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RESEARCH PAPER

Anthropomorphism in AI-enabled technology: A literature review

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Abstract
Research advances in artificial intelligence (AI) capabilities have resulted in intelligent and humanlike AI-enabled technology (AIET). The concept of anthropomorphism—the attribution of human characteristics to nonhuman beings or entities—has received increasing attention from academia and industries. However, research on anthropomorphism in the AIET context is relatively new and fragmented, with limited efforts to evaluate current research or consolidate existing knowledge. To bridge this gap, this descriptive literature review of 55 studies seeks to identify research trends, AIET types, theoretical foundations, and methods. The study also analyzes how anthropomorphism has been conceptualized and operationalized in the AIET context, and the thematic analysis identifies research gaps and suggests future explorations. The proposed conceptual framework for exploring the interplay of anthropomorphism with its antecedents and consequences provides a nomological network for future research.

Keywords Anthropomorphism · Artificial intelligence · AI-enabled technology · Literature review

JEL classification O30 · O39

Introduction

Artificial intelligence (AI) has been proven to be significant and influential in the processes of revolutionizing and innovating in the digital era (GrandViewResearch, 2020). In recent years, advances in AI capabilities (e.g., machine learning, natural language processing, speech recognition) have driven the rapid development of AI-enabled technology (AIET). Examples of AIET include voice assistants (e.g., Amazon's Alexa, Apple's Siri), chatbots (e.g., Facebook Messenger bots), social robots (e.g., Hilton's hotel concierge 'Connie'), and autonomous driving systems. AIET has not only changed the way people communicate, think, and learn (Pradhan et al., 2018; Son & Oh, 2018) but has also influenced the way people purchase products and interact with firms (McLean & Osei-Frimpong, 2019), shaping innovation across several industries (Juniper, 2021). Today, AIET has become pervasive and is increasingly used in diverse fields, such as e-commerce (Go & Sundar, 2019), education (Chassignol et al., 2018), and healthcare (GrandViewResearch, 2020). Moreover, AIET is predicted to play a key role in daily life and work (Borges et al., 2021; Maedche et al., 2019), affecting every facet of society (Bawack et al., 2019).

Given its AI capabilities, all AIET exhibits intelligent characteristics and abilities that can be perceived as humanlike in terms of design or application. The attribution of human characteristics to nonhuman beings or entities is known as anthropomorphism, which is a relatively new field in information systems (IS) research. Despite increasing scholarly interest, studies of anthropomorphism in the AIET context (Li & Suh, 2021; Maedche et al., 2019; Pfeuffer et al., 2019) are relatively new and fragmented; and the conceptualization and operationalization of anthropomorphism vary across the existing literature. Consequently, different perspectives and inconsistent findings from various fields have made it difficult for researchers and practitioners to comprehend the nature of anthropomorphism, how it is induced, and what consequences it causes in the AIET context.

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In light of increasing interest in AIET, its projected future growth, and its significant implications for business and society, a comprehensive review of existing studies is necessary to clarify the concept of anthropomorphism and consolidate its existing knowledge in AIET research. To this end, we begin this review by synthesizing existing research trends, topics, methods, and theoretical foundations. Subsequently, how anthropomorphism is conceptualized and operationalized in the AIET context is analyzed to trace its antecedents and consequences. Finally, based on thematic analysis, we develop a conceptual framework for exploring anthropomorphism and its associated factors in the AIET context. Specifically, we address the following research questions:

1. What does the concept of anthropomorphism mean in the AIET context?
2. What are the focal issues for anthropomorphism research in the AIET context?

In answering these research questions, this study aims to deepen the understanding of anthropomorphism and related existing literature in the AIET context as a basis for future research.

The remainder of this paper is organized as follows. The next section introduces the concepts of AIET and anthropomorphism in this field. The procedures for searching literature and identifying relevant publications are then described. After reporting key findings of the reviewed papers, we discuss potential future research and propose a conceptual framework for anthropomorphism and its associated factors in the AIET context. Finally, we discuss the theoretical and practical implications, along with its limitations, and conclude the paper.

Related literature

AIET

AI is the concept of "making a machine behave in ways that would be called intelligent if a human were so behaving" (McCarthy et al., 1955, p. 11). AI is then widely viewed as a technology with the capability to imitate humans and complete tasks in an intelligent manner (Kumar et al., 2021). The intelligent component of AI is exhibited via cognitive, emotional, and/or social aspects (Haenlein & Kaplan, 2019) and is based on its self-learning capability and constant updating and enrichment of its knowledge base (Kumar et al., 2021).

AI has recently become prevalent in both academia and industries (Toorajipour et al., 2021) and is considered as the core technology and way of the future in the Fourth Industrial Revolution (Kim, Cho, et al., 2019a; Kumar et al., 2021; Toorajipour et al., 2021). The rapid development of AI capabilities (e.g., deep learning, natural language processing) has provided information technology (IT) with humanlike capabilities to communicate and control other IT, enhance human-to-machine interactions, automate routine business processes, and improve customer experiences, thus bringing benefits to individuals and firms (Kumar et al., 2021). Furthermore, recent technological developments in AI capabilities have widened its range of applications (Toorajipour et al., 2021). In particular, such progress and breakthroughs have enabled existing systems to improve their performance, and IT providers have utilized these capabilities to develop new systems and applications. With advanced AI capabilities, AIET can sense, comprehend, learn from previous experiences, and intelligently perform tasks (Bawack et al., 2019; Rzepka & Berger, 2018). According to Rzepka and Berger (2018), AIET is categorized into AI-enhanced and AI-based technologies; the former refers to existing systems (e.g., decision support systems) imbued with AI capabilities to improve their performance and the latter refers to new technologies, such as smart speakers and chatbots that are developed using the latest AI capabilities. Recent studies suggest that AIET has profound implications for individuals, organizations, and society (Bawack et al., 2019; Rzepka & Berger, 2018). Thus, an increasing number of researchers from multiple disciplines, such as communication, psychology, IS, and human-computer interaction (HCI), have begun exploring AIET from different perspectives, such as the individual acceptance (Lu et al., 2019), the user experience (Cowan et al., 2017), and the effects of AIET (Gu et al., 2020).

Anthropomorphism in the AIET context

Anthropomorphism in the AIET context is a complex concept that generally involves three most widely used subconcepts in the prior literature: a technological stimulus, a tendency, and a perception. As a technological stimulus, anthropomorphism has been identified as a key characteristic that distinguishes AIET from non-AIET (Troshani et al., 2021), and attracts increasing interest among HCI researchers to explore its effects on user interaction with AIET (Li & Suh, 2021; Li & Sung, 2021). Second, the concept of anthropomorphism can be understood as an innate tendency in human psychology (e.g., Oh et al., 2017), indicating a psychological phenomenon in which individuals tend to anthropomorphize AIET when interacting with it (Li & Sung, 2021). Finally, anthropomorphism is explored as the perception of AIET as humanlike (e.g., Moussawi & Benbunan-Fich, 2021), and its consequences have attracted the most considerable attention in recent AIET research.

The above sub-concepts as technological stimulus, tendency, and perception have enriched our understanding of the concept and importance of anthropomorphism in the AIET context. However, divergences in conceptualization

and operationalization have caused difficulties to consolidate the existing knowledge; for example, Wagner et al. (2019) and Niu et al. (2018) defined anthropomorphism as a tendency but measured it as a perception. In this background, a literature review can help to clarify the nature of anthropomorphism, summarize existing findings, identify ways of advancing current understanding, and highlight the implications of anthropomorphism's effects on adoption and continued use for AIET developers.

Literature search and identification

We conducted a descriptive literature review corresponding to our research goals (Paré et al., 2015). A descriptive literature review seeks to "determine the extent to which a body of empirical studies in a specific research area supports or reveals any interpretable patterns or trends with respect to pre-existing propositions, theories, methodologies or findings" (Paré et al., 2015, p. 186). Therefore, a descriptive literature review serves as a database to present existing conceptualizations, methods, propositions, or findings (Paré et al., 2015).

We followed the guidelines proposed by Webster and Watson (2002) and adopted a two-stage approach in searching for and identifying studies that examined anthropomorphism in the AIET context. In the first stage, we executed a systematic search in several online databases: Web of Science, EBSCOhost, ProQuest, SAGE, ScienceDirect, Taylor and Francis Online, and Scopus. During this stage, we only searched for peer-reviewed journals indexed in the Social Sciences Citation Index given the assured quality of these studies (Suh & Prophet, 2018). To identify relevant articles, we used keywords, such as "anthropomorphism," "artificial intelligence technology," and "AI-enabled technology." To ensure that no major study on anthropomorphism in the AIET context would be missed, we manually searched eleven major IS journals, including *Management Information Systems Quarterly (MISQ)*, *Information Systems Research (ISR)*, *Journal of Management Information Systems (JMIS)*, *Journal of the Association of Information Systems (JAIS)*, *Information Systems Journal (ISJ)*, *European Journal of Information Systems (EJIS)*, *Journal of Strategic Information Systems (JSIS)*, *Journal of Information Technology (JIT)*, *Decision Support Systems (DSS)*, *Information & Management (I&M)*, and *Computers in Human Behavior (CHB)* and seven conference proceedings including *International Conference on Information Systems (ICIS)*, *Americas Conference on Information Systems (AMICS)*, *European Conference on Information Systems (ECIS)*, *Pacific Asia Conference on Information Systems (PACIS)*, *Hawaii International Conference on Information Systems (HICSS)*, *Conference on Computer Supported Cooperative Work (CSCW)*, and *Conference on Human Factors in Computing Systems (CHI)*. A total of 926 papers were initially found. After removing duplicates, 489 studies remained.

During the second stage, inclusion and exclusion criteria were applied to validate the relevance of the initial set of articles. As this review focused on recent studies on anthropomorphism in the AIET context, only studies published between 2000 and 2020 were examined. The inclusion criteria for the studies were as follows: (1) published in 2000–2020, (2) examined anthropomorphism in the AIET context, and (3) included conceptual and/or operational definitions of anthropomorphism. The application of the inclusion criteria yielded 68 studies. Given that a descriptive review should only draw on existing empirical studies and exclude conceptual research (Paré et al., 2015), we follow the following exclusion criteria for studies: (1) were not written in English and (2) had no empirical results. Two authors independently reviewed and removed articles that did not meet the selection criteria. Finally, we identified 54 relevant articles based on the inclusion and exclusion criteria. One additional study was found via forward and backward searches, resulting in 55 relevant articles identified for subsequent analysis. Figure 1 shows the literature search and identification procedures. The reviewed studies are listed in Appendix 1 Table 7.

Overview

Following the work of Webster and Watson (2002), we analyzed the research trends, technologies, theoretical foundations, and research methods to effectively synthesize previous findings and structure the literature review (Chan et al., 2020). In our study, the first author performed the coding procedure, and then the coauthors cross-verified the results. When disagreements occurred, the coded results were discussed until a consensus was reached.

Overview of research trends

Research on anthropomorphism in the AIET context has gained increasing scholarly attention in recent years. As shown in Fig. 2, the number of studies on anthropomorphism in the AIET context has exponentially increased since 2019. More than four-fifth of the studies ($n = 48$) were published between 2019 and 2020. On the basis of our review, anthropomorphism in the context of AIET is a broad research topic involving various research domains, including communication, HCI, hospitality and tourism, IS, marketing, and psychology. Most studies were published in the field of IS ($n = 23$), followed by hospitality and tourism ($n = 10$), marketing ($n = 10$), and HCI ($n = 8$).

