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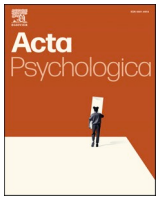

How culture modulates anthropomorphism in Human-Robot Interaction: A review

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ABSTRACT

Anthropomorphism is the tendency to attribute human-like characteristics to nonhuman agents, including robots. In the context of Human-Robot Interaction (HRI) research, it is relevant to understand what factors are at play in modulating individuals' anthropomorphism towards robots. This literature review addresses whether and how people's culture, which we identified as a potential factor of interest, affects their tendency to attribute anthropomorphic traits to robots. Moreover, we sought to determine whether the presence (or absence) of a relationship between culture and anthropomorphism towards robots varies as a function of i) the definition of both culture and anthropomorphism and ii) methodological factors, such as the measurements of culture and anthropomorphism adopted in the reviewed studies, as well as participants' and robot's characteristics. In most of the studies we reviewed, we observed a relationship between culture and anthropomorphism, i.e., individuals' cultural profile significantly affects how and how much they attribute anthropomorphic traits to robots. However, the directionality of the relationship is not consistent across studies. Furthermore, there is a small number of reviewed studies that showed a lack of relationship between culture and anthropomorphism towards robots. Although our findings do not vary as a function of the theoretical and methodological factors we identified, results are mixed, probably due to the large variability in those methods. The review contributes to extending current knowledge regarding the impact of individuals' culture on anthropomorphism towards robots, and provides suggestions towards a more controlled and rigorous investigation of the phenomenon.

1. Introduction

1.1. Anthropomorphism: a definition

In his *Natural History of Religion*, philosopher Davide Hume observed that "there is a universal tendency among mankind to conceive all beings like themselves, and to transfer to every object those qualities with which they are familiarly acquainted, and of which they are intimately conscious"; such that "we find human faces in the moon, and armies in the cloud" (Hume, 2007, section 3, paragraph 2). This tendency to "humanize" everything was a subject of philosophical analysis in ancient Greece, where Xenophanes was the first to use the term 'anthropomorphism' to illustrate how Greek gods were invariably light-skinned and blue-eyed, whereas African gods were invariably dark-skinned and dark-eyed (6th century B.C., as cited by Lesher, 2001). This is what Fischer (2011) recently called *imaginative* anthropomorphism, i.e., the representation of imaginary and fictional characters as human-like so that people represent them as having human-like characteristics such as personalities, emotions, and interests. However, Fischer also identified *interpretative* anthropomorphism, i.e., attributing intentions, beliefs, and emotions to nonhuman agents (for example, animals) based on their behavior. In line with this latter definition, Ruijten (2015) described anthropomorphism as an automatic cognitive process of attributing human nature or human uniqueness characteristics to nonhuman technological, mental, or natural objects, which elicits a mixture of affective, behavioral, and cognitive responses. This cognitive process can be implicit and spontaneous or explicit and reflective (Urquiza-Haas & Kotrschal, 2015), and thus classified as a type 1 or type 2 process according to dual process theories of thinking (Frankish, 2010).

In this context, the nature of anthropomorphism can be twofold. First, it can be an objective property of non-human agents. Based on this, something is anthropomorphic if it is objectively similar - according to some reasonable measure of similarity - to the typical appearance and behavior of human beings. There is a clear sense in which the face of a

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humanoid robot like the iCub robot (Metta et al., 2010) is objectively more like a human face than a screwdriver. To clarify this perspective, one would need to formulate a precise and plausible measure of objective similarity between two individuals. Second, anthropomorphism can be seen as a psychological phenomenon. From this perspective, something is anthropomorphic if a subject or class of subjects "sees" it as such in some sense of the term.

1.2. Why anthropomorphizing?

Defining anthropomorphism can be very helpful in exploring its underlying mechanisms, and formulating hypotheses about its nature (see Urquiza-Haas & Kotrschal, 2015 for a comprehensive review of current theories on anthropomorphism). For example, Epley et al. (2007) defined anthropomorphism as the tendency of individuals to attribute human-like characteristics, motivations, intentions, or emotions to the real or imagined behavior of non-human agents (Epley et al., 2007). According to this definition, anthropomorphism has strong motivational triggers, particularly (i) effectance, namely the need to make sense of the actions of others to reduce uncertainty concerning their behavior, and (ii) sociality, namely the need for people to create and maintain social connections. Therefore, an increased tendency to anthropomorphize is expected to emerge in situations of high cognitive load (i.e., when a lot of information needs to be processed at the same time) (Waytz, Gray, et al., 2010). Sociality, and in general people's need to establish fruitful interactions with others, seems to be the core of anthropomorphism also for other authors, who proposed that the human brain evolved to efficiently process social information (Caporael & Heyes, 1997). Therefore, anthropomorphism would be an automatic response to any human-like behavior or human-like feature.

In our view, what is interesting is that these definitions of anthropomorphism, as well as their underlying mechanisms, are not limited to interactions with other humans, but also with nonhuman agents such as animals or technology. For example, coming back to the distinction between objective and psychological anthropomorphism we described above, in the context of interactions between humans and technology Fischer (2021) distinguished between *anthropomorphic design*, which describes the set of social cues and triggers built in by technology designers to elicit certain responses in humans when interacting with them, and *psychological anthropomorphism*, which is the socio-cognitive phenomenon comprising psychological mechanisms that determine people's behavior towards other agents (including conspecifics, but also nonhuman agents such as animals or technology). In the context of Human-Robot Interaction (HRI), this is the two-sided perspective that also Ziemke (2024) advocates in his recent paper. Specifically, he illustrates that the "social" nature of interactions between humans and robots surely depends on the objective pre-programmed capacity of robots to communicate, understand, and interact with us (*anthropomorphic design*) but it is still largely in the eye of the beholder, who attributes human-like behaviors and characteristics to robots (*psychological anthropomorphism*). Therefore, it is clear that anthropomorphizing robots, intended as a psychological phenomenon that leads people to ascribe human-like traits to robots, is a fundamental aspect of promoting smooth and successful interactions between humans and robots. Taking these considerations together, from now on, we will use the term "anthropomorphism" to refer to the tendency to attribute human-like characteristics to non-human agents, such as computers and robots.

