sense of vulnerability when sensitive data is involved.

The mediation analysis further supports that privacy concern partially explains the relationship between design cues and acceptance, confirming its central role in the privacy calculus process. Users weigh the benefits of engaging in human-like interaction against the risks of personal data exposure. This partial mediation also suggests that other factors, such as trust and perceived control, may concurrently influence acceptance decisions. Together, these results extend the TAM by positioning privacy concern as a critical antecedent in data-intensive technologies, aligning with the growing recognition that emotional design and risk perception jointly determine user behavior in autonomous systems.

Moreover, the moderated mediation analyses indicate that both individual cultural value and technical familiarity significantly weaken the negative impact of privacy concern on acceptance. Users with stronger collectivist orientations or higher technical familiarity were less deterred by privacy concerns, suggesting that cultural and experiential differences shape how individuals interpret and manage perceived risks. Notably, although these moderators were not directly correlated with privacy concern, they effectively altered the strength of its influence on behavioral intention, reinforcing the idea that user characteristics operate as boundary conditions rather than independent predictors. This finding advances current understanding of cross-cultural and experiential effects in human–technology interaction by demonstrating that acceptance dynamics are not uniform across user groups.

Theoretically, these findings contribute to the refinement of both the Privacy Calculus Framework and TAM by integrating emotional, cognitive, and cultural dimensions into a unified model of technology acceptance. The results reveal that anthropomorphism's benefits depend on contextual and personal factors, and that privacy concern serves as a psychological bridge connecting interface design and user adoption. Practically, the study suggests that designers and policymakers should exercise caution in applying anthropomorphic features in high-sensitivity contexts, as such designs may inadvertently increase users' privacy anxiety. Privacy-sensitive interface strategies—such as adaptive disclosure, transparent data communication, and culturally attuned messaging—can help balance emotional engagement and perceived security. Moreover, enhancing users' technical literacy and offering customization options for privacy settings may mitigate negative perceptions without compromising usability.

In summary, this study underscores that acceptance of autonomous vehicles is governed by a dynamic tension between human-like engagement and data privacy concerns. Anthropomorphism enhances acceptance only under low perceived risk, while privacy concern mediates and individual differences moderate this relationship. These findings enrich theoretical perspectives on human–AI interaction and provide actionable guidance for developing human-centered, context-aware, and privacy-responsible autonomous vehicle systems.

V. Conclusion and Implications

A. Conclusion

This research investigated how anthropomorphic design, information sensitivity, and individual differences influence privacy concern and technology acceptance in AVs. The findings reveal that when anthropomorphic features are combined with highly sensitive information, users experience greater privacy concern, which subsequently lowers technology acceptance. Conversely, under low information sensitivity, anthropomorphic elements enhance trust without significantly increasing privacy concern. Moreover, individual characteristics—particularly individual cultural values and technical familiarity—moderate these relationships. Users with stronger individualistic orientations or lower levels of technical familiarity exhibit heightened privacy concern in response to anthropomorphic cues. These results highlight the importance of context-aware design and the need to tailor AV interfaces to user characteristics.

Theoretically, this study extends privacy research into the autonomous mobility domain and identifies a dynamic balance mechanism in interface design. It underscores the dual role of anthropomorphism—serving as both a trust-enhancing and a privacy-threatening factor. Practically, the findings emphasize the necessity for adaptive AV interfaces, transparent data communication, and culturally and technically sensitive design strategies that foster acceptance while safeguarding user privacy.

B. Limitations and Future Research

Despite its contributions, this study has several limitations. First, the experimental stimuli, though carefully controlled, may not fully capture the complexity of real-world autonomous vehicle interactions. Participants' reactions in a laboratory setting may differ from those in immersive, on-road contexts. Future research could employ field experiments or longitudinal designs to enhance ecological validity. Second, the sample composition may constrain the generalizability of the findings. Extending the study to participants from diverse cultural backgrounds, age groups, and levels of digital literacy would strengthen external validity and allow cross-cultural comparisons. Third, this study captured users' responses at a single point in time, without accounting for how privacy concerns, trust, and acceptance evolve through repeated use. Longitudinal approaches could reveal how familiarity or habituation influences these dynamics over time. Finally, while this research focused on key predictors—anthropomorphism, information sensitivity, individual cultural value, and technical familiarity—other psychological constructs such as perceived control, algorithm transparency, and social influence may also shape users' acceptance of AVs. Future studies could integrate these factors to develop a more comprehensive framework for understanding how interface design and data characteristics jointly influence privacy perceptions and technology adoption.

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