Three major research streams emerged from the reviewed articles. The first research stream examined the role of anthropomorphism in the acceptance/adoption intention of

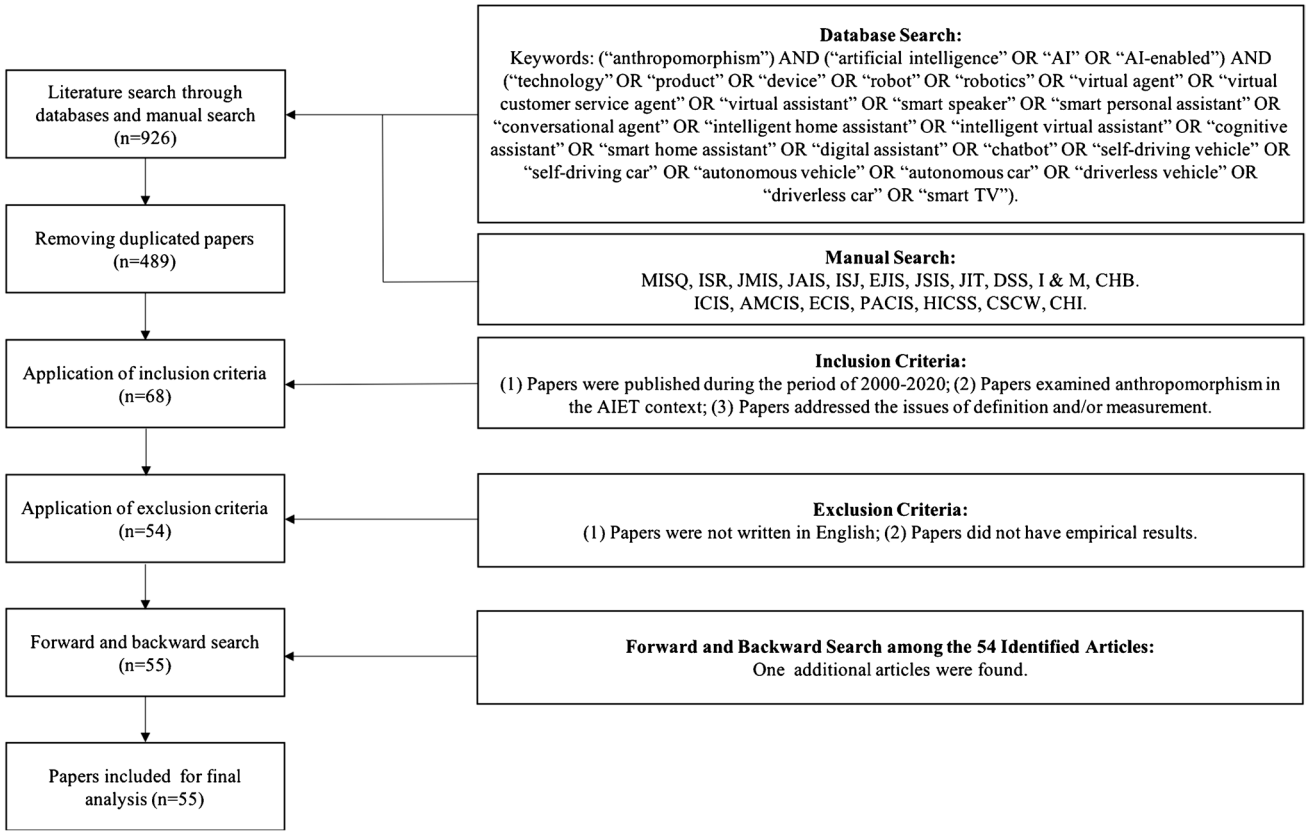

Fig. 1 Literature search and identification procedures

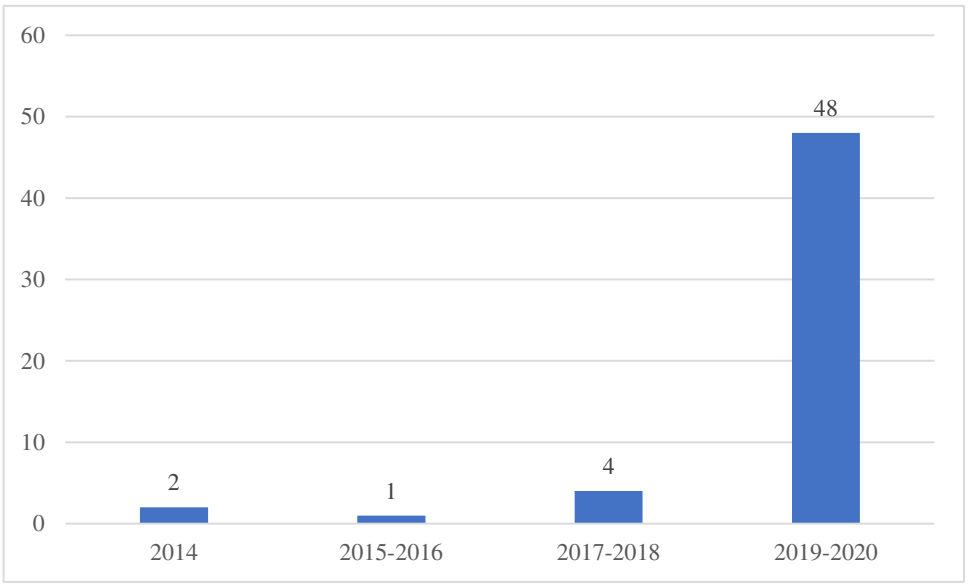

Fig. 2 Publication years of the articles

AIET. For example, Lu et al. (2019) and Sinha et al. (2020) tested the direct relationship between anthropomorphism and acceptance intention. Shin and Jeong (2020) applied the uncanny valley theory to explore the effect of anthropomorphism on adoption intention via individuals' attitudes toward AIET. Shi et al. (2021) examined how anthropomorphism

influences the intention to adopt AIET. The second research stream focused on the effect of anthropomorphism on individuals' perceptions. Most of these studies examined an individual's perceived trust (e.g., Moussawi et al., 2021; Niu et al., 2018; Waytz et al., 2014), followed by social presence (e.g., Lee et al., 2015; Wambsganss et al., 2020), warmth (Kim et al., 2019a; Kim et al., 2019b), and competence (Kim et al., 2019b; Toader et al., 2020) while using AIET. The third research stream dealt with how individuals anthropomorphize AIET. For example, Schweitzer et al. (2019) explored the phenomenon of anthropomorphism from the perspective of relationship building with AIET. Wagner and Schramm-Klein (2019) examined anthropomorphism in terms of social behavior and the AIET adaptability, as well as its relationships with personality, independence, voice, appearance, similarity to the user, and interaction with individuals.

Overview of technologies

This review revealed that AIET consists of diverse types of technology. Among the identified articles, more than one-third ($n=20$) examined chatbots, which were mostly developed by researchers for diverse research contexts, such as e-commerce (Go & Sundar, 2019) and tourism (Melián-González et al., 2021). Approximately 27% ($n=15$) of the studies examined voice assistants, which can be embedded in smartphones, smart speakers, smart TVs, and autonomous vehicles, indicating that voice assistants have become part of these products. Popular examples of voice assistants were Apple's Siri, Amazon's Alexa, and Google's Google Assistant among the reviewed studies. Over 16% ($n=9$) focused on social robots, such as the Nadine robot and Hilton's Connie. Approximately 11% ($n=6$) of the reviewed papers explored AI-based systems for specific purposes, such as job recommendations, travel planning recommendation, financial planning, detecting traffic violations, playing board games, and curating trip destination reviews. Approximately 7% ($n=4$) of the articles examined autonomous vehicles, with the majority examining autonomous driving systems built in driving simulators. Finally, approximately 5% ($n=3$) of the papers did not specify the technology type examined in the research but addressed AIET issues using general terms (e.g., AI devices or machines).

Overview of theoretical foundations

Several theories were adopted to understand anthropomorphism in the AIET context. Table 1 summarizes the theories and frameworks used in the 55 identified papers, 75% ($n=41$) of which had theoretical foundations.

Social response theory, as defined by Reeves and Nass (1996) and other researchers (Moon, 2000; Nass & Moon, 2000), was the most commonly used theoretical approach for examining the effect of anthropomorphism in eliciting individuals' social responses to AIET. Some researchers applied the uncanny valley theory to explain how anthropomorphism affects individuals' emotional responses to AIET (Kim et al., 2019b; Shin & Jeong, 2020; Wagner & Schramm-Klein, 2019; Yu, 2020). Upon further review, we found that unified theory of acceptance and use of technology (UTAUT) (Lu et al., 2019; Melián-González et al., 2021), the artificially intelligent device use acceptance (AIDUA) model (Chi et al., 2022; Lin et al., 2020), the cognition–motivation–emotion framework (Gursoy et al., 2019), the technology acceptance model (TAM) (Bruckes et al., 2019), the stimulus–organism–response (S–O–R) model (Moussawi & Benbunan-Fich, 2021), and dual-process theory (Shi et al., 2021) were adopted to examine individuals' acceptance/adoption of AIET. TAM (Moussawi et al., 2021; Pillai & Sivathanu, 2020) and UTAUT (Melián-González et al., 2021; Moriuchi, 2021; Wagner et al., 2019) were used to explore the relationship between anthropomorphism and the continued use of AIET. To examine the effects of anthropomorphism on individuals' perceptions, researchers applied trust theory (Mesbah et al., 2019; Moussawi & Benbunan-Fich, 2021; Schroeder & Schroeder, 2018; Waytz et al., 2014; Yen & Chiang, 2021), social presence theory (Lee et al., 2015), the computers-are-social-actors (CASA) paradigm (Kim et al., 2019a; Toader et al., 2020), social information processing theory (Toader et al., 2020), reactance theory (Pizzi et al., 2021), and communication privacy management theory (Ha et al., 2021). When examining factors that evoke anthropomorphism, researchers focused on the modality–agency–interactivity–navigability (MAIN) model (Go & Sundar, 2019; Ischen et al., 2020), media equation theory (Toader et al., 2020; Wagner & Schramm-Klein, 2019), and three-factor theory of anthropomorphism (Wagner & Schramm-Klein, 2019). To explain the relationship building between individuals and AIET, researchers used parasocial interaction theory (Whang & Im, 2021) and extended-self theory (Schweitzer et al., 2019).

Overview of research methods

As shown in Fig. 3, the experimental method was the most popular research method, followed by the survey method. Among the selected studies, 11% ($n=6$) combined more than one research method. By using the experimental method, researchers can draw causal relationships (e.g., how the anthropomorphic cues of AIET induce perceived anthropomorphism) by manipulating the design of the anthropomorphic conditions of AIET (e.g., high/middle/low/no anthropomorphic conditions), as well as identify and compare the level of perceived anthropomorphism under different anthropomorphic conditions. Moreover, researchers can

Table 1 Summary of theoretical foundations

Theory	Description	Application	References
Social response theory	Social response theory holds that people view computer systems as social actors and respond socially to them.	Research has applied this theory to examine how anthropomorphism facilitates individuals' social responses to a technology.	Verhagen et al. (2014), Diederich et al. (2019a), Diederich et al., (2019b), Adam et al. (2021), Lembcke et al. (2020), Morana et al. (2020), and Wambsganss et al. (2020)
Uncanny valley theory	Uncanny valley theory suggests that individuals initially exhibit positive affinity toward humanlike technologies. However, when these technologies become too humanlike, people experience a feeling of eeriness or uncanniness.	AIET research has adopted uncanny valley theory to examine the relationship between anthropomorphism degree and individuals' emotional responses to a technology.	Kim et al.,(2019b), Wagner and Schramm-Klein (2019), Shin and Jeong (2020), and Martin et al. (2020)
UTAUT	UTAUT explores factors that influence the technology acceptance, adoption, and usage behavior of individuals.	AIET research has utilized this framework to examine how anthropomorphism exerts additional effects on users' technology acceptance/adoption or continued use.	Gursoy et al. (2019), Melián-González et al. (2021), Wagner et al. (2019), and Moriuchi (2021)
TAM	TAM posits that perceived ease of use and perceived usefulness are two primary factors that influence individuals' intention to accept and use a technology.	This model has been used to explore how anthropomorphism affects individuals' acceptance/adoption or continued use of AIET.	Bruckes et al. (2019), Pillai and Sivathanu (2020), and Moussawi et al. (2021)
Cognition-motivation-emotion framework	The cognition–motivation–emotion framework proposes that people go through several stages of appraisals during a decision-making process. These stages include assessing relevance and importance (primary appraisal), evaluating benefits and costs (secondary appraisal), and creating emotions toward the stimulus that lead to behavioral intention.	On the basis of the cognition–motivation–emotion framework, Gursoy et al. (2019) proposed the AIDUA model that aims to explain individuals' willingness to accept or refuse the use of AIET.	Gursoy et al. (2019)
AIDUA model	The AIDUA model explains how individuals utilize a multistep process to determine their acceptance intention of AIET.	This model has been used to explore how anthropomorphism exerts an indirect effect on individuals' willingness to accept or reject the use of AIET through performance expectancy, perceived effort expectancy, and emotion.	Lin et al. (2020) and Chi et al. (2022)
Trust theory	Trust theory states that a humanlike machine will increase individuals' trust when it performs intelligently and competently.	This theory has been applied to explore how anthropomorphism promotes people's trust in AIET.	Waytz et al. (2014), Schroeder and Schroeder (2018), Mesbah et al. (2019), Yen and Chiang (2021), and Moussawi and Benbunan-Fich (2021)
Social presence theory	Social presence theory asserts that individuals believe that they are interacting with a genuine social actor and their interactions are socially meaningful.	Researchers have adopted this theory to explain the relationship between social presence and anthropomorphism.	Lee et al. (2015) and Schuetzler et al. (2020)
CASA paradigm	The CASA paradigm assumes that people mindlessly apply social heuristics to computers.	Researchers have utilized the CASA paradigm to investigate how anthropomorphism affects individuals' social perceptions of AIET.	Kim et al., (2019a) and Toader et al. (2020)