1.3. The case of robots

The *Computers Are Social Actors (CASA) Framework* is one of the most important theoretical contributions to the field of human-machine communication. It suggested that humans apply the same heuristics used for human interactions to nonhuman artificial agents (e.g., computers, chatbots, and robots), and thus interact with them as if they were humans (Nass & Moon, 2000). In other words, individuals mindlessly apply social rules and expectations to machines, including computers and robots.

Specifically, one category of great interest is *social robots*- that is, physical entities embedded in a social environment with humans, and sufficiently empowered to behave in a way that is functional to their own goals and those of their community (Duffy, 2003). Given the increasingly massive presence of social robots in human spaces, as they can serve as assistants or companions at schools, in hospitals, or at work, it is not surprising that exploring anthropomorphism towards robots- as well as the conditions under which it occurs, and its implication for our society- quickly become a topic of interest in the Human-Robot Interaction (HRI) field. Indeed, anthropomorphizing robots has considerable benefits for people's choices and beliefs when engaged in an interaction with them (Złotowski et al., 2015); in this context, it is important to understand what factors are at play in affecting, and modulating, people's tendency to anthropomorphize robots.

For example, morphological factors (related to the appearance and physical shape of the robot) have been considered. One interesting study was the large survey conducted by Rosenthal-von der Pütten and Krämer (Rosenthal-Von Der Pütten & Krämer, 2014), in which they asked participants to evaluate pictures of 40 robots. Results showed that six clusters of robots emerged, with distinct design characteristics; interestingly, these characteristics (and the related clusters) determined how people evaluated robots (e.g., the extent to which they were perceived as human-like, threatening, or likable). Other studies have combined behavioral with neuroimaging techniques. For example, Krach et al. (2008) asked participants to perform an interactive game with a partner, while their neural activity was monitored through functional magnetic resonance imaging (fMRI). Importantly, participants could be paired with a computer, a functional (non-anthropomorphic) robot, an anthropomorphic robot, and a human partner. Results showed that the activation of the medial prefrontal cortex and the right temporoparietal junction, which are associated with the activation of the Theory of Mind (ToM), for both the human and the robot partner depended on the degree of anthropomorphic features displayed by them; the more anthropomorphic features, the greater ToM activation (Krach et al., 2008).

Other studies have focused on how the level of anthropomorphism affects our interaction with robots. For example, studies using behavioral measures (e.g., reaction times) showed that anthropomorphic robots lead to levels of motor inhibition that are similar to other humans (Klapper et al., 2014; Stenzel et al., 2012). The extent to which individuals represent the actions of a robot- and treat it as a social partner- might depend on the degree of attributed anthropomorphic features to it; the more anthropomorphic design the robot has, in terms of appearance, the greater motor inhibition.

This said, what factors shape our perception of robots as human-like? One answer might be that individuals often explain robot behavior with reference to attributed mental states, but i) only to some extent and ii) with large interindividual variability in their tendency to attribute mental states to robots (Marchesi et al., 2019). Notably, Fischer (2011) observed the existence of a large interpersonal variation in HRI; when analyzing a corpus of verbal HRI studies, she observed that only a subset of people treat robots as social agents. Interestingly, neurological evidence is also consistent with behavioral evidence, reporting different responses to human and robotic actors. For example, Chaminade et al. (2010) used functional magnetic brain stimulation (fMRI) to assess how brain areas activated by the perception of basic emotions responded to a human or a robot displaying the same emotions. The results showed increased responses to robots compared to human stimuli in the occipital and posterior temporal cortices, which the author explained as the result of additional visual processing when perceiving a mechanical anthropomorphic agent (Chaminade et al., 2010).

Taken together, these studies suggest that people may have different personal characteristics that influence how they perceive and interact with robots, and thus their tendency to anthropomorphize them. For the

purpose of this review, we have chosen to focus on one particular characteristic: people's cultural background.

1.4. Culture and anthropomorphism in HRI

Two decades ago, Baldwin et al. (2006) listed 313 definitions of culture, adopted through many years of research in disciplines such as psychology, sociology, linguistics, anthropology, political science, and philosophy. What immediately stands out is the lack of a unitary and comprehensive definition of culture, which in turn makes its operationalization extremely difficult in empirical studies. One might think of using language as an index of culture, another might adopt the country of birth as a reference; despite being useful in both cases, it is evident that the plethora of definitions causes conceptual incoherence (Smith, 2016) and leads to a lack of generalizability of results, since different studies stick to different definitions (and operationalizations) of culture. In this context, one of the most influential conceptualizations of culture is the cross-country model proposed by Hofstede (2011). The model was originally conceived to understand differences in individuals' cultural values across countries, and specifically among the employees of a multinational corporation (IBM). According to the model, culture is a "collective programming of the mind" that distinguishes members of one group, or a category of people, from others. It means that people learn culture from the social groups and environments they are immersed in, such as family and school; therefore, culture is always a shared, collective phenomenon (Hofstede, 2001). The model proposed five dimensions along which individuals' cultural values can be analyzed: i) individualism-collectivism; (ii) uncertainty avoidance; (iii) power distance; (iv) long-term orientation; and (v) masculinity-femininity. Despite some refinements over the years, the model has been largely employed to collect the values and sentiments of similar respondents from two or more countries, thus configuring as a country (nationality)-based model of culture (Hofstede & Minkov, 2013).

