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A literature review on anthropomorphism of robots

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Abstract. Anthropomorphism plays a pivotal role in robot design and human-robot interaction, significantly shaping user perceptions and behaviors. Despite a growing body of research, the current understanding of robot anthropomorphism remains fragmented, with limited differentiation across various concepts, research lenses, research methods, and theoretical contributions. This ambiguity hinders the effective design of anthropomorphic features that could enhance human-robot interactions and foster broader adoption of robots. To address these issues, this study conducted a systematic literature review, analyzing 431 previous studies to explore the conceptualization of robot anthropomorphism, along with design-oriented, user-oriented perspectives, and the relationships between the two dimensions. In so doing, this study contributes to the literature by offering a comprehensive understanding of how anthropomorphism has been studied in literature and proposing a research agenda to address unresolved challenges.
Keywords: Robot, Anthropomorphism, Literature Review.

1 Introduction

The use of robots, such as social robots, conversational agents, virtual advisors, and chatbots, has grown exponentially across various domains, such as business, education, and healthcare [1]. Despite their increasing adoption, significant challenges persist in meeting user expectations and fostering positive user experiences with these technologies [1]. To address these challenges, researchers from diverse disciplines have focused on robot design and human-robot interaction [2, 3]. Among these efforts, the concept of anthropomorphism of robots has emerged as a dominant and influential area of study. Prior research has examined robot anthropomorphism from various theoretical lenses, which can be broadly classified into two main perspectives: (1) the IS designed perspective, focusing on external features designed and incorporated into robots to evoke perceptions of human-like characteristics, such as humanlike appearance or motion [4], and (2) the user-oriented perspective, centering on user perceptions that a robot has human-like features from the human aspect, such as perceived anthropomorphism [5, 6]. While these research streams have offered rich insights, a key issue arises from the mixed use of these two concepts without a clear and explicit distinction between them. This lack of clarity has led to conceptual ambiguity and confusion. Additionally, different types of robots—ranging from virtual agents to physical humanoid robots—exhibit varying levels of anthropomorphic features,

producing diverse and sometimes contradictory outcomes, which complicates the field even further [2, 7]. The relationship between specific designed features and user perceptions of anthropomorphism remains unclear. These complexities underscore the need for a comprehensive literature review that synthesizes existing knowledge, addresses these concept ambiguities, and clarifies the roles of both designed features and perceived anthropomorphism in shaping user experiences.

To address the above gaps, this study conducts a systematic literature review on the anthropomorphism of robots. This study aims to offer a systematic synthesis of existing research, with the following objectives: (1) to explore the conceptualization of anthropomorphism in the literature; (2) to examine how anthropomorphism has been studied from the IS-designed perspective; (3) to investigate user perceptions of anthropomorphism in the literature; and (4) to analyze the relationships between the two dimensions of anthropomorphism.

The paper proceeds as follows. Then Section 2 describes the procedures applied in the literature search and identification. Section 3 provides a preliminary analysis of identified articles and an overview of the current state of research on the anthropomorphism of robots. Afterward, in Section 4, we proposed a future research agenda and concluded our contribution and limitations in Section 5.

2 Method

2.1 Literature search

This study adopts a systematic literature review approach [8, 9] to identify and review existing research concerning the anthropomorphism of robots. To search and identify relevant literature, we developed a protocol specifying the databases used, search terms, and screening criteria. The literature search was conducted in September 2024 across five major databases, including Web of Science, PsycInfo, AIS eLibary, ACM Digital Library, and Scopus. These databases were chosen for their well-established reputations and comprehensive indexing of multidisciplinary, peer-reviewed literature. We applied the following search query in the title, abstract, or keywords of articles: *((Robot OR agent OR *bot) AND (Anthropomorphi* OR humanlike* OR humanness OR human-like*).* No timeframe was applied to the search, and the publication language was restricted to English. The initial search yielded a total of 7444 results. After removing duplicates across different databases, 6359 articles remained for further selection.

2.2 Study screening and selection

The initial set of articles was imported into the reference management tool EndNote for systematic screening. To ensure the relevance and quality of the articles, we applied strict inclusion and exclusion criteria (see Table 1). Finally, a total of 431 articles were included in the literature review (see Figure 1).