Table 1 (continued)

Theory	Description	Application	References
MAIN model	The MAIN model explores ways in which four technological features (i.e., modality, agency, interactivity, and navigability) shape user perceptions.	This model has been applied to examine factors that evoke anthropomorphism.	Go and Sundar (2019) and Ischen et al. (2020)
Theory of reasoned action	Theory of reasoned action describes the relationship among individuals' attitudes, intentions, and behavior.	This theory has been used to examine the interplay between anthropomorphism and individuals' attitudes, intentions, and AIET adoption behavior.	Rzepka et al. (2020)
Extended-self theory	Extended-self theory postulates that individuals see certain people and certain tangible and intangible possessions as part of themselves.	Researchers have applied this theory to investigate how anthropomorphism affects the relationships that individuals built with AIET (i.e., AIET as a servant, friend, or master).	Schweitzer et al. (2019)
Three-factor theory of anthropomorphism	Three-factor theory of anthropomorphism focuses on three psychological determinants (i.e., elicited agent knowledge, effectance motivation, and sociality motivation) to explain when people are likely to anthropomorphize and when they are not.	Researchers have adopted this theory to describe the reasons for anthropomorphizing AIET.	Wagner and Schramm-Klein (2019)
Language expectancy theory	Language expectancy theory asserts that people develop expected norms about appropriate language usage in specific contexts.	AIET research has applied this theory to examine how anthropomorphism affects the relationship between the language styles of AIET and individuals' service encounter evaluations or perceived credibility.	Choi et al. (2019)
Realism maximization theory	Realism maximization theory states that minimum resemblance to humans is insufficient for enhancing the interaction between people and technology.	Researchers have used this theory to explore the effect of anthropomorphism on individuals' engagement in AIET.	Moriuchi (2021)
Social information processing theory	Social information processing theory explains how individuals develop and manage impressions and relationships via computer-mediated communication.	Researchers have adopted this theory to examine the interplay between anthropomorphism and individual's perceptions of AIET (i.e., social presence, trust, and perceived competence).	Toader et al. (2020)
Media equation theory	Media equation theory suggests that people respond to computers and other technologies as they do to actual people.	This theory has been applied to investigate what factors can evoke anthropomorphism.	Wagner and Schramm-Klein (2019) and Toader et al. (2020)
S–O–R model	The S–O–R model posits that environmental stimuli can trigger individuals' internal states (i.e., cognitive and affective states), subsequently leading to behavioral changes.	Researchers have adopted this model to examine how stimuli (AIET's voice and humor characteristics) influence anthropomorphism and trust, subsequently resulting in AIET adoption intention.	Moussawi and Benbunan-Fich (2021)

Table 1 (continued)

Theory	Description	Application	References
Attribution theory	Attribution theory indicates how individuals attribute an event's results on the basis of the locus of causality (the result is external or internal) and the cause's stability and controllability.	AIET research has utilized this theory to understand how anthropomorphism influences the relationship between perceived attributional qualities (i.e., perceived internality, stability, and controllability) and perceived ability of AIET.	Ha et al. (2020)
Communication privacy management theory	Communication privacy management theory suggests how individuals manage their private information.	Researchers have used this theory to identify how anthropomorphism affects individual's privacy concerns in using AIET.	Ha et al. (2021)
Parasocial interaction theory	Parasocial interaction theory explains the development of social relationships between people and technologies.	This theory has been applied to examine how anthropomorphism promotes the formation of parasocial relationship between individuals and AIET.	Whang and Im (2021)
Reactance theory	Reactance theory asserts that when people perceive a threat to or loss of behavioral freedom, reactance will be aroused as a motivational state.	AIET research has adopted this theory to investigate the relationship among anthropomorphism, reactance, and satisfaction.	Pizzi et al. (2021)
Self-determination theory	Self-determination theory is an extensive theory regarding motivation, personality, and wellness.	AIET research has used this theory to explore how anthropomorphism contributes to individuals' intrinsic motivation.	Lembcke et al. (2020)
Dual-process theory	Dual-process theory explains how thoughts arise in two ways: fast and automatic process or slow and deliberative process.	Researchers have adopted this theory to analyze how anthropomorphism as a heuristic factor affects adoption intention via trust.	Shi et al. (2021)
Value-based adoption model	The value-based adoption model suggests that behavioral intention is influenced by perceived value. Moreover, perceived benefit and perceived sacrifice are the two major factors that influence individuals' perceived value.	Researchers have applied this theory to understand the interplay among anthropomorphism, perceived benefits, perceived risks, perceived value, satisfaction, and revisit intention in a restaurant that uses robots.	Jang and Lee (2020)

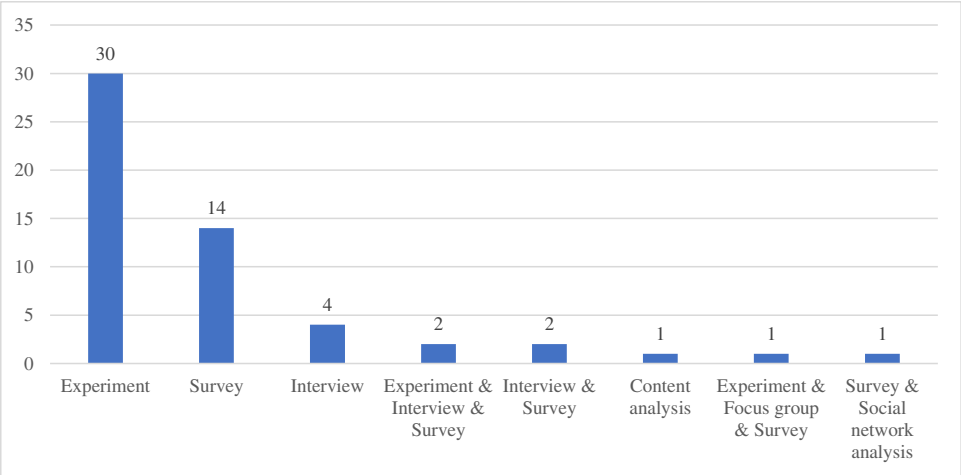

Fig. 3 Summary of research methods

compare the differences among technology types (e.g., chatbots and websites) or relationship types (e.g., a friend and a servant) in evoking perceived anthropomorphism using the experimental method. In addition, the experiment and survey methods were used to collect theoretically related but unobservable constructs, such as individuals' perceptions, attitudes, and behavioral intentions. Thus, the relationships between anthropomorphism and these unobservable constructs can be investigated. Apart from these two research methods, alternative diverse research methods, such as interviews, content analysis, a focus group, and social network analysis, were used to understand anthropomorphism in the AIET context. For example, Sinha et al. (2020) used social network analysis via data mining (i.e., description analysis based on hashtags, geospatial analysis, network analysis, sentiment analysis) with a computational approach to identify anthropomorphism-related keywords.

Thematic analysis

We analyzed studies through thematic analysis (Braun & Clarke, 2006) to capture major themes in a given content. Thematic analysis enables researchers to combine an analysis of the frequency of a theme with an analysis of the overall content, thereby providing a broader understanding of the research issue (Alhojailan, 2012).

What is anthropomorphism?

According to our literature analysis, researchers defined anthropomorphism from different perspectives. In particular, anthropomorphism has been conceptualized as (1) a tendency, (2) a technological stimulus, (3) a perception, (4) a process, and (5) an inference. Among these, the first three are consistent with the most widely used sub-concepts involved with anthropomorphism as discussed earlier.

As shown in Table 2, the first and most common perspective conceptualizes anthropomorphism as a tendency. Among the reviewed papers, 36% ($n = 20$) understood anthropomorphism as users' tendency to attribute humanlike characteristics to a technology. The second perspective is to understand anthropomorphism as a technological stimulus that features human likenesses, such as a humanlike appearance, emotions, personalities, and behavior. Among the reviewed studies, 15% ($n = 8$) conceptualized anthropomorphism as a technological stimulus. For the third perspective, 13% ($n = 7$) of the reviewed studies described anthropomorphism as individuals' perception of objects as humanlike. Meanwhile, 7% ($n = 4$) of the reviewed literature conceptualized anthropomorphism as a process through which individuals attribute humanlike characteristics to objects. Lastly, 4% ($n = 2$) of the reviewed studies viewed anthropomorphism as an inference that an object's mental state is similar to that of humans or an inference in which people attribute humanlike characteristics to objects. Notably, 22% ($n = 12$) of the studies did not provide a definition of anthropomorphism.

Our literature review reported that in researchers' definitions of anthropomorphism, they explained what people attribute to AIET differently and varied in focus on which AIET features were similar to those of human beings. For example, according to Waytz et al. (2014), anthropomorphism is the attribution of human characteristics to autonomous vehicles, and human characteristics are the capacity for rational thought and conscious feeling. Moreover, Lu et al. (2019) stated that anthropomorphism occurs when people attribute human appearance to social robots, and a human appearance includes psychological (e.g., emotions, personalities, and gestures) and nonpsychological (e.g., head, eyes, arms, and legs) features. In terms of voice assistants, anthropomorphism is the attribution of actual or perceived behavior, human characteristics, motivations, intentions, or emotions to this type of technology (e.g., Wagner et al., 2019).

Table 2 Definitions of anthropomorphism

Category	Definition	Reference
A tendency	"The tendency to attribute something (e.g., human/humanlike characteristics, motivations, intentions, and/or emotions) to non-human agents."	Oh et al. (2017), Niu et al. (2018), Wagner and Schramm-Klein (2019), Wagner et al. (2019), and Kuzminykh et al. (2020)
	"People tend to associate humanlike characteristics to these non-human entities."	Seeber et al. (2020)
	"People tend to apply their beliefs and knowledge about humans to non-human objects when they have humanlike features."	Choi et al. (2019)
	"People tend to apply social attributes to artificial agents."	Verhagen et al. (2014)
	"People tend to apply humanlike characteristics, motivations, intentions, or emotions to nonhuman agents."	Wambsganss et al. (2020)
	"People tend to see humanlike agents in all sorts of nonhuman things and events."	Schweitzer et al. (2019)
	"Anthropomorphism is a natural human tendency and a phenomenon that pervades the everyday thoughts and actions of most individuals and influences human perceptions and responses throughout life."	Pizzi et al. (2021)
	"The attribution of something (e.g., human/humanlike characteristics, human capacities, traits, motivations, intentions, mental states, properties, self-consciousness, intelligence, appearance, human form, and/or emotions) to inanimate."	Lee et al. (2015), Moussawi and Koufaris (2019), Bruckes et al. (2019), Martin et al. (2020), Adam et al. (2021), Rzepka et al. (2020), Morana et al. (2020), Sinha et al. (2020), and Jang and Lee (2020)
A process	"The process by which people attribute humanlike factors (e.g., characteristics, properties, traits, features, and/or mental states) to a non-human entity."	Melián-González et al. (2021), Ischen et al. (2020), and Ochmann et al. (2020)
	"A process of inductive inference whereby people attribute to nonhumans distinctively human characteristics, particularly the capacity for rational thought (agency) and conscious feeling (experience)."	Waytz et al. (2014)
A perception	"Users' perceptions of nonhuman agents as humanlike/humans."	Banks (2019), Moussawi et al. (2021), Pillai and Sivathanu (2020), Moussawi and Benbunan-Fich (2021), Shi et al. (2021), Ha et al. (2021), and Whang and Im (2021)
Technological stimuli	"Humanlike features/traits (e.g., humanlike appearance, emotions, personalities, and behaviors) of a product."	Lin et al. (2020), Gursoy et al. (2019), Moriuchi (2021), and Martin et al. (2020)
	"The level of an object's humanlike characteristics (e.g., human appearance, self-consciousness, and emotion)."	Gursoy et al. (2019)
	"Anthropomorphism is the application of humanlike attributes and characteristics such as personality, verbal and nonverbal behaviors, politeness, and embodiment to non-human objects."	Schuetzler et al. (2020)
	"Perceiving humanlike traits in nonhuman agents."	Kim et al., (2019b)
	"The extent to which service robots simulate the characteristics, behaviors or appearances of humans."	Qiu et al. (2020)
An inference	"Individuals' inferences that a chatbot's mental states are similar to those of a human."	Lee et al. (2020)
	"Inductive inference in which the perceiver attributes humanlike characteristics, motivations, intentions or underlying mental states to a non-human entity."	Sheehan et al. (2020)
Other	"The assignment of human traits and characteristics to computers."	Araujo (2018) and Yen and Chiang (2021)

How to measure anthropomorphism?