A national-based perspective seems to be frequently adopted also in the HRI domain. A recent review (Lim et al., 2021) extensively documented that individuals' cultural background influences people's perception of, and interaction with, robots. As the authors stated, culture is mainly operationalized as national culture, i.e., a set of values, norms, and practices that are undertaken by a country. Specifically, most HRI studies tend to focus on the dichotomy between individualism and collectivism dimension as coined by Hofstede (2011), i.e., a means of explaining the variations of people's behavior depending on their group membership to national cultures. Thus, culture was conceived as the contrast between the philosophical systems of the West (e.g., Europe and the Americas) and those of the East (e.g., Asia and the Middle East), with the former seeking a systematic, consistent, and comprehensive understanding of our universe, and the latter adopting a more holistic and circular view in their understanding of the world. Notably, this binary distinction (which groups people based on their national country along the Eastern-Western axis) seems to impact their tendency to anthropomorphize robots.

Generally speaking, when relating individuals' cultural background with their tendency to anthropomorphize robots, what emerges is that people are more likely to ascribe anthropomorphic features to robots with whom they share some aspects of their identity. For example, Eyssel and Kuchenbrandt (2012) performed a study investigating the effect of social category membership on the evaluation of humanoid robots. Specifically, German participants were presented with a picture of a humanoid robot, which they believed to belong either to their national in-group (Germany) or to an out-group (Turkey). When asked to rate the robot regarding its degree of anthropomorphism, warmth, and psychological closeness, participants evaluated more positively, and attributed more anthropomorphic characteristics, to the robot that was presented as a national in-group member, compared to the out-group one (Eyssel & Kuchenbrandt, 2012). However, at present, it is not fully understood whether, and how, individuals' cultural background affects their tendency to anthropomorphize robots.

That being said, the present review aims to address this issue, i.e., to understand whether there is a relationship (and, if so, of what sort) between individuals' culture and their anthropomorphism towards robots. To do so, the review presents 17 primary studies across multiple disciplines (e.g., psychology, engineering, robotics) to address four specific questions:

RQ1: how has culture been defined in the context of HRI research on anthropomorphism towards robots?
RQ2: which methods have been used to explore the relationship between culture and anthropomorphism towards robots in HRI?
RQ3: what are the main findings regarding the role of culture in anthropomorphism towards robots in HRI?
RQ4: do findings vary as a function of (i) the definition of culture and anthropomorphism, and (ii) the methodological factors (participants' characteristics, robot's characteristics)?

2. Methods

The present review has been conducted based on the guidelines provided by the PRISMA 2020 Statement (Page et al., 2021), designed to help researchers correctly and transparently report why a review is conducted, which steps the authors followed, and what the main findings are. Another source of inspiration was the extensive and rigorous HRI review published by Thellman et al. (2022).

Before the review, the authors developed a review protocol, which comprised the following steps: (i) the state-of-the-art as well guiding the rationale of the review, (ii), the research question to address, (iii) the literature research strategy including query strings and search systems used, (iv) the study selection criteria and procedures, and (iv) a data extraction strategy specifying how the information required for each study has been obtained. It was made to clearly define the methods used to undertake a systematic review and to ensure following and rigorous and replicable methodology. Whereas the first two steps (the state-of-the-art and the research questions) were described in the previous Introduction section, in the following sections we are describing the three steps of the review process in detail.

2.1. Data source and research strategy

One fundamental step of the review process is to identify the academic research systems that are suitable for a literature review. According to a recent study (Gusenbauer & Haddaway, 2020), not all systems are eligible; for instance, Google Scholar seems to be inadequate, as its search results might be misinterpreted in a way that impinges on research validity (Gusenbauer & Haddaway, 2020). Based on this, we used the following academic search systems, which are eligible for literature review because of the quality of the search functionality they offer and the large size of the databases they index: PubMed, Web of Science (Core Collection), Scopus, Science Direct, ACM Digital Library, IEEE Xplore, Wiley Online Library. During the time that the review was conducted (May/June 2024), all these search systems indexed publications belonging to the research areas that the authors identified as relevant: Psychology, Neuroscience, Social Sciences, Engineering, Computer Science, Robotics, and Human-Robot Interaction (HRI).

For all academic search systems, an initial search query string was developed using the terms that we derived from the research questions we seek to address. This meant including all the relevant terms associated with culture, anthropomorphism, robots, and their various permutations. It resulted in "cultur*", "anthropomorph*", and "robot*" respectively, and they were mixed into a functional string using the AND operator. The search was conducted in May 2024 and resulted in several lists comprising 8 (PubMed), 53 (Web of Science), 58 (Scopus), 186 (Science Direct), 148 (ACM Digital Library), 12 (IEEE Xplore), 56 (Wiley Online Library) publications. The merged lists consisted of 521

publications.