2.3 Data extraction and analysis

We developed a data extraction table in Microsoft Excel to extract and analyze detailed information from the included studies. For each article, we extracted data on the following: research focus, theoretical background, applied context, research methods, robot type, anthropomorphism-related concepts, and main findings. A content analysis

[10] was conducted on that table, where information within each category was coded, analyzed, and integrated. Two authors independently performed the coding, with discrepancies resolved through discussion to ensure reliability and consistency.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Articles must be published in academic, peer-reviewed journals.	Non-journal publications such as conference papers, books, and book chapters.
Articles must present full-text empirical studies, based on original data and analysis.	Articles that do not present empirical results, including literature reviews, editorials, book reviews, education materials, and research notes.
Articles must explicitly focus on robots, agents, or bots, aligning with the definition of robots (Duffy, 2003).	Articles focusing on technologies outside the scope of robots, such as algorithms, Industry machinery, or traditional IS digital platforms.
Articles must examine the anthropomorphism of robots in-depth and specify which anthropomorphic elements have been studied.	Articles that do not emphasize the anthropomorphism of robots, such as those focusing solely on robot functional design, or that only briefly mention the concept of anthropomorphism in the introduction or literature review sections.

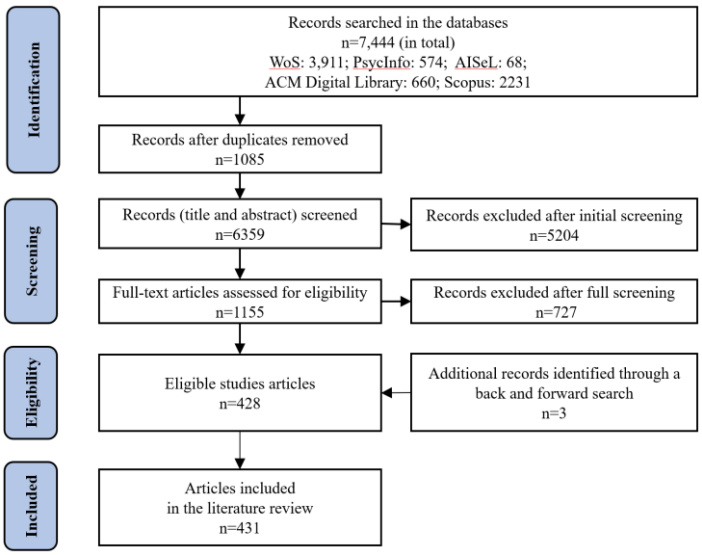

Fig. 1. Literature search and identification procedure

3 Result

3.1 Conceptualization of robot anthropomorphism

The identified studies commonly used anthropomorphism and related concepts. Among these, anthropomorphism is the most frequently applied term (N=207), serving as a foundational concept in understanding how human-like qualities are attributed to robots

[11]. However, its conceptualization in the literature varies, leading to inconsistencies and potential confusion. On one hand, anthropomorphism is often interpreted as a psychological attribution from the user perspective, such as perceived anthropomorphism, referring to the outcome of an inductive inference process that occurs in the mind of the perceiver [12].

On the other hand, anthropomorphism is used to describe external features or cues of robots that are designed to evoke human-like perceptions from the IS design perspective, such as anthropomorphic features/cues [11]. These features include static attributes, such as eyes, gender, face, and body shapes [13], as well as dynamic and behavioral characteristics, such as communication styles and movements [14]. The mixed-use of anthropomorphism as both an internal psychological process of a human and an external design characteristic of a robot creates conceptual ambiguity, which is rarely addressed explicitly in the literature.

Variations of the term, such as anthropomorphic (N=51) [14], anthropomorphizing (N=5) [15], and anthropomorphized/anthropomorphized (N=5) [16], are often used interchangeably without clear distinctions. Related concepts like human-like (N=47) [17], human likeness (N=31) [18], humanoid (N=31) [19], and humanness (N=26) [20] emphasize the physical and behavioral aspects of anthropomorphic robots but lack precise definitions in the literature. Similarly, terms such as humanization (N=5) [21], human-oriented (N=1) [22], humanized (N=1) [23], and humanizing (N=1) [24] extend the focus to cognitive, emotional, and social dimensions but are used inconsistently in the literature, without clear definitions.