Objective or subjective measures are used to capture anthropomorphism in the AIET context. In particular, most of the identified studies used subjective measures to understand individuals' perceptions of the anthropomorphism level based on broad or specific aspects. For example, broad aspects that measure anthropomorphism in the AIET context include the overall view that AIET is machinelike or humanlike, artificial or lifelike, or fake or natural (e.g., Banks, 2019; Sheehan et al., 2020). However, depending on the technology type, specific aspects that measure anthropomorphism in the AIET context are AI-related (e.g., perceived personality, the mental state of AI) and/or non-AI-related (e.g., visual appearance of AIET) factors. For chatbots, the AI-related factors used to measure anthropomorphism included the personality (Araujo, 2018; Ischen et al., 2020), conversations (Melián-González et al., 2021; Schroeder & Schroeder, 2018), and mental states (Lee et al., 2020; Morana et al., 2020; Pillai & Sivathanu, 2020) of AIET, whereas its visual appearance was addressed as a non-AI-related factor (Go & Sundar, 2019; Toader et al., 2020). For voice assistants, AI-related factors, such as sociability (Wagner et al., 2019) and personality (Moriuchi, 2021; Moussawi et al., 2021; Moussawi & Benbunan-Fich, 2021; Moussawi & Koufaris, 2019), were used to measure anthropomorphism. For social robots, some researchers focused on a social robot's mental state as an AI-related factor (Choi et al., 2019; Lin et al., 2020; Lu et al., 2019; Sinha et al., 2020), whereas others focused on its appearance as a non-AI related factor (Jang & Lee, 2020; Shin & Jeong, 2020) to measure anthropomorphism. For AI-based systems for specific purposes, mental states (Shi et al., 2021), conversations (Mesbah et al., 2019) as AI-related factors, and appearance (Mesbah et al., 2019) as a non-AI related factor were used to measure anthropomorphism. For autonomous vehicles, AI-related factors, such as mental states and conscious feelings (Bruckes et al., 2019; Niu et al., 2018; Waytz et al., 2014), were used to measure anthropomorphism.

By contrast, several studies (n = 9) used objective measures to measure anthropomorphism as a technological stimulus in the AIET context. In this case, anthropomorphism was manipulated via different experimental conditions (i.e., high/middle/low/no anthropomorphic conditions). Overall, most researchers operationalized anthropomorphism as a perception, then as a technological stimulus.

Our analysis demonstrated that most of the reviewed papers largely regarded anthropomorphism as a unidimensional construct, although three studies have a multidimensional view. Specifically, Araujo (2018) and Ischen et al. (2020) used two dimensions, namely, mindful anthropomorphism (i.e., individuals' conscious evaluation of human likeness to AIET) and mindless anthropomorphism (i.e., a passive process in which individuals attribute human likeness to AIET), to capture anthropomorphism. Moreover, Wagner et al. (2019) presented three dimensions of anthropomorphism: animacy (i.e., the degree to which individuals perceive AIET to be lifelike), perceived sociability (i.e., the degree to which individuals perceive AIET's capability to display sociable behavior), and humanlike fit (i.e., individuals' attitudes toward the human similarity of AIET). Table 3 provides a summary of the measurements used for anthropomorphism, and Fig. 4 shows a word cloud of the measurements and highlights the most common. For the words, the sizes in Fig. 4 solely depend on their frequency in the selected studies. The word cloud displays only those that appear at least twice in the measurements. Thus, Fig. 4 provides a broad picture of which specific or broad factors are commonly used to measure anthropomorphism in the AIET context.

Antecedents of anthropomorphism

Our literature review and analysis demonstrated that technological factors are important in inducing anthropomorphism. *AIET's anthropomorphic cues* were identified as a major antecedent of anthropomorphism among the reviewed studies. The reason is that the ability of individuals to anthropomorphize AIET highly depends on whether they can observe anthropomorphic cues in AIET (Ha et al., 2021; Whang & Im, 2021). In particular, our analysis indicated that identity, conversation-related, and AIET's psychological cues can evoke anthropomorphism in the AIET context. Identity cues received considerable attention in studies on chatbots, voice assistants, social robots, and autonomous vehicles, whereas conversation-related cues were extensively studied in chatbots and voice assistants. Psychological cues were frequently mentioned in the contexts of chatbots, voice assistants, and autonomous vehicles. Moreover, certain studies did not focus on which specific anthropomorphic cues induce anthropomorphism, but rather considered AIET as a whole to explore how *AIET itself* affects anthropomorphism (Banks, 2019; Choi et al., 2019; Ischen et al., 2020; Whang & Im, 2021). Our review demonstrated that AIET itself can evoke anthropomorphism. Besides, researchers further explored the level of anthropomorphism between AIET (chatbots, voice assistants, and social robots) and non-AIET (human agents, computers, and websites). In particular, apart from Choi et al. (2019) who reported a difference in anthropomorphism between a human agent, a social robot, and a computer, studies demonstrated that AIET and non-AIET can produce the same level of anthropomorphism. For example, the level of anthropomorphism is the same between a chatbot and a smart speaker-based voice assistant (Banks, 2019), between a chatbot and a website (Ischen et al., 2020), and between a smart speaker-based voice assistant and a

Table 3 Summary of measurement

Technology	Items or experimental design	Scale	Reference
Chatbots	Anthropomorphism was manipulated using different experimental conditions (i.e., high/middle/low/no anthropomorphic conditions).	Anthropomorphism was measured as a dummy variable.	Verhagen et al. (2014), Adam et al. (2021), Lembcke et al. (2020), Wambsganss et al. (2020), and Pizzi et al. (2021)
	Anthropomorphism was manipulated using different experimental conditions (i.e., high/middle/low/no anthropomorphic conditions).	Anthropomorphism was measured as a perception.	Toader et al. (2020), Schroeder and Schroeder (2018), and Morana et al. (2020)
	Mindful anthropomorphism -Human or machine-like -Natural or unnatural -Lifelike or artificial *Mindless anthropomorphism* -Likeable -Sociable -Friendly -Personal	7-point semantic differential scale for mindful anthropomorphism 10-point semantic differential scale for mindless anthropomorphism	Araujo (2018) and Ischen et al. (2020)
	-How intelligent did he/she seem? -How responsive did he/she seem? -How sophisticated did he/she seem? -How superficial (lacking depth) did he/she seem? -To what extend did he/she seem to have a mind of his/her own?	7-point Likert scale (1 = not at all, 7 = extremely)	Schroeder and Schroeder (2018)
	-Does not look human/looks very human. -Does not look realistic/looks very realistic. -Looks very cartoon-like/does not look like a cartoon.	Semantic differential scale	Go and Sundar (2019) and Toader et al. (2020)
	-It is important that the conversation with a chatbot resembles one with a human being. -Conversations with chatbots should be natural. -Chatbots should seem as if they understand the person with whom they are interacting. -Conversation with a chatbot should not be artificial.	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Melián-González et al. (2021)
	-Extremely inhuman-like –> extremely human-like -Extremely unskilled –> extremely skilled -Extremely unthoughtful –> extremely thoughtful -Extremely impolite –> extremely polite -Extremely unresponsive –> extremely responsive -Extremely unengaging –> extremely engaging	9-point semantic differential scale	Diederich et al., (2019a) and Diederich et al., (2019b)
	-Fake –> natural -Machinelike –> humanlike -Unconscious –> conscious -Artificial –> lifelike -Moving rigidly –> moving elegantly	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Banks (2019)
	-Fake –> natural -Machinelike –> humanlike -Unconscious –> conscious -Artificial –> lifelike -Communicates inelegantly –> communicates elegantly	Semantic differential scale	Sheehan et al. (2020)
	-The conversational agent is natural. -The conversational agent is humanlike. -The conversational agent is polite. -The conversational agent is authentic. -The conversational agent is realistic	5-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Yen and Chiang (2021)
	-I felt that the chatbot was able to think by itself. -I felt that the chatbot behaved of its own volition. -I felt that the chatbot was conscious.	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Lee et al. (2020)
	-The robo-advisory chatbot has a free will. -The robo-advisory chatbot has consciousness. -The robo-advisory chatbot has a mind of its own.	7-point Likert scale	Morana et al. (2020)
	-Chatbots for tourism have their own mind. -Chatbots for tourism can experience emotions. -I fell that chatbots for tourism are –inanimate: living. -I fell chatbots for tourism are computer- animated: real.	5-point Likert scale	Pillai and Sivathanu (2020)
	-My chat partner was definitely computer/probably computer/not sure, but guess computer/not sure, but guess human/probably human/definitely human.	6-point scale	Schuetzler et al. (2020)

Table 3 (continued)

Technology	Items or experimental design	Scale	Reference
Voice assistants	Anthropomorphism was manipulated using different experimental conditions (i.e., high/low anthropomorphic conditions).	Anthropomorphism was measured as a dummy variable.	Sah (2021) and Ha et al. (2021)
	Anthropomorphism was manipulated using different experimental conditions (i.e., high/low anthropomorphic conditions).	Anthropomorphism was measured as a perception.	Schroeder and Schroeder (2018)
	-I felt that the AI I had interactions with was like human beings. -I felt that the AI I had interactions with was like natural. -I felt that the AI I had interactions with was conscious like human beings.	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Kim et al., (2019a)
	-Fake –> natural -Machinelike –> humanlike -Unconscious –> conscious -Artificial –> lifelike -Moving rigidly –> moving elegantly	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Banks (2019)
	-Fake –> natural -Machinelike –> humanlike -Unconscious –> conscious -Artificial –> lifelike	Semantic differential scale	Whang and Im (2021)
	-How intelligent did he/she seem? -How responsive did he/she seem? -How sophisticated did he/she seem? -How superficial (lacking depth) did he/she seem? -To what extend did he/she seem to have a mind of his/her own?	7-point Likert scale (1 = not at all, 7 = extremely)	Schroeder and Schroeder (2018)
	Through three subdimensions *Animacy* -Dead–> alive -Stagnant –> lively -Mechanical –> organic -Artificial –> lifelike -Inert –> interactive -Apathetic- > responsive *Perceived sociability* -I feel the voice assistant understands me. -I think the voice assistant is nice. -I consider the voice assistant a pleasant conversational partner. -I find the voice assistant pleasant to interact with. *Humanlike fit* -Dissimilar/similar -Inconsistent/consistent -Atypical/ typical -Unrepresentative/representative -Not complementary/complementary -Low fit/high fit -Does not make sense/ makes sense	5-point semantic differential scale for animacy 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) for perceived sociability 7-point semantic differential scale for humanlike fit	Wagner et al. (2019)
	-The personal intelligent agent is able to speak like a human. -The personal intelligent agent can be happy. -The personal intelligent agent can be friendly. -The personal intelligent agent can be respectful. -The personal intelligent agent can be funny. -The personal intelligent agent can be caring.	7-point scale	Moussawi and Koufaris (2019), Moussawi and Benbunan-Fich (2021), and Moussawi et al. (2021)
	-I experienced human warmth with a voice assistant. -I felt there was human contact with a voice assistant. -I experience sociability on this voice assistant. -I felt there was sensitivity on this voice assistant.	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Moriuchi (2021)

Table 3 (continued)