2.2. Study selection

The 521 publications were identified based on predefined inclusion and exclusion criteria. The inclusion criteria were: (1) publication date (2000–2024); (2) nature of the study, i.e., we included only publications reporting empirical data; (3) language, i.e., we included only publications in English; (4) papers published in peer-reviewed journal or conference proceedings, and (5) open-access. The exclusion criteria were: (1) publications not subjected to a peer-review process, and/or not open access; (2) non-empirical papers (e.g., reviews); (3) publications in other languages than English; (4) unpublished papers (e.g., articles stored in ArXiv); (5) in cases where a publication appeared in one or more research systems, we kept that publication only once. Then, all publications (521) were examined on their actual relevance following the three-step study selection as conceived by Thellman et al. (2022) (see Fig. 1 for a summary of the study selection process).

Step 1. Each publication (N = 521) was independently judged by all authors as irrelevant, relevant, or extremely relevant based on its title. It would mean that all authors independently judged whether the title contains- totally or partially- the three relevant terms associated with culture, anthropomorphism, and robots (i.e., the main themes that we identified and focused on). Publication titles that were perceived as difficult to judge, for example, because one or more terms were not explicitly referring to one or more terms but it was implicitly recalling them (e.g., "nationality" instead of "culture", or "machine/artifacts" instead of "robots") were conservatively marked as relevant. All publications judged as relevant or extremely relevant by at least two authors were kept; the rest were discarded.
Step 2. Each of the remaining publications (N = 92) was independently judged by all the authors as irrelevant, relevant, or extremely relevant based on its abstract. As for Step 1, it would mean that all authors judged independently whether the abstract contains- totally or partially- the three relevant terms associated with culture, anthropomorphism, and robots. Abstracts that were perceived as difficult to judge, for example because they were not explicitly referring to one or more terms but implicitly recalling (e.g., "nationality" instead of "culture", or "machine/artifacts" instead of "robots") were conservatively marked as relevant. All publications judged as relevant or extremely relevant by at least two authors were kept; the rest were discarded.
Step 3. Each of the remaining publications (N = 40) was independently judged by all the authors as irrelevant, relevant, or extremely relevant based on a full read-through. As for the previous steps, it would mean that the authors independently judged whether the full paper was irrelevant, relevant, or highly irrelevant concerning the main themes of our review (culture, anthropomorphism, and robots). The publications judged as irrelevant by at least two authors were discarded, whereas the others were kept; it resulted in a final selection of N = 17 publications (see Supplementary Materials, Table SM.1., p.3, for a summary of the included publications).

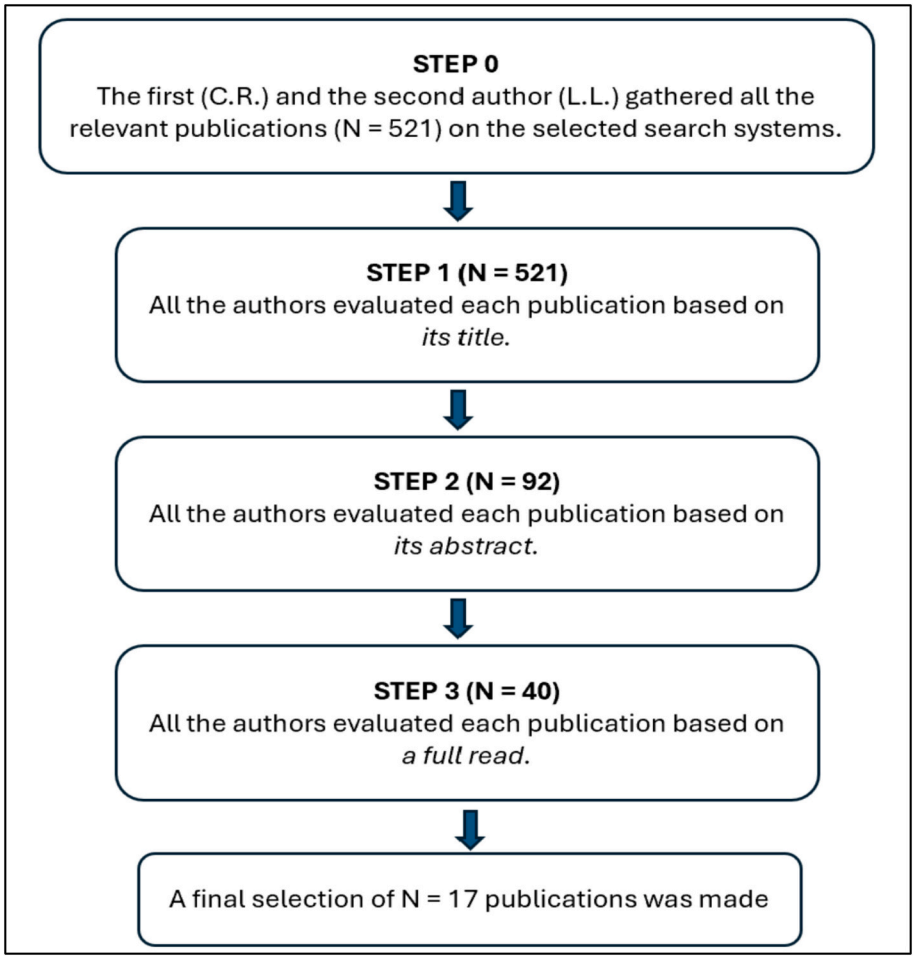

Fig. 1. Schematic representation of the search selection process.

2.3. Data extraction

The data extraction process aimed to collect all the information necessary to answer the research questions as listed in the Introduction section (RQ1–RQ4) and was conducted by the first author. Data were extracted from each of the publications included in the review (N = 17). The categories of the data extracted were inspired by the ones used by Thellman et al. (2022) and adapted to the specific scopes of this review (a summary of each category is also provided in Table 1).