3.2 Robot anthropomorphism from the IS design perspective

The reviewed studies explored a wide range of robot types and employed various anthropomorphic features/cues to designate these robots. To categorize them, the studies can be grouped into two main categories based on the robots' physical presence: physical robots (N=53) and virtual robots (N=225). Table 2 provides an overview of anthropomorphic design features/cues.

Table 2. Anthropomorphic cues identified in articles

Robot type	Anthropomorphic cues								
	Verbal			Non-verbal				Human identity	
	Social function	Structure	Content	Facial	Vocal	Bodily	Emotional	Demographic	Visual
Physical		X	X	X		X		X	X
Virtual	X	X	X	X	X		X	X	X

Physical robots refer to robots with tangible, physical embodiment (e.g., body) that can interact with humans in the real world. Research on physical robots primarily emphasizes the design of non-verbal cues, such as facial features and bodily movements. For instance, studies have explored anthropomorphic facial cues like smiles and eye gaze [25], as well as bodily movements such as head movement and gestures [26]. Verbal cues for physical robots focus on both verbal content and structure. Studies focusing on the verbal content of physical robots emphasize the informational and emotional aspects through verbal communication, such as emotional responses [27], conversation styles (e.g., warmth vs. competence) [28], humor [29], and self-description [30]. Verbal structural cues involve sentence/dialogue structure, such as response variety [31], initiative dialogue [32], and experience-based dialogue

structures [33], which can shape the form and flow of the communication between users and physical robots. Research has also examined the human identity of physical robots, including demographic cues and visual representations. For example, studies have investigated the impact of physical robots' gender and age [34], as well as their personality traits (e.g., optimistic and impatient)[35]. Additionally, the level of anthropomorphism in the physical robot's visual representation, ranging from mechanical designs to highly human-like appearances, has been analyzed to understand user perceptions and preferences [29].

Virtual robots are software-based entities that simulate the appearance, voice, or behavior of robots in a digital environment. Research on virtual robots has largely focused on verbal cues, addressing social functions, verbal structure, and verbal content. For example, common manipulated verbal features of virtual robots include emotional messages [36], humor [37], self-disclosure [38], and conversation styles (e.g., cute vs. formal) [39]. Some studies have examined the use of interjections (e.g., basic interjections, emotive expressions, linguistic responses, and repetitions) to enhance the robot's social function in verbal communication [40]. Verbal structural elements, such as adaptive response speed and temporal cues, have also been explored to improve conversational fluency [41]. While non-verbal cues are less directly applicable to virtual robots, studies have investigated the design of facial cues (e.g., facial expressions, eye movement, and smiles) for virtual avatars [42], as well as vocal tones [43] and the use of emoticons and other emotional cues [41]. Furthermore, the human identity of virtual robots has been another focus, with studies exploring demographic cues such as gender, race, names, and personality [44]. Virtual avatars' anthropomorphic appearances manipulated by their profile pictures and avatars have also been analyzed to assess how these designed features influence user perceptions and engagement [45].

The direct influence of designed anthropomorphic features on human reactions has been documented in prior literature. For example, from the perspective of social presence theory, presenting anthropomorphic features has been suggested to evoke a sense of "being with another human" [46]. Additionally, drawing on social response theory, these features serve as social cues that trigger user responses to robots [47]. In other words, presenting certain anthropomorphic features or combinations of such features of a robot can directly arouse users' reactions akin to those experienced in human-to-human interactions. Such findings have been further supported by various other theoretical lenses, such as anthropomorphic features as stimulus within stimulus–organism–response (SOR) framework [48], and anthropomorphic features as social attributes in computers as social actors (CASA) theory [49]. However, designed anthropomorphic features do not always lead to positive reactions. According to the uncanny valley [50], when the anthropomorphic features of a robot exceed a certain threshold, users may experience eeriness discomfort, or even fear.