Technology	Items or experimental design	Scale	Reference
Social robots	Anthropomorphism was manipulated using different experimental conditions (i.e., high/middle/low/no anthropomorphic conditions).	Anthropomorphism was measured as a dummy variable.	Kim et al., (2019b)
	Anthropomorphism was manipulated using different experimental conditions (i.e., high/middle/low anthropomorphic conditions).	Anthropomorphism was measured as a perception.	Shin and Jeong (2020)
	-AI devices have a mind of their own. -AI devices have consciousness. -AI devices have their own free will. -AI devices will experience emotions.	5-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Lin et al. (2020)
	-Artificially intelligent devices such as robots will have a mind of their own. -Artificially intelligent devices such as robots will have consciousness. -Artificially intelligent devices as robots will have their own free will. -Artificially intelligent devices such as robots will experience emotions. -Artificially intelligent devices such as robots will have intentions. -I personally feel artificially intelligent devices such as robots are inanimate/living. -I personally feel artificially intelligent devices such as robots are computer animated/real.	Not mentioned	Gursoy et al. (2019)
	-This robot feels like a person. -I think about this robot as a person. -This robot has its own personality. -This robot has its own intention.	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Choi et al. (2019)
	-Robots experience emotions. -Robots have free will. -Robots are conscious. -Robots are efficient.	5-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Sinha et al. (2020)
	-The appearance of a serving robot is similar to that of a human being. -A serving robot looks similar to a human. -Serving robots seem to have the ability to perceive and judge like human beings. -Serving robots look natural. -Serving robots move gracefully like human beings.	5-point Likert scale (1 = highly disagree, 5 = highly agree)	Jang and Lee (2020)
	-All items are same as Banks (2019)	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Qiu et al. (2020)
	-All items are same as Go and Sundar (2019)	Not mentioned	Shin and Jeong (2020)
AI-based systems for specific purposes (i.e., job recommendation, travel planning recommendation, financial planning, detecting traffic violations, playing the board game, and curating trip destination reviews)	Anthropomorphism was manipulated using different experimental conditions (i.e., an anthropomorphic condition/a non-anthropomorphic condition).	Anthropomorphism was measured as a dummy variable	Ochmann et al. (2020)
	Anthropomorphism was manipulated using different experimental conditions (i.e., an anthropomorphic condition/a non-anthropomorphic condition).	Anthropomorphism was measured as a perception.	Mesbah et al. (2019)
	Individual differences in anthropomorphism questionnaire (IDAQ)	7-point Likert scale	Martin et al. (2020)
	-All items are same as Lin et al. (2020)	5-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Shi et al. (2021)
	-How natural do you think the system is? -How humanlike do you think the system is? -How conscious do you think the system is? -How lifelike do you think the system is?	5-point Likert scale (1 = not at all, 5 = very much)	Ha et al. (2020)
	-If the robo-advisor would enter into a dialogue with me like a human being, my trust would increase. -If the robo-advisor would have a visual appearance, such as a figure, then my trust would increase.	7-point Likert scale (1 = strongly disagree, 7 = strongly agree)	Mesbah et al. (2019)

Table 3 (continued)

Technology	Items or experimental design	Scale	Reference
Autonomous vehicles	-How smart does this car seem? -How well do you think this car could feel what is happening around it? -How well do you think this car could anticipate what is about to happen, before it actually happens? -How well do you think this car could plan the best route available?	10-point Likert scale (1 = not at all, 10 = very much) used by Waytz et al. (2014) 7-point Likert scale (1 = strongly disagree, 7 = strongly agree) used by Bruckes et al. (2019)	Waytz et al. (2014) and Bruckes et al. (2019)
	-Humanlike -Natural -Conscious -Moving elegantly	Not mentioned	Lee et al. (2015)
	-The car is smart. -The car can feel what is happening around the car. -The car can anticipate what is about to happen. -The car decides about its action. -The car has intention. -The car has a mind of its own. -The car experiences emotion.	7-point Likert scale (1 = not at all, 7 = very much)	Niu et al. (2018)
Others	-All items are same as Lin et al. (2020)	5-point Likert scale (1 = strongly disagree, 5 = strongly agree)	Gursoy et al. (2019) and Chi et al. (2022)

website (Whang & Im, 2021). In addition, *relationship type* (e.g., *a friend or a servant*), *communication performance* (i.e., *interpreting human utterances and responding to humans with or without errors*), *perceived intelligence of AIET*, *perceived usage experience with AIET*, *and perceived social presence* promoted anthropomorphism. Table 4 summarizes the antecedents of anthropomorphism among the identified papers. Interestingly, few of these studies focused on the effects of moderating variables on the relationship between anthropomorphism and its antecedents. Only one study examined the moderating role of participants' age and AIET usage frequency on the relationship between AIET's anthropomorphic cues and anthropomorphism (Diederich, Lichtenberg, et al., 2019b).

Consequences of anthropomorphism

This review found that anthropomorphism leads to several consequences, which can be categorized into three groups: (1) overall appraisal, (2) intention, and (3) behavior.

Overall appraisal First, the literature analysis showed that anthropomorphism plays a driver/an inhibitor/no role in determining individuals' *perceptions*. For example, a greater anthropomorphism in the AIET context results in a greater degree of trust (e.g., Waytz et al., 2014), warmth (Kim, Cho, et al., 2019a), intelligence of AIET (Sah, 2021), and social presence (Ischen et al., 2020). However, findings were inconsistent regarding the effects of anthropomorphism on trust and social presence. For example, Moussawi et al. (2021) found that anthropomorphism does not significantly influence trust. Schroeder and Schroeder (2018) explained that individuals might feel threatened by AIET with a high level of intelligence, thus explaining why anthropomorphism is unlikely to always result in trust. It was also found that anthropomorphism does not always lead to social presence (e.g., Go & Sundar, 2019; Toader et al., 2020). One possible explanation is that the anthropomorphic features of AIET do not achieve a threshold of humanness, leading to AIET being machinelike and further inhibiting social presence. Second, findings differed on the effects of anthropomorphism on *attitudes*. That is, anthropomorphism plays a positive role in attitudes toward the advice provided by AIET (Martin et al., 2020), but it plays a positive (Shin & Jeong, 2020) or negative role (Kim et al., 2019b) in attitudes toward AIET itself. Kim et al., (2019b) explained that anthropomorphism increases the uncanniness from the perceived warmth, and further decreases individuals' attitudes toward AIET. Third, anthropomorphism showed no effect on *satisfaction* with AIET's recommendations (Pizzi et al., 2021), but the *evaluations* of such recommendations can be enhanced by developing parasocial relationships with AIET (Whang & Im, 2021). Fourth, anthropomorphism promoted the development of *human–AIET relationship*, such as rapport building (Qiu et al., 2020) and emotional closeness (Lee et al., 2020). Fifth, anthropomorphism positively influenced positive *emotions*, that is enjoyment (e.g., Sah, 2021), pleasure (Kim et al., 2019a), and liking of AIET (e.g., Niu et al., 2018). In addition, anthropomorphism facilitated individuals' *engagement* with (e.g., Moriuchi, 2021) and *motivations* of interacting with AIET (Lembcke et al., 2020). Tables 5 and 6 show the direct and indirect effects of anthropomorphism, respectively.

Intention First, this literature analysis indicated that anthropomorphism is an important factor influencing *AIET acceptance/adoption intention* for individuals who had no direct experience with such technology. Most studies identified a positive association between anthropomorphism and acceptance/adoption intention (e.g., Sheehan et al., 2020; Sinha

et al., 2020), although others demonstrated a negative association (Lu et al., 2019). Lu et al. (2019) explained that using a human appearance in social robots could increase individuals' discomfort due to the deterrence of perceived threats to human identity, and thus anthropomorphism decreases individuals' acceptance/adoption intention. Moreover, anthropomorphism was suggested to affect AIET acceptance/adoption intention via various mechanisms, such as technophobia (Sinha et al., 2020), effort expectancy (e.g., Gursoy et al., 2019), and trust (e.g., Bruckes et al., 2019). Second, anthropomorphism can positively and directly affect *AIET continued intention* (e.g., Lee et al., 2020) or indirectly through different factors, such as the likeability of AIET (Wagner et al., 2019) and enjoyment (Moussawi et al., 2021). Among the identified studies, the continued intention of AIET focuses on individuals with direct experience with AIET. In addition, anthropomorphism positively affects *acceptance intention of AIET's recommendations* (Ochmann et al., 2020), *intention to follow AIET's advice* (Morana et al., 2020), *intention to purchase* (Yen & Chiang, 2021) *or revisit* (Jang & Lee, 2020) *triggered by AIET*, and *willingness to spend more time with AIET* (Qiu et al., 2020). Finally, our review showed that moderating variables have been sparingly investigated in the relationship between anthropomorphism and its consequences in the AIET context. Only Sheehan et al. (2020) reported that the need for human interaction moderates the relationship between anthropomorphism and adoption intention.

Behavior Our analysis showed that the impact of anthropomorphism on individuals' behavior has been largely overlooked among the reviewed papers. Only three studies explored the role of anthropomorphism in behavior, specifically its positive role in individuals' *active responses to AIET's requests* (Adam et al., 2021) and *AIET continued usage behavior* (Moriuchi, 2021; Pillai & Sivathanu, 2020).

Discussion

To synthesize and consolidate the existing knowledge on anthropomorphism in the AIET context, we reviewed the current state of research, particularly on how this phenomenon has been defined and measured. Our analysis confirmed that, as yet, no definition of anthropomorphism is universally accepted and the approaches vary regarding its measurement. Many of the reviewed papers offered no AIET-specific conceptualization or definition of anthropomorphism. Those that did, however, commonly defined anthropomorphism as a tendency, and then as a technological stimulus perspective and as a perception (see Table 2). Our analysis also revealed that most of the studies fail to align the conceptualization and operationalization of anthropomorphism. For example, studies that conceptualize anthropomorphism as a tendency or as a technological stimulus use the basis of users' perceptions of AIET as humanlike. This misalignment between conceptualization and operationalization has produced inconsistent and fragmented findings that ultimately preclude further progress in understanding anthropomorphism in the AIET context.

Therefore, we contend that anthropomorphism needs a precise definition in the AIET context before it can be properly operationalized. Specifically, our analysis indicates in this context, anthropomorphism should be defined either (1) from a subjective perspective as the extent to which an individual perceives AIET to be humanlike or (2) from an objective perspective as a technological stimulus. When conceptualizing anthropomorphism as a tendency, researchers should confine their attention to measuring the individual's tendency to anthropomorphize in the given context rather than their general perception of AIET.

In the following sections, we discussed AIET-specific aspects of anthropomorphism and identified research gaps that invite future research. By consolidating existing literature of anthropomorphism and its associated factors, we developed a framework for exploring the antecedents and consequences of anthropomorphism in the AIET context.

Recommendations for future research

Elaborating on the operationalization of anthropomorphism

In this literature analysis, anthropomorphism was shown to have different measures among all the identified studies. As indicated in Table 3, many studies broadly measured anthropomorphism (e.g., by using participants' ratings of fake/natural, or machinelike/humanlike features to capture individuals' overall perceptions of AIET) or mainly focused on measuring how individuals perceive its psychological (e.g., personality and mental states) aspect. The latter has received attention because an increasing number of psychological features, such as autonomy (Lee et al., 2015), politeness and emotions (Diederich, Lichtenberg, et al., 2019b), humor, friendliness, and empathy (Wagner & Schramm-Klein, 2019), are being incorporated into AIET with recent advancements in AI capabilities. However, in addition to the psychological aspect, visual and verbal aspects of anthropomorphism have received considerable attention in previous studies, particularly in the fields of psychology and HCI, although AI capabilities (e.g., natural language processing, natural language understanding) are still in their early stages (Pfeuffer et al., 2019). Given that these psychological, visual, and verbal aspects of anthropomorphism are essential for understanding its concept from different perspectives, we suggest the following:

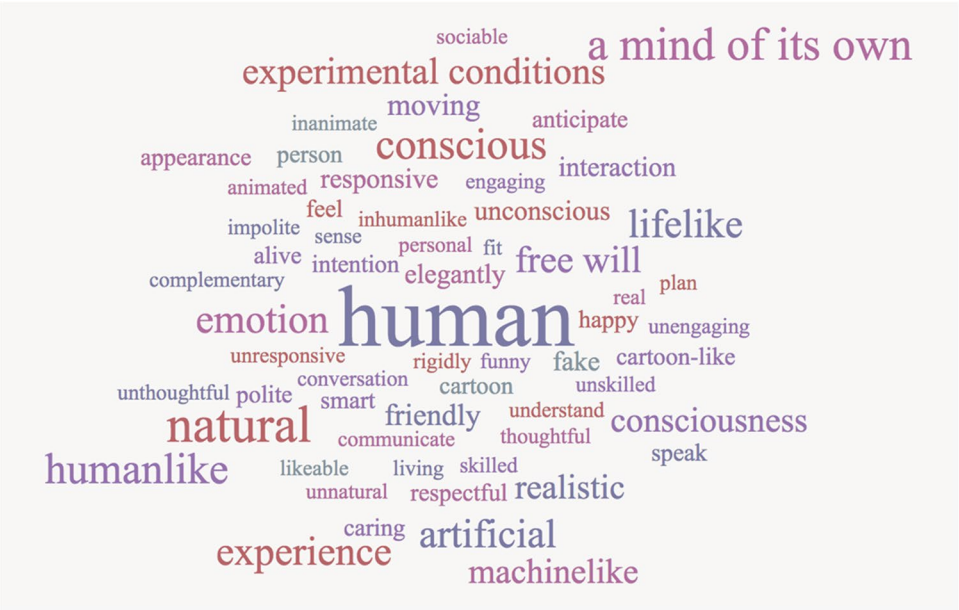

Fig. 4 Word cloud of measurements

Recommendation 1 Future studies can consider to separately or jointly measure the psychological, visual, and verbal aspects of anthropomorphism.