2.3.1. Definition of the variables of interest

The first step consisted of listing how the two variables of interest (culture and anthropomorphism towards robots) have been defined and operationalized in each study included in the review (see Supplementary Materials, Table SM.2, p., 5, for a summary of all definitions).

2.3.2. Participants

Information regarding participants was collected in terms of 1) sample size, to check for robustness of results, and 2) age of participants, to see whether the relationship between culture and anthropomorphism towards robots as a function of age (we followed the basic distinction between children and adults).

2.3.3. Study setting

This category refers to where each study was performed (Lab/Field/Online). Specifically, studies that took place in a controlled environment and under the supervision of an experimenter were labelled as "lab studies"; studies that were set up in the field (e.g., in the street or another public space) were labelled as "field study"; studies that were conducted by recruiting participants through an online platform, and thus was not carried out in a physical space, were labelled as "online study".

2.3.4. Robot characteristics

We collected three types of information related to robot characteristics. The first related to *robot presentation*, i.e., how the robot has been presented to participants in each study (text/image/video/physical). "Text" refers to a verbal description of the robot; "image" refers to a picture of the robot; "video" refers to a video presentation, and "physical" refers to a physical present robot. The second characteristic related to *robot morphology*¸ i.e., the shape of the robot presented in each study (anthropomorphic/zoomorphic/functional/not applicable). "Anthropomorphic" and "zoomorphic" refer to an anthropomorphic and zoomorphic shape, respectively. "Functional" refers to a robot that does not have an anthropomorphic or zoomorphic shape; "Not applicable" was used if the author(s) did not provide any information on the shape of the robot they used in their study. Finally, the third characteristic is *robot behavior* (interaction with participants/interaction with others (non-participants)/non-social/no behavior). "Interaction with participants" means that, during the experiment, participants directly interacted with the robot; "interaction with others (non-participants)" means that, during the experiment, participants observed an interaction between the robot and another human; "non-social" means that the study did not include an interaction between the robot and a human (either the participants or another human); finally, "no behavior" means that the author(s) did not report any information regarding the behavior of the robot, or that the robot did not have any (for example, when the robot was presented in terms of pictures).

Table 1
Categories and subcategories of data extracted from each primary study are included in the review, inspired by Thellman and colleagues' review paper (Thellman et al., 2022).

Category	Subcategories
Definitions	[Culture]
	[Anthropomorphism]
Participants	[Sample size]
	[Age]
Study setting	[Lab]
	[Field]
	[Online]
Robot characteristics: Presentation	[Text]
	[Image]
	[Video]
	[Physical]
Robot characteristics: Morphology	[Anthropomorphic]
	[Zoomorphic]
	[Functional]
	[Not applicable]
Robot characteristics: Behavior	[Interaction with participants]
	[Interactions with others (non-participants)]
	[Non-social]
	[No behavior]
Measure: culture	[Verbal]
	[Behavioral]
	[Neurological]
Measure: anthropomorphism	[Verbal]
	[Behavioral]
	[Neurological]
Findings	[Yes]
	[No]
Statement about the reason why	[Textual]

2.3.5. Measure

This category comprises the measurements of the two variables of interest, i.e., culture and anthropomorphism. In other words, it refers to the type of data collected in each study we reviewed, concerning both participants' cultural values (culture) and their likelihood to anthropomorphize robots (anthropomorphism) (verbal/behavioral/neurological). "Verbal" refers to participants' subjective reports, and this includes Likert scales and other qualitative methods. "Behavior" refers to non-verbal data only, e.g., data collected through quantitative methods (Reaction Times, accuracy ratings). Finally, "neurological" refers to data obtained by applying electrophysiological or functional techniques (e.g., electroencephalography, functional magnetic resonance, etc.).

2.3.6. Findings

This category refers to the findings of the study (yes/no). "Yes" refers to the emergence of a relationship between culture and anthropomorphism towards robots; conversely, "no" refers to a lack of relationship between the two variables of interest. It is important to note that, in the case of a relationship between culture and anthropomorphism, the corresponding details (e.g., whether the relationship was positive or negative) will be further discussed in detail.

2.3.7. Statement about the reason why, and how, culture affects anthropomorphism towards robots in HRI

This category refers to the author(s)' statement or speculation regarding the findings of their study. In other words, it collects information regarding how they explained their findings (or the lack of).

3. Overview of included publications

Out of the 17 publications included in the review, the majority (52.9 %) reported a study conducted online, 29.4 % reported a study conducted in a laboratory setting, and 5.9 % reported a mixed study (online + laboratory setting); the remaining 11.8 % reported a study conducted in the field. The publication year includes publications ranging from 2008 (the oldest) to 2024 (the latest). 64.7 % of included papers were published in a journal, where *Computers in Human Behavior* (11.76 %) and *International Journal of Social Robotics* (11.76 %) were the most representative. The remaining 35.3 % were published in a conference proceeding, where the *ACM/IEEE International Conference on Human-Robot Interaction (HRI)* was the most representative (23.5 %).

Regarding participants, all the included publications reported studies involving samples of adult participants, except for one which included children ranging between 5 and 11 years of age. Notably, they

all involved individuals from the general population, except for one study involving a sample of specialized participants (namely, design students and professional designers). Where reported, all the studies were well-balanced in sex and/or gender, i.e., they reported a balanced proportion between male and female participants.

Note that all proportions (%) mentioned in this section, as well as the proportions presented in the next sections, are relative to the total number of included publications (N = 17).