To capture and measure the anthropomorphic features of various robots from the design perspective, experimental methods (N=302, 70.1%) [51, 52] were most commonly used. Experiments provide a controlled environment that allows researchers to manipulate various robot features systematically. This includes testing the presence or absence of a specific design feature or a combination of such features, comparing designs that range from mechanical forms to highly human-like forms, and even benchmarking against real human counterparts. These controlled comparisons allow for

the examination of whether the presence of anthropomorphic design features directly triggers user reactions.

3.3 Anthropomorphism from the user perspective

The reviewed studies have explored user perceptions of anthropomorphism through various theoretical lenses, uncovering a spectrum of outcomes, both positive and negative. Specifically, on the positive side, when users perceive a robot as human-like, they tend to exhibit positive perceptions, emotions, attitudes, and behaviors toward it. For instance, perceived anthropomorphism was reported to positively affect user perceptions related to human-like attribution directly, such as the perceived social presence of chatbots in commercial contexts based on social presence theory [53]. Also, perceived anthropomorphism has been reported to affect perceptions related to traditional IS, such as perceived usefulness and perceived ease of use regarding service robots in restaurants, as outlined in the Unified Theory of Acceptance and Use of Technology (UTAUT) [54]. Additionally, user perceived anthropomorphism has been identified to influence user emotions, such as positive emotions toward AI devices based on the conservation of resources theory [55], and intimacy toward service robots from the affect-as-information theoretical lens [56]. Furthermore, user perceived anthropomorphism can exert impacts on user attitudes and behaviors, such as trust and use intention of AI devices, according to the CASA theory [49].

On the negative side, negative consequences are also reported, for instance, the uncanny theory suggests that users' psychological discomfort occurs as the perceived anthropomorphism of a robot increases beyond a certain threshold [57]. Beyond the aforementioned theories, the reviewed studies also draw on frameworks from socio-psychology, communication, and information systems (IS), offering valuable insights into how users perceive various types of robots and how such perceptions lead to different reactions. These additional theories include mind perception theory [58], cognitive appraisal theory [59], technology acceptance model [60], expectation disconfirmation theory [61], attribution theory [62], social response theory [63], and psychological ownership theory [64].

To capture user perceptions of anthropomorphism, self-reported questionnaires were the most common method [51, 52], while a smaller number of studies employed neurophysiological methods, such as fMRI [65], eye-tracking [19], and electroencephalography [19]. Qualitative methods were also used in 10 studies, including techniques such as interviews [34], focus groups [66], reflection notes [67], and projective techniques [68], to assess user perceived anthropomorphism.

3.4 The relationship between anthropomorphic features and perceived anthropomorphism

In the literature, several studies have examined the relationship between the designed anthropomorphic features and user perceptions of anthropomorphism. Unlike studies that focus on the direct influence of anthropomorphic features on user reactions, or those examining the outcomes of perceived anthropomorphism, these studies concentrate on user perception of anthropomorphism as the cognitive interpretation that happens in the users' psychology and mind based on the anthropomorphic features presented by the robot. From a positive standpoint, user perceived anthropomorphism has been found to be enhanced by increasing the level of anthropomorphic designed features. For instance, in the context of elder care, robots with higher levels of

anthropomorphic features (e.g., Android robot) were perceived more humanlike than those with lower levels of anthropomorphic features (e.g., humanoid robots) by caregivers [69]. Regarding a specific anthropomorphic feature, such as verbal feature, robots that can make experience-based dialogue were perceived as anthropomorphism [33]. Likewise, robots exhibiting face-hand-face gaze behavior during human-to-robot handovers were perceived as anthropomorphism [70].

However, some studies indicated that robots' designed human-like appearance alone may not be adequate to foster user response, and should be combined with other features, such as robot communication in the context of care robots [71]. In these studies, most of the features were examined either generally (i.e., from a general level), or alone and separately (i.e., a specific feature), and only several studies examined the impacts of combinations of multiple anthropomorphic features on user perceptions. For example, Seeger et al. found that combining nonverbal and verbal features can increase perceived anthropomorphism while combining verbal and human identity features cannot [41].