Recommendation 2 In conceptualizing anthropomorphism as a technological stimulus, researchers should operationalize it considering not only the psychological features of AIET but also the visual and verbal features to specifically understand anthropomorphism and its consequences in the AIET context.

While mainly considered as unidimensional, anthropomorphism was considered multidimensional by three of the reviewed papers. Wagner and Schramm-Klein (2019) suggested that anthropomorphism may be superficial as a unidimensional construct, whereas a multidimensional construct could better capture the meaning of anthropomorphism in the AIET context because it entails a closer and more detailed consideration. Similarly, Złotowski et al. (2014) argued that anthropomorphism could better explain the uncanny valley phenomenon as a multidimensional construct. Thus, we suggest the following:

Recommendation 3 Researchers may benefit from developing a multidimensional scale to advance the understanding of anthropomorphism in the AIET context. For example, visual, verbal, and psychological aspects may be considered three dimensions of anthropomorphism.

Furthermore, the key terms (i.e., human or humanlike characteristics) associated with anthropomorphism were differently defined or undefined regarding the types of AIET. Given this uncertainty in the conceptualization of anthropomorphism, the consensus on its measurement is minimal. Thus, we suggest the following:

Recommendation 4 To enable future studies to more accurately facilitate anthropomorphism measurements and understand its effects on the overall appraisal, intention, and behavior, researchers should develop a precise definition by focusing on its specific aspects (e.g., personality and mental states) or by clarifying its subdimensions (e.g., visual, verbal, and psychological).

Identifying the antecedents of anthropomorphism

The literature analysis demonstrates that despite being antecedents of anthropomorphism, technological factors have not received equal attention. For instance, many studies focus on anthropomorphic cues but few explore perceived intelligence and communication performance. Thus, we suggest the following:

Recommendation 5 Future research should explore technological factors in depth and breadth. For example, this review shows that recent studies on perceived intelligence focus only on individuals' perceptions of AIET's functional intelligence (Moussawi et al., 2021; Moussawi & Benbunan-Fich, 2021; Moussawi & Koufaris, 2019). Therefore, with regard to depth, future research should explore separately or jointly how individuals' perceptions of AIET's functional, emotional, and social intelligence influence anthropomorphism. With regard to breadth, researchers should qualitatively explore the factors that lead to anthropomorphism in the AIET context and then quantitatively investigate these possible antecedents of anthropomorphism. For example, the qualitative work of Kuzminykh et al. (2020) indicated that in addition to perceived intelligence, AIET's social approachability, projected sentiment toward the user, professionalism,

Table 4 Antecedents of anthropomorphism

Constructs	AIET type	Reference
Technological factors		
1. AIET's anthropomorphic cues		
Identity cues		
- Appearance	Chatbots, social robots, or autonomous vehicles	Lee et al. (2015), Go and Sundar (2019), Diederich et al., (2019b), Diederich et al., (2019a), Toader et al. (2020), Morana et al. (2020), and Shin and Jeong (2020)
- Eyes	Autonomous vehicles	Niu et al. (2018)
- Voice	Voice assistants or autonomous vehicles	Waytz et al. (2014), Schroeder and Schroeder (2018), Moussawi and Benbunan-Fich (2021), and Ha et al. (2021)
- Gender	Chatbots or autonomous vehicles	Waytz et al. (2014), Diederich et al.. (2019b), and Diederich et al., (2019a)
- Name	Chatbots or autonomous vehicles	Waytz et al. (2014), Araujo (2018), Diederich et al., (2019b), Diederich et al.. (2019a), Toader et al. (2020), and Morana et al. (2020)
Conversation-related cues		
- Response time	Chatbots	Diederich et al., (2019b), Diederich et al., (2019a), Toader et al. (2020), and Morana et al. (2020)
- Tying indicator	Chatbots	Diederich et al., (2019b), Diederich et al., (2019a), Toader et al. (2020), and Morana et al. (2020)
- Dialogue	Chatbots	Araujo (2018)
- Informal language	Chatbots	Araujo (2018)
- Self-reference	Chatbots	Diederich et al., (2019b), Diederich et al., (2019a), and Morana et al. (2020)
- Self-disclosure	Chatbots	Diederich et al., (2019b) and Diederich et al., (2019a)
- Response variety	Chatbots	Diederich et al., (2019b), Diederich et al., (2019a), and Schuetzler et al. (2020)
- Personal introduction	Chatbots	Diederich et al., (2019b) and Diederich et al., (2019a)
- Greeting	Chatbots	Diederich et al., (2019b), Diederich et al., (2019a), and Morana et al. (2020)
- Farewell	Chatbots	Morana et al. (2020)
- Actively talks to users	Voice assistants	Ha et al. (2021)
- Tailored responses	Chatbots	Schuetzler et al. (2020)
- Remember user's name	Chatbots	Morana et al. (2020)
Psychological cues		
- Autonomy	Autonomous vehicles	Lee et al. (2015)
- Emotions	Voice assistants	Ha et al. (2021)
- Politeness	Chatbots	Diederich et al., (2019b), Diederich et al., (2019a), and Morana et al. (2020)
- Humor	Voice assistants	Moussawi and Benbunan-Fich (2021)
2. AIET itself		
- Chatbots	Chatbots	Banks (2019) and Ischen et al. (2020)
- Voice assistants	Voice assistants	Banks (2019) and Whang and Im (2021)
- Social robots	Social robots	Choi et al. (2019)
3. Relationship type (i.e., *a friend or servant)*	Voice assistants	Kim et al., (2019a)
4. Communication performance	Chatbots	Sheehan et al. (2020)
5. Perceived intelligence of AIET	Voice assistants	Moussawi and Koufaris (2019), Moussawi et al. (2021), and Moussawi and Benbunan-Fich (2021)
6. Perceived usage experience with AIET	Voice assistants	Moriuchi (2021)
7. Perceived social presence	Chatbots	Schuetzler et al. (2020)

Notes: AIET's anthropomorphic cues, AIET itself, relationship type, and communication performance are objective constructs. Perceived intelligence of AIET, perceived usage experience with AIET, and perceived social presence are subjective constructs

and the specifics of AIET's individuality affect how individuals anthropomorphize AIET, while Oh et al. (2017)'s qualitative study showed that creativity is essential for anthropomorphizing AIET. Thus, we call for future quantitative research to further investigate how perceptions of its social or emotional distance, genuineness, professionalism, ordinariness, and creativity influence anthropomorphism in AIET.

Additionally, with the recent advancements in AI capabilities, several AIET, such as chatbots (Skjuve et al., 2021) and voice assistants (Ki et al., 2020), are similar to humans due to their emotional responses to individuals, who in turn are affected by the AIET's moods and emotions (Poushneh, 2021). Thus, we suggest the following:

Recommendation 6 Future research may identify how AIET's perceived emotions affect anthropomorphism.

Moreover, the antecedents of anthropomorphism are extensively examined in marketing, psychology, and human–robot interaction domains. For example, anthropomorphism can be determined on the basis of three psychological variables: elicited agent knowledge, effectance motivation, and sociality motivation (Epley et al., 2007). Therefore, we recommend the following:

Recommendation 7 To extend or replicate extant findings on the antecedents of anthropomorphism in the AIET context, existing constructs that promote anthropomorphism in non-AIET contexts can be applied to the AIET context.

Understanding the consequences of anthropomorphism

The analysis showed that anthropomorphism positively influences individuals' perceptions, attitudes, acceptance/adoption, and continued use of AIET. However, we also found that anthropomorphism plays an insignificant or negative role in shaping perceptions, attitudes, satisfaction, and acceptance/adoption of AIET. Although the role of anthropomorphism in the AIET context has received increasing attention, few studies explore how and why it exerts insignificant or negative effects. As such, we suggest the following:

Recommendation 8 A more in-depth investigation of the underlying mechanisms of anthropomorphism is a possible research opportunity. For example, according to our review, anthropomorphism does not always lead to trust. Most of the identified studies that examined the effects of anthropomorphism on trust viewed trust as a unidimensional construct. Given that an individual always thinks and feels trust (Komiak & Benbasat, 2004), applying the trust model proposed by Komiak and Benbasat (2004) may be beneficial in exploring how the subdimensions of anthropomorphism (e.g., visual, verbal, psychological) affect those of trust (i.e., cognitive and emotional trust). Moreover, examining whether these insignificant or negative effects are produced by anthropomorphic features embedded in AIET that are inappropriately combined or do not achieve a threshold of "human likeness" may be useful. Furthermore, investigating these effects from the perspectives of the uncanny valley, expectancy violations, mental model differences, and human identity may be beneficial.

In addition, our literature analysis indicated that in regard to AIET usage, research mainly examines the effects of anthropomorphism on individuals' acceptance/adoption of AIET, and neglects those on continuance intention to and continued use of AIET. However, considering these aspects is important to retain users, facilitate long-term development, advance AIET, and achieve sustainable business growth (e.g., voice commerce). Thus, we suggest the following:

Recommendation 9 Future studies can explore the effects of anthropomorphism on individuals' continued intention to and continued use of AIET.

Moreover, our review showed an increasing attention on understanding how anthropomorphism leads to the development of the human-AIET relationship, such as rapport building (Qiu et al., 2020), intimacy (Sah, 2021), emotional closeness (Lee et al., 2020), and a parasocial relationship (Whang & Im, 2021). Given that such relationships may affect individuals' affective and social processes alongside well-being (Skjuve et al., 2021), we suggest the following:

Recommendation 10 Researchers can investigate how anthropomorphism affects the human–AIET relationship in different usage stages (e.g., exposure, acceptance/adoption, continued use, discontinued use).

Meanwhile, AIET is predicted to be applicable in different life domains (e.g., personal/familial, work, health, social) (GrandViewResearch, 2020; Maedche et al., 2019). Hence, we suggest the following:

Recommendation 11 Future research can examine whether the relationships between anthropomorphism and its consequences (e.g., perceptions, attitudes, interaction quality, psychological well-being) vary in different usage contexts (e.g., private versus workplace). For example, Maedche et al. (2019) suggested examining how anthropomorphism influences interaction quality between individuals and AIET at home and at work.

Reconsidering research methods for capturing anthropomorphism

Based on our literature analysis, experiment and survey methods were the most popular research techniques used

Table 5 The direct effect of anthropomorphism

Category	Factor	Hypothesis	Reference
Overall appraisal of AIET	Perceptions of AIET	Anthropomorphism→trust in AIET*	Waytz et al. (2014), Niu et al. (2018), Schroeder and Schroeder (2018), and Mesbah et al. (2019)
		Anthropomorphism→trust in AIET#	Toader et al. (2020) and Moussawi et al. (2021)
		Anthropomorphism→warmth of AIET*	Kim et al., (2019a)
		Anthropomorphism→privacy concerns*	Ha et al. (2021)
		Anthropomorphism→morality*/dependency*	Banks (2019)
		Anthropomorphism→humanness*/social attraction*	Sah (2021)
		Anthropomorphism→perceived persuasiveness of AIET*	Diederich, Lichtenberg, et al. (2019b)
		Anthropomorphism→intelligence*	Qiu et al. (2020) and Sah (2021)
		Anthropomorphism→competence#	Toader et al. (2020) and Kim et al., (2019b)
		Anthropomorphism→social presence*	Ischen et al. (2020)
		Anthropomorphism→social presence#	Go and Sundar (2019), Toader et al. (2020), and Wambsganss et al. (2020)
		Anthropomorphism→perceived homophily#	Go and Sundar (2019)
		Anthropomorphism→perceived risk#	Jang and Lee (2020)
	Perceptions of AIET's recommendations	Anthropomorphism→perceived reactance to AIET recommendations*	Pizzi et al. (2021)
	Attitudes towards AIET's advice	Anthropomorphism→attitudes towards a trip advice provided by AIET*	Martin et al. (2020)
	Satisfaction with AIET's recommendations	Anthropomorphism→choice satisfaction with a product recommended by AIET#	Pizzi et al. (2021)
	Human-AIET relationship	Anthropomorphism→customer-robot rapport building*	Qiu et al. (2020)
		Anthropomorphism→intimacy towards AIET*	Sah (2021)
		Anthropomorphism→parasocial relationship*	Whang and Im (2021)
		Anthropomorphism→emotional closeness*	Lee et al. (2020)
	Emotions	Anthropomorphism→enjoyment*	Sah (2021) and Moussawi et al. (2021)
		Anthropomorphism→pleasure*	Kim et al., (2019a)
		Anthropomorphism→liking of AIET*	Niu et al. (2018) and Wagner et al. (2019)
	Engagement	Anthropomorphism→ involvement*	Sah (2021)
		Anthropomorphism→engagement*	Moriuchi (2021)
Intention	AIET acceptance/adoption intention	Anthropomorphism→willingness to use*	Gursoy et al. (2019)
		Anthropomorphism→acceptance intention*	Sinha et al. (2020)
		Anthropomorphism→adoption intention*	Sheehan et al. (2020)
		Anthropomorphism→usage intention*	Melián-González et al. (2021)
	AIET continued intention	Anthropomorphism→intention to use*	Lee et al. (2020)
		Anthropomorphism→usage intention*	Melián-González et al. (2021)
	Intended time spent with AIET	Anthropomorphism→willingness to spend more time with AIET*	Qiu et al. (2020)
	Acceptance intention of AIET's recommendations	Anthropomorphism→acceptance intention of AIET's recommendations*	Ochmann et al. (2020)
Behavior	Active responses to AIET's requests	Anthropomorphism→user compliance with AIET's request for service feedback*	Adam et al. (2021)

Notes: *Significant effect; #Insignificant effect; Hypothesized as negatively related

in the identified studies. Other approaches, such as qualitative (e.g., interviews, case studies), mixed, and computational research methods, were less frequently adopted. Given that qualitative methods can offer a rich and detailed understanding of anthropomorphism in the AIET context, mixed methods can be used to collect different types of data (e.g., subjective versus objective) to present various aspects of anthropomorphism. Meanwhile, computational methods (e.g., user log analytics, text mining, network analysis) can be used to recognize the novel antecedents and consequences of anthropomorphism. Thus, we suggest the following:

Recommendation 12 Future studies can diversify research methods to understand anthropomorphism in the AIET context and explore its antecedents and consequences from multiple perspectives.