4. Literature review

To address the aims of the review, i.e., to understand whether there is a relationship (and, if so, of what sort) between individuals' culture and their anthropomorphism towards robots, we analyzed the publications included in the review to answer the four research questions as listed above (RQ1–RQ4). In the next sections, each question (and the corresponding answer) will be listed separately.

Beforehand, it is important to underline that, for each study included in the review, we carefully considered whether, and how, the author(s) defined the concept of anthropomorphism, and how they used it in the context of studies involving robots. It was made to ensure that all authors provide a clear definition of anthropomorphism, and thus that it was possible to examine its relationship with individuals' cultural background- and draw generalizable conclusions about.

We observed that all the included publications adopted- to various degrees- the two perspectives on anthropomorphism as described in the Introduction (and by Fischer, 2021). Concerning what Fischer (2021) called the anthropomorphic design (see the Introduction), some publications emphasized the similarity with humans, as the concept was treated as the equivalent of human likeness (Castelo & Sarvary, 2022; Liberman-Pincu et al., 2024; Salem, Ziadee, & Sakr, 2014), both in terms of appearance (Li et al., 2024) and physiological and psychological traits (Mehmood et al., 2024), or the degree of humanness expressed by the robot (Yu & Ngan, 2019). While stressing the similarity with humans, only one study adopted a broader definition (Ikari et al., 2023), i.e., the authors related anthropomorphism to the extent to which moral care is shown to robots- as well as we experience with other humans. More strictly, it was also defined as the capacity of "acting like a human", and/or "having characteristics that also a human would have" (Evers et al., 2008). Other publications stuck to the definition proposed by Epley et al. (2007), according to which anthropomorphism is the individuals' tendency to imbue the real or imagined behavior of nonhuman agents with human-like characteristics (Epley et al., 2007). For example, anthropomorphism was defined as the tendency to attribute human-like characteristics to nonhuman agents (Bartneck, 2008; Dang & Liu, 2023; Li et al., 2022; Spatola et al., 2022) or the "perception of human-like traits to nonhuman agents" (Muniz et al., 2024), specifically the "attribution of mental states to robots" (Trovato & Eyssel, 2017).

RQ1. How has culture been defined in the context of HRI research on anthropomorphism towards robots?

Our first research question was related to the definition of culture that the reviewed publications adopted in the context of HRI research on anthropomorphism towards robots. Surprisingly, none of the publications provided an explicit definition of culture. Instead, all of them implicitly referred to culture as a national-based identity. Only one study (Ríos Rincón et al., 2022) considered two different subgroups within the same national identity, by making a distinction between "rural" and "urban" settings.

Some of the studies explicitly referred to Hofstede's model of culture (Hofstede, 2011). For example, two studies (Li et al., 2024; Yu & Ngan, 2019) defined culture as participants' cultural orientation along Hofstede's dimension of power distance, i.e., the extent to which the less powerful members of an institution/organization within a country accept that power is distributed unequally (Hofstede & Minkov, 2013). Other studies (Mehmood et al., 2024; Salem et al., 2014) implicitly referred to Hofstede's dimension of individualism/collectivism by adopting the binary distinction between Western and Eastern countries (representative of individualistic and collectivistic cultures, respectively).

Notably, only one study (Spatola et al., 2022) adopted a broader definition of culture, by considering both the national (i.e., participants' country of origin) and the individual culture (i.e., individual cultural values expressed by participants). Another study (Haring et al., 2015) considered various layers of culture, stating that "cultural attributes" are intended not only as nationality but also as religion, race, and socio-economic class.

RQ2. Which methods have been used to explore the relationship between culture and anthropomorphism towards robots in HRI?

Our second research question related to the methods used in the HRI literature to address what relationship exists between individuals' culture and their likelihood to anthropomorphize robots, including the stimuli and measures that the author(s) of the reviewed publications used in their studies. Specifically, the "stimuli" referred to the robot, and were classified according to three robot characteristics: how it is presented in the study (robot presentation), its physical appearance (robot morphology), and the type of behavior it exhibited (if any; robot behavior). Conversely, the "measures" comprised two different aspects: i) tool type, i.e., how culture was measured in each primary study, and 2) data type, i.e., which type of data was collected. The two categories (stimuli/measures) will be treated separately in the next subsections (RQ2A and RQ2B).

RQ2A. What types of stimuli have been used in HRI studies exploring the relationship between culture and anthropomorphism towards robots?

As described above, the category of "stimuli" refers to the robot used in the studies included in the review, and to its characteristics: presentation, morphology, and behavior (if any). Regarding the presentation, in the majority of studies (6/17; 35.3 %) the robot was presented in the form of images, i.e., participants were presented with pictures of the robot. In other studies (3/17; 17.6 %) the robot was presented in the form of text, i.e., using verbal description (sentences or stories) provided to participants. The 11.76 % of the studies (2/17) used video presentation of the robot, and the same proportion (2/17; 11.76 %) applied to the last attribute, i.e., "physical robot"- namely, the robot was physically present and sharing the same experimental context than participants. In the remaining studies, the presentation of the robot was mixed: image + text (2/17; 11.76 %), video + physical (1/17; 5.89 %). Only one study envisaged a "mental" (and subjective) presentation of the robot, since participants were asked to create a mental image of the robot to draw it (Ríos Rincón et al., 2022).

Regarding morphology, more than half of the studies (9/17; 52.9) used a robot having anthropomorphic features, whereas a small proportion (2/17; 11.76 %) employed a functional robot, i.e., a robot that does not have an anthropomorphic or zoomorphic shape, and no studies used a zoomorphic robot.