While anthropomorphic features are external design elements, perceived anthropomorphism represents the internal psychological process by which users interpret these features, ultimately influencing various user responses. This distinction underscores the importance of understanding how these anthropomorphic features are cognitively processed and how such perceptions of anthropomorphism shape users' other perceptions, emotions, attitudes, and behaviors. However, despite the significance of the relationship between the two, few studies have tried to examine such an underlying mechanism, presenting a notable research gap in the literature.

4 Identified research gaps and future research directions

First, the inconsistent use of anthropomorphism-related terminology across the reviewed studies underscores a critical lack of unified conceptualization. Although the widely recognized definition of anthropomorphism by Epley et al. [3] has been extensively adopted, significant variability exists in the scope and focus of studies in prior literature. Many fail to clearly delineate the boundaries, distinctions, and interrelationships between key aspects of anthropomorphism, such as anthropomorphic features/cues (design elements that mimic human traits) and perceived anthropomorphism (users' subjective perceptions of human likeness). This conceptual ambiguity generates confusion, complicates the accurate measurement and assessment of these constructs, and undermines the reliability and comparability of research findings. To address these challenges, future research should prioritize a more rigorous exploration of the conceptual foundations of robot anthropomorphism. This includes providing clear definitions, distinguishing between the various facets of anthropomorphism, establishing precise boundaries for each aspect, and elucidating their interconnections.

Second, only a few studies have explored the relationship between anthropomorphic features and perceived anthropomorphism. This relationship warrants further investigation, as understanding the psychological mechanisms behind how users interpret the humanlike features presented by a robot is crucial. Future research should focus on elucidating how different anthropomorphic features are perceived and the psychological processes that drive user reactions.

Third, while many anthropomorphic features have been examined in the literature, there is a lack of standardized terminology and classification systems. Although virtual and physical robots may share some similar features, the distinctions between the features' impacts across these two forms remain unclear. Future studies should develop clear, standardized terminologies and classification frameworks to differentiate between the specific features of virtual and physical robots. This would enable more precise comparisons across different forms of robots and facilitate a deeper understanding of the commonalities and differences in how identical designs influence user reactions in virtual and physical robots.

Finally, inconsistencies were observed in the findings related to perceived anthropomorphism. For example, perceived anthropomorphism has been shown to significantly influence use intention in certain contexts, such as AI devices [49] and chatbots in tourism [72]. However, other studies, such as those focusing on digital voice assistants, have found this relationship to be insignificant [73]. These discrepancies may stem from variations in robot types and contextual factors. To address these inconsistencies, future research should prioritize the clear identification and reporting of robot forms and their implementation settings. Emphasizing robot forms and contextual sensitivity will enable a deeper understanding of the commonalities and differences among robot types in diverse contexts.

5 Conclusion

This research significantly advances our understanding of robot anthropomorphism by providing a rigorous and comprehensive literature analysis. First, it offers a detailed examination of the conceptualization of anthropomorphism and its research from two primary perspectives: the IS design perspective and user perceptions. This analysis provides a clear overview of the current state of anthropomorphism. Second, this study serves as a crucial first step toward a more thorough understanding of robot anthropomorphism. It highlights critical issues in the existing literature and proposes actionable future research directions. Specifically, it recommends that future research should clearly refine the conceptualization of anthropomorphism, develop standardized terminologies to classify various humanlike features, explicitly report context and robot types to clarify the inconsistent findings regarding user perceptions of anthropomorphism, and further deepen the understanding between external designed anthropomorphic features and internal psychological consequences of user perceptions.

This study also has several limitations. First, this literature review remains a work in progress, with the current version offering only a preliminary overview of the existing research. Future efforts should delve deeper into the intricate relationships between users' cognitive, emotional, and behavioral responses to robots' anthropomorphism, such as through quantitative meta-analyses. Second, the review is restricted to journal articles that match the search criteria, excluding other valuable sources such as conference papers, books, and book chapters. Future research could expand the scope to incorporate a wider range of literature, enriching the understanding of robot anthropomorphism.

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