Table 6 The indirect effect of anthropomorphism

Category	Factor	Hypothesis	Reference
Overall appraisal of AIET	Perceptions of AIET	Anthropomorphism→social presence* → intelligence*/safety*/cognitive trust*/affective trust*	Lee et al. (2015)
		Anthropomorphism→humanness* → perceived inclusiveness of AIET* Anthropomorphism→social presence* → perceived inclusiveness of AIET*	Lembcke et al. (2020)
	Attitudes towards AIET	Anthropomorphism→warmth of AIET* → uncanniness* → attitudes toward AIET*	Kim et al., (2019b)
	Motivations of interacting with AIET	Anthropomorphism→humanness*/social presence* → need supportive environment* → need satisfaction* → intrinsic motivation*/introjected regulation#/external regulation#/amotivation* of interacting with AIET	Lembcke et al. (2020)
	Evaluations of AIET's recommendations	Anthropomorphism→parasocial relationship* → evaluations of a product that is recommended by AIET*	Whang and Im (2021)
Intention	AIET acceptance/adoption intention	Anthropomorphism→performance expectancy# → positive emotion* → willingness to use*/objection of using* Anthropomorphism→effort expectancy* → positive emotion* → willingness to use */objection of using*	Lin et al. (2020)
		Anthropomorphism→performance expectancy# → emotion* → willingness to use*/objection of using* Anthropomorphism→effort expectancy* → emotion* → willingness to use*/objection of using*	Gursoy et al. (2019) and Chi et al. (2022)
		Anthropomorphism→technophobia* → acceptance intention*	Sinha et al. (2020)
		Anthropomorphism→emotion-based trust* → intention to use*	Moussawi and Benbunan-Fich (2021)
		Anthropomorphism→emotional trust* → intention to adopt as a decision aid*/intention to adopt as a delegated agent* Anthropomorphism→emotional trust* → cognitive trust* → intention to adopt as a decision aid*/ intention to adopt as a delegated agent#	Shi et al. (2021)
		Anthropomorphism→trust in AIET* → intention to use* Anthropomorphism→trust in AIET* → usefulness* → intention to use*	Bruckes et al. (2019)
		Anthropomorphism→attitudes toward AIET* → adoption intention*	Shin and Jeong (2020)
	AIET continued intention	Anthropomorphism→likeability of AIET* → behavioral intention*	Wagner et al. (2019)
		Anthropomorphism→emotional closeness* → intention to use* Anthropomorphism→co-presence* → intention to use#	Lee et al. (2020)
		Anthropomorphism→enjoyment* → adoption intention*	Moussawi et al. (2021)
		Anthropomorphism→disconfirmation of expectations* → usefulness*/satisfaction with use* → continuance intention*	Moussawi and Koufaris (2019)
	Intention to follow AIET's advice	Anthropomorphism→social presence* → likeliness to follow advice provided by AIET # Anthropomorphism→social presence* → trusting beliefs* → likeliness to follow advice provided by AIET*	Morana et al. (2020)
	Purchase/revisit intention trigger by AIET	Anthropomorphism→trust in AIET* → trust in seller* → purchase intention triggered by AIET*	Yen and Chiang (2021)
		Anthropomorphism→perceived benefits* → perceived value* → satisfaction* → revisit intention to a robot restaurant*	Jang and Lee (2020)

Table 6 (continued)

Category	Factor	Hypothesis	Reference
Behavior	AIET continued use	Anthropomorphism→adoption intention* → actual use of AIET*	Pillai and Sivathanu (2020)
		Anthropomorphism→engagement* → reuse intention* → actual use of AIET*	Moriuchi (2021)
	Active responses to AIET's requests	Anthropomorphism→social presence* → user compliance with AIET's request for service feedback*	Adam et al. (2021)

Notes: *Significant effect; #Insignificant effect; Hypothesized as negatively related

Exploring anthropomorphism in various AIET contexts

In our review, chatbots and social robots were primarily used for customer service, which can be categorized as utilitarian AIET providing utilitarian value to individuals. However, hedonic AIET, such as companion chatbots (e.g., XiaoIce, Replika) and companion robots (e.g., Buddy), that primarily provides hedonic and social value to individuals has been largely ignored in prior studies. Given the increasing popularity of hedonic and multipurpose AIET, we suggest the following:

Recommendation 13 Future studies can compare how anthropomorphism influences individuals' interactions and use of utilitarian, hedonic, and multipurpose AIET.

In addition, given the importance of anthropomorphism in AIET and the rapid tremendous advancements in AI capabilities, AIET designers can benefit in rethinking and adjusting the level of anthropomorphism according to people's reactions, feedback, and acceptance of new AIET types and the most recent AI-related anthropomorphic features in a platform before launching such technologies. Therefore, we suggest the following:

Recommendation 14 Future research can examine anthropomorphism in new AIET types and the most recent AI-related anthropomorphic features in a platform. For example, Ameca is a humanoid robot platform (Engineered-Arts, 2021) that can show what appears to be the most humanlike facial expressions in a robot to date (Yirka, 2021).

Framework development

Although previous studies have explored the antecedents and consequences of anthropomorphism in the AIET context, no framework synthesizes the current findings. On the basis of our literature review, we developed a conceptual framework to explore the interplay between anthropomorphism and its antecedents and consequences. Our approach builds on the work of Olanrewaju et al. (2020) and Suh and Cheung (2019) that center on the core construct of an IT phenomenon and link it with its antecedents and consequences. Identifying antecedents and consequences of a research construct contributes to theory development by building a nomological network to verify the utility of the new construct in a given context (Zhang & Venkatesh, 2017). Based on our review, we consolidated several technological factors as key antecedents of anthropomorphism: anthropomorphic cues, AIET itself, relationship type, communication performance, perceived AIET intelligence, perceived AIET usage experience, and perceived social presence. The framework suggests that the more these technological features resemble human appearance, behavior, and psychology, the more likely users are to attribute human characteristics to that technology. Table 4 lists the technological factors identified as antecedents of anthropomorphism and the relevant AIET type.

As Rzepka and Berger (2018) suggest, the perceived humanness of AIET also depends on individual and environmental factors, and the framework includes these factors as antecedents of anthropomorphism. While most previous empirical studies investigated the effects of technological factors on anthropomorphism in the AIET context, few of these considered the individual and environmental factors. For our present purposes, we identified user, social, task, and contextual characteristics that may induce anthropomorphism and categorized them as individual or environmental factors. Individual factors included competence to complete a task successfully (Blut et al., 2021), demographic characteristics (Blut et al., 2021), and personality traits (Rzepka & Berger, 2018); environmental factors included social influence (Lin et al., 2020), task characteristics (Whang & Im, 2021), and AIET's application contexts (Rzepka & Berger, 2018). By incorporating technological, individual, and environmental factors, we believe that our framework provides a more comprehensive view of the relationships between anthropomorphism and associated factors. In Fig. 5, the white legends refer to the factors explored in previous empirical studies, while the gray legends refer to the factors identified by the authors as potential antecedents of anthropomorphism.

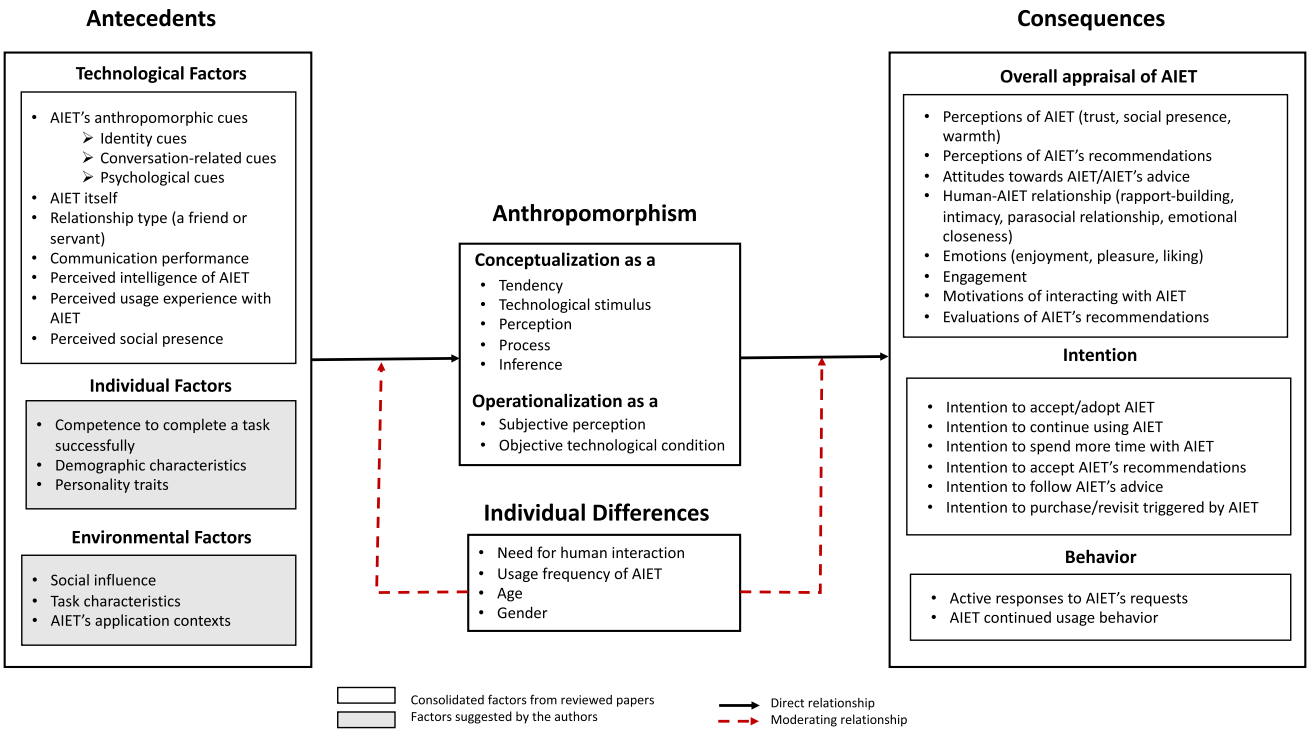

Fig. 5 Framework for anthropomorphism in the AIET context

Based on our analysis of the direct and indirect effects of anthropomorphism, its consequences were classified into three groups: overall appraisal of AIET, intention, and behavior (see Tables 5 and 6). According to our framework, anthropomorphism has a significant influence on individual perceptions, attitudes, emotions, motivations, intentions, and behaviors in the AIET context. The framework also reveals that the relationships between anthropomorphism and its associated factors (i.e., antecedents and consequences) may be shaped by individual differences such as gender, age, need for human interaction, and usage frequency of AIET. The framework suggests that researchers should consider the moderating effects of individual differences on the relationship between anthropomorphism and associated factors when developing a nomological network. In Fig. 5, the moderating effects of individual differences are depicted by dotted lines.