Finally, in two studies (2/17; 11.76 %) it was not possible to collect information regarding the morphology, either because the authors did not provide details about it (Liberman-Pincu et al., 2024) or because it depended on the mental image that the participants created, which was not accessible to the experimenters (Ríos Rincón et al., 2022).

Regarding the behavior, in almost the totality of the studies (12/17; 70.6 %) the robot did not exhibit any behavior; in the remaining studies, the robot was programmed to interact with participants (3/17; 17.65 %) or with other humans (1/17; 5.89 %). In only one study (1/17; 5.89 %) the robot was programmed to have mixed behaviors, i.e., based on the experimental conditions it could have no behavior, or behave mechanically or socially (Fraune et al., 2020).

RQ2B. What types of measures have been used in HRI studies

exploring the relationship between culture and anthropomorphism towards robots?

As described above, the category "measure" refers to how the two variables of interest, namely culture and anthropomorphism, were measured in each primary study we included in the review- and thus which type of data was collected.

4.1. Measure: culture

In the reviewed studies, the author(s) did not employ any measure to quantify participants' culture (with only one exception discussed below). Instead, participants were recruited based on the a priori criterion of their nationality, sticking to the binary distinction between Eastern (collectivistic) and Western (individualistic) countries (Hofstede, 2011). In some cases, the national-based selection of participants was more fine-grained; for example, participants were recruited based on their country of birth (Fraune et al., 2020; Ríos Rincón et al., 2022; Spatola et al., 2022; Liberman-Pincu et al., 2024), citizenship/residency (Ikari et al., 2023) or mother tongue (Salem et al., 2014; Muniz et al., 2024). In one case, the author(s) determined participants' culture (in the national sense) by asking them to indicate where they were born, where they lived, and whether they had lived in the host country for more than three months at the time of the study (Li et al., 2022). In some cases, the author(s) explicitly referred to one of the dimensions of Hofstede's national model, i.e., the subscale of power distance (Yu & Ngan, 2019; Li et al., 2024). Spatola and colleagues (Spatola et al., 2022) were the only ones to evaluate individual cultural values by asking participants to fill out the Cultural Values Scale (CVS; Yoo et al., 2011).

In summary, when measuring participants' culture, the unique type of measure- used in 100 % of the reviewed studies- was the verbal measure. It could be either participants' explicit report regarding their nationality, collected based on the above-mentioned criteria, or the use of Likert-like scales evaluating participants' cultural values. No behavioral or neurological data was collected.

4.2. Measure: anthropomorphism

The first step to describe how the reviewed studies measured anthropomorphism is to make a distinction between when it was used as dependent vs. independent variable. Indeed, in almost the totality of the study (14 out of 17 studies), participants' anthropomorphism was the dependent variable, since the study aimed to address the effect of individuals' culture (which then was the independent variable) on their likelihood to anthropomorphize robots. However, there was a small proportion of studies (3 out of 17 studies) in which anthropomorphism was an independent variable, and thus its effect was evaluated in combination with participants' culture to see whether, and how, it affected the dependent variable- for example, customers' engagement (Mehmood et al., 2024) or moral care towards robots (Ikari et al., 2023).

In the former case (anthropomorphism as the dependent variable), the totality of the studies (100 %) relied on verbal measures of anthropomorphism towards robots. Specifically, the predominant type of measure was the verbal measure, in the form of a Likert scale assessing participants' tendency to anthropomorphize robots. Several studies used existing questionnaires, such as the Individual Differences in Anthropomorphism Questionnaire (IDAQ) from Waytz et al. (2010) (e.g., Trovato & Eyssel, 2017; Ikari et al., 2023); the anthropomorphism subscale of the Godspeed questionnaire from Bartneck et al. (2009) (Haring et al., 2015; Li et al., 2022); or the anthropomorphism subscale from the larger questionnaire developed by Powers and Kiesler (Powers & Kiesler, 2006). Other questionnaires were the Mind Attribution Scale and the InStance Test developed by Marchesi et al. (2019) (Spatola et al., 2022). In other studies, the author(s) did not use questionnaires, but alternative methods comprising Likert-like scales through which participants rated their perceived degree of anthropomorphism. For example, (Dang & Liu, 2023) created an "anthropomorphism index" by asking participants to indicate how capable the robot was of having a mind of its own, intentions, free will, and consciousness, as well as of experiencing and expressing emotions. Otherwise, they used a single Likert-like item to ask participants how much real and human-like the robot seemed (Muniz et al., 2024). Alternatively, they asked participants some open questions regarding the attribution of human-like traits to robots (Ríos Rincón et al., 2022). In one publication, anthropomorphism also operationalized the robot's behavior towards humans or other robots (Fraune et al., 2020), in such a way that social behavior (compared to functional) increases anthropomorphism towards robots. Finally, in two studies (Salem et al., 2014; Yu & Ngan, 2019), anthropomorphism was operationalized as interpersonal warmth, under the assumption that the more human-like the robot, the higher was the level of people's acceptance of it (Yu & Ngan, 2019); thus, it was measured using the Interpersonal Warmth Scale developed by Mara and Appel (2015).

In the latter case (anthropomorphism as an independent variable), anthropomorphism was directly manipulated by the experimenters, who presented participants with robots having various degrees of anthropomorphic features. For example, in Castelo and Sarvary's study (Castelo & Sarvary, 2022), the authors manipulated the robot morphology by having four degrees of physical anthropomorphism, which corresponded to four different robots. Similarly, in another study (Li et al., 2024), the robot morphology sequentially increased the level of anthropomorphism.