Theoretical implications

This study presents several important theoretical implications. First, it contributes to the existing literature by analyzing research trends, contexts, methods, and theories related to anthropomorphism in the AIET context. In providing an overview of the current state of such research, we identify the relevant theoretical and methodological approaches. Second, the present study contributes to theory development by analyzing how anthropomorphism is conceptualized and operationalized in different AIET contexts. Despite the increasing academic interest in anthropomorphism as a result of advances in AIET, no coherent theoretical explanation has been provided regarding its role in AIET adoption and post-adoption behavior, and findings remain inconsistent and fragmented. By highlighting the misalignment between such conceptualization and operationalization, our analysis offers a basis for future theory development. Additionally, by identifying research gaps in the existing literature, we present directions for future empirical research to clarify and explain the phenomena associated with anthropomorphism in the AIET context. Finally, the proposed conceptual framework contributes to theory development regarding anthropomorphism in the use of technology by providing a comprehensive overview of the interplay between anthropomorphism and its antecedents and consequences. Specifically, our framework indicates what is already known by showing a list of factors associated with anthropomorphism in the AIET context that have received scholarly attention, while our framework suggests a list of the factors that require additional investigation in future studies. In doing so, our framework reports the empirically validated relationship in the existing research and serves as a foundation

to indicate future research opportunities about anthropomorphism in the AIET context. Researchers can deploy the proposed framework to develop, extend, and modify research models for exploring anthropomorphism in the AIET context.

Practical implications

The literature review also has several practical implications for developers in relation to the role of anthropomorphism in AIET use. Notably, regarding the effects of anthropomorphism on acceptance/adoption and continued use, our findings indicate that such effects are not always positive. To increase acceptance/adoption, AIET developers should identify and rectify any conditions under which anthropomorphism may negatively affect acceptance/adoption, taking account of the visual, verbal, and psychological aspects of anthropomorphic design that most people find acceptable. For instance, an appropriate design of the AIET's appearance, facial expressions, and intelligence may help to mitigate user discomfort. Based on the uncanny valley theory, we suggest that AIET developers should identify an optimal ratio of human-likeness to machine-likeness by conducting user studies in person or online, utilizing the most recent AI-related humanoid platform (e.g., Ameca). An appropriate level of human-likeness can promote positive emotional responses to AIET (e.g., liking, intimacy), while that of machine-likeness can mitigate any feelings of discomfort, threat, and eeriness caused by excessive human-likeness. As our analysis demonstrated that anthropomorphism plays a positive role in the individual's continued use of AIET, constant training and development of AI capabilities can ensure appropriate humanlike AIET-to-user interaction, which is also critical for companies to maintain consumer interest and continued use.

Limitations

This review showed certain limitations that require acknowledgement. First, given that a descriptive review shows state-of-the-art findings in a specific research domain, we focused on empirical studies and excluded conceptual work (Paré et al., 2015). Although we used inclusion and exclusion criteria to identify relevant studies, we may have missed some that did not meet our selection criteria, including conceptual studies, literature reviews, industrial reports, books, and magazines. To gain a broader understanding of anthropomorphism, future studies should conduct different kinds of literature reviews (e.g., narrative reviews, realist reviews) by incorporating both conceptual and empirical studies and address ethical and social issues related to anthropomorphism in the AIET context. Additionally, although our framework encompasses the antecedents and consequences of anthropomorphism in the AIET context based on the reviewed studies, anthropomorphic phenomena cannot be perfectly captured because only certain studies were reviewed in this emerging line of research. Future research could further enrich our conceptual framework.

Conclusion

Despite the growing interest in anthropomorphism in the AIET context, several key questions remain to be answered regarding the nature of anthropomorphism, its antecedents, and its consequences. Our study shows that the concept of anthropomorphism in the AIET context is interpreted in varied ways with different foci, mainly involving technological stimulus, tendency, and perception. By conducting a thematic analysis of the literature, we identified key issues in the AIET literature, including how to conceptualize anthropomorphism in a certain AIET context, how to measure it, and what the antecedents and consequences of anthropomorphism are. As potential ways to deal with these issues, we offered specific recommendations based on the gaps we identified in the extant literature. We hope that our findings and suggestions can contribute to a fuller understanding of anthropomorphism in the AIET context as a basis for future research. In the next steps, we call for more rigorous empirical studies that precisely align anthropomorphism's conceptualization and operationalization. Future research should move beyond the individual impacts of anthropomorphism shown in previous research to consider the economic, societal, environmental, and health impacts of anthropomorphism in the AIET context.

Appendix 1

Table 7 List of reviewed articles

No.	Reference	Title	AIET type	Method
1	Verhagen et al. (2014)	Virtual customer service agents: Using social presence and personalization to shape online service encounters	Chatbots	Experiment
2	Araujo (2018)	Living up to the chatbot hype: The influence of anthropomorphic design cues and communicative agency framing on conversational agent and company perceptions	Chatbots	Experiment
3	Go and Sundar (2019)	Humanizing chatbots: The effects of visual, identity and conversational cues on humanness perceptions	Chatbots	Experiment
4	Diederich, Lichtenberg, et al. (2019b)	Promoting sustainable mobility beliefs with persuasive and anthropomorphic design: Insights from an experiment with a conversational agent	Chatbots	Experiment
5	Diederich et al., (2019a)	Design for fast request fulfillment or natural interaction? Insights from an experiment with a conversational agent	Chatbots	Experiment
6	Sheehan et al. (2020)	Customer service chatbots: Anthropomorphism and adoption	Chatbots	Experiment
7	Lee et al. (2020)	Perceiving a mind in a chatbot: Effect of mind perception and social cues on co-presence, closeness, and intention to use	Chatbots	Experiment
8	Toader et al. (2020)	The effect of social presence and chatbot errors on trust	Chatbots	Experiment
9	Adam et al. (2021)	AI-based chatbots in customer service and their effects on user compliance	Chatbots	Experiment
10	Lembcke et al. (2020)	Supporting design thinking through creative and inclusive education facilitation: The case of anthropomorphic conversational agents for persona building	Chatbots	Experiment
11	Morana et al. (2020)	The effect of anthropomorphism on investment decision-making with robo-advisor chatbots	Chatbots	Experiment
12	Wambsganss et al. (2020)	Unleashing the potential of conversational agents for course evaluations: Empirical insights from a comparison with web surveys	Chatbots	Experiment
13	Pizzi et al. (2021)	Artificial intelligence and the new forms of interaction: Who has the control when interacting with a chatbot?	Chatbots	Experiment
14	Ischen et al. (2020)	"I am here to assist you today": The role of entity, interactivity and experiential perceptions in chatbot persuasion	Chatbots	Experiment

Table 7 (continued)

No.	Reference	Title	AIET type	Method
15	Schuetzler et al. (2020)	The impact of chatbot conversational skill on engagement and perceived humanness	Chatbots	Experiment
16	Melián-González et al. (2021)	Predicting the intentions to use chatbots for travel and tourism	Chatbots	Survey
17	Yen and Chiang (2021)	Trust me, if you can: A study on the factors that influence consumers' purchase intention triggered by chatbots based on brain image evidence and self-reported assessments	Chatbots	Survey
18	Pillai and Sivathanu (2020)	Adoption of AI-based chatbots for hospitality and tourism	Chatbots	Survey & interview
19	Schroeder and Schroeder (2018)	Trusting in machines: How mode of interaction affects willingness to share personal information with machines	Chatbots & voice assistants	Experiment
20	Banks (2019)	A perceived moral agency scale: Development and validation of a metric for humans and social machines	Chatbots & voice assistants	Experiment
21	Kim, Cho, et al. (2019a)	Effects of gender and relationship type on the response to artificial intelligence	Voice assistants	Experiment
22	Sah (2021)	Talking to a pedagogical agent in a smart TV: Modality matching effect in human-TV interaction	Voice assistants	Experiment
23	Moussawi and Benbunan-Fich (2021)	The effect of voice and humour on users' perceptions of personal intelligent agents	Voice assistants	Experiment
24	Ha et al. (2021)	Exploring the privacy concerns in using intelligent virtual assistants under perspectives of information sensitivity and anthropomorphism	Voice assistants	Experiment
25	Whang and Im (2021)	"I like your suggestion!" the role of humanlikeness and parasocial relationship on the website versus voice shopper's perception of recommendations	Voice assistants	Experiment
26	Wagner et al. (2019)	Is it human? The role of anthropomorphism as a driver for the successful acceptance of digital voice assistants	Voice assistants	Survey
27	Moussawi and Koufaris (2019)	Perceived intelligence and perceived anthropomorphism of personal intelligent agents: Scale development and validation	Voice assistants	Survey
28	Moussawi et al. (2021)	How perceptions of intelligence and anthropomorphismaffect adoption of personal intelligent agents	Voice assistants	Survey
29	Moriuchi (2021)	An empirical study on anthropomorphism and engagement with disembodied AIs and consumers' re-use behavior	Voice assistants	Survey
30	Wagner and Schramm-Klein (2019)	Alexa, are you human? Investigating the anthropomorphism of digital voice assistants -- a qualitative approach	Voice assistants	Interview

Table 7 (continued)

No.	Reference	Title	AIET type	Method
31	Rzepka et al. (2020)	Why another customer channel?Consumers' perceived benefits and costs of voice commerce	Voice assistants	Interview
32	Kuzminykh et al. (2020)	Genie in the bottle: Anthropomorphized perceptions of conversational agents	Voice assistants	Interview
33	Schweitzer et al. (2019)	Servant, friend or master? The relationships users build with voice-controlled smart devices	Voice assistants	Experiment & interview & survey
34	Kim, Schmitt, and Thalmann (2019b)	Eliza in the uncanny valley: Anthropomorphizing consumer robots increases their perceived warmth but decreases liking	Social robots	Experiment
35	Choi et al. (2019)	"How may i help you?" says a robot: Examining language styles in the service encounter	Social robots	Experiment
36	Shin and Jeong (2020)	Guests' perceptions of robot concierge and their adoption intentions	Social robots	Experiment
37	Lin et al. (2020)	Antecedents of customers' acceptance of artificially intelligent robotic device use in hospitality services	Social robots	Survey
38	Jang and Lee (2020)	Serving robots: Management and applications for restaurant business sustainability	Social robots	Survey
39	Yu (2020)	Humanlike robots as employees in the hotel industry: Thematic content analysis of online reviews	Social robots	Content analysis
40	Sinha et al. (2020)	Robotics at workplace: An integrated Twitter analytics – SEM based approach for behavioral intention to accept	Social robots	Survey & social network analysis
41	Lu et al. (2019)	Developing and validating a service robot integration willingness scale	Social robots	Survey & interview
42	Qiu et al. (2020)	Enhancing hospitality experience with service robots: The mediating role of rapport building	Social robots	Experiment & interview & survey
43	Oh et al. (2017)	Us vs. them: Understanding artificial intelligence technophobia over the Google DeepMind challenge match	AI-based systems for playing the board game	Interview
44	Mesbah et al. (2019)	Promoting trust in AI-based expert systems	AI-based systems for financial planning	Survey
45	Martin et al. (2020)	The influence of consumer anthropomorphism on attitudes towards artificial intelligence trip advisors	AI-based systems for curating trip destination reviews	Survey
46	Ha et al. (2020)	Examining the effects of power status of an explainable artificial intelligence system on users' perceptions	AI-based systems for detecting traffic violations	Experiment
47	Ochmann et al. (2020)	The influence of algorithm aversion and anthropomorphic agent design on the acceptance of AI-based job recommendations	AI-based systems for job recommendation	Experiment
48	Shi et al. (2021)	Antecedents of trust and adoption intention toward artificially intelligent recommendation systems in travel planning: A heuristic–systematic model	AI-based systems for travel planning recommendation	Experiment & focus group &survey

Table 7 (continued)

No.	Reference	Title	AIET type	Method
49	Waytz et al. (2014)	The mind in the machine: Anthropomorphism increases trust in an autonomous vehicle	Autonomous vehicles	Experiment
50	Lee et al. (2015)	Can autonomous vehicles be safe and trustworthy? Effects of appearance and autonomy of unmanned driving systems	Autonomous vehicles	Experiment
51	Niu et al. (2018)	Anthropomorphizing information to enhance trust in autonomous vehicles	Autonomous vehicles	Experiment
52	Bruckes et al. (2019)	Paving the way for adoption of autonomous driving: Institution-based trust as a critical success factor	Autonomous vehicles	Survey
53	Gursoy et al. (2019)	Consumers acceptance of artificially intelligent (AI) device use in service delivery	Others	Survey
54	Seeber et al. (2020)	Machines as teammates: A research agenda on AI in team collaboration	Others	Survey
55	Chi et al. (2022)	Tourists' attitudes toward the use of artificially intelligent (AI) devices in tourism service delivery: Moderating role of service value seeking	Others	Survey

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