RQ3. What are the main findings regarding the role of culture in anthropomorphism towards robots in HRI?

In this section, we present research findings on the relationship between the two variables of interest, i.e., participants' culture and their likelihood to anthropomorphize robots. As described in the Methods section, we categorized the studies' results in two categories, namely "yes" and "no". "Yes" comprises studies showing an existing relationship between culture and anthropomorphism towards robots; conversely, "no" comprises studies showing a lack of relationship between the two. Moreover, we added another category labelled "statement about the reason why"; it corresponds to the explanations that, where present, the author(s) of the reported studies provided to interpret their results.

The majority of the reviewed studies (14/17; 82.3 %) reported a relationship between participants' culture and their likelihood to anthropomorphize robots. Among them, what emerged was that participants' tendency to anthropomorphize robots was higher in Eastern than Western countries. For example, Chinese participants (representative of an Eastern culture) showed a higher tendency towards anthropomorphism than US participants (representative of a Western culture) (Evers et al., 2008; Li et al., 2022). A similar pattern occurred for Japanese participants, who were also chosen as representatives of an Eastern country: indeed, a positive relationship between cultural values and anthropomorphism emerged, whereas it was not true for US participants (Ikari et al., 2023), and they are even more prone to attribute anthropomorphic features to robots who do not display physical traits belonging to their culture (i.e., robots having Caucasian physical appearance; (Trovato & Eyssel, 2017). Interestingly, the positive link between Japanese culture and anthropomorphism occurred also when participants directly interacted with the robot and when they observed the robot interacting with another human (Haring et al., 2015), whereas it was not true for Australian participants- who were representatives of Western culture. A similar cultural difference between Eastern and Western countries emerges also when considering other countries; for example, Arabic participants (representatives of Eastern culture) resulted to anthropomorphize the robots more, as well as have a higher tendency to consider them as members of the in-group and thus show more willingness to interact with them (Salem et al., 2014).

When providing potential explanations of the cultural differences in anthropomorphizing robots among Eastern and Western countries, two main interpretations emerged. The first one calls for religion-related

values, which are often treated as part of participants' cultural values. In other words, participants belonging to Eastern cultures (e.g., Chinese, Japanese) are more likely to advocate animism and thus are more prone to attribute human-like anthropomorphic traits to robots (Li et al., 2022). The second interpretation calls for familiarity with robots, and specifically with some kinds of robots. For example, it has been proposed that, in Eastern countries, people's media coverage (and thus exposure to robots) is more frequent for functionally android robots than for social humanoid robots. It might help explain the opposite pattern of results that emerged in other reviewed studies, according to which Western countries showed a higher tendency towards anthropomorphizing robots than Eastern countries. For example, Mehmood et al. (Mehmood et al., 2024) recently showed that Canadian participants (who are representative of a Western culture) are more indulgent towards using anthropomorphic robots, whereas Indian participants (who are representative of an Eastern culture) are more restrained in accepting anthropomorphic robots. It might also explain the more anthropocentric view that emerged in Western participants (from Germany and the US) from Spatola and colleagues' study (Spatola et al., 2022) as compared to Eastern (Korea and Japan).

Another relevant aspect that emerged is that, when anthropomorphism was an independent variable, a combined effect of both the independent variables (anthropomorphism and culture) appeared on the dependent variable. For example, Western participants (US) reported liking anthropomorphic robots more (Bartneck, 2008), but finding them less comfortable (Castelo & Sarvary, 2022) and less trustworthy (Li et al., 2024) than Eastern participants (Japanese).

However, it is important to consider that research findings were not entirely convergent, namely, they did not all show the existence of cultural differences in anthropomorphizing robots. For example, (Fraune et al., 2020) showed that, consistently across Eastern and Western cultures (Japan and the US, respectively), when the robot behaves socially rather than functionally (machine-like), participants anthropomorphize it more, 2) express more positive emotions and 3) they are more willing to engage in an interaction with it. Similarly, Liberman-Pincu et al. (Liberman-Pincu et al., 2024) showed that no cultural differences between Israeli and German participants emerged in the process of anthropomorphizing robots. However, in this case, it is worth noticing that it was the only study that recruited specialized participants (design students and professional designers) instead of individuals from the general population.

RQ4. Do findings vary as a function of (i) the definition of culture and anthropomorphism, (ii) the methodological factors used (participants' characteristics, robot's characteristics)?

When looking at the results outlined in the previous section, what immediately stands out is the large variability of the research outcomes. First, the results were mixed, i.e., some of the reviewed studies highlighted the existence of a relationship between participants' culture and their likelihood to anthropomorphize robots, whereas some others reported a lack of relationship between the two. Second, when considering only research outcomes showing the effect of participants' culture on their anthropomorphism towards robots, we observed systematic variations in those outcomes. Therefore, we sought to understand whether these variations (at least in part) might be related to some methodological factors. Specifically, we wanted to address whether they might depend on i) the way the two variables of interest, i.e., culture and anthropomorphism, were defined; ii) the methodological factors used, in terms of participants' characteristics and robot characteristics. Therefore, in the next subsections, we addressed the contribution of these factors separately.

RQ4A. Do research findings vary depending on the definition of culture and anthropomorphism?

In the previous section, we stated that none of the reviewed studies provided a clear and explicit definition of culture. This is not true for the other variable of interest, i.e., anthropomorphism, which has been more clearly defined. However, although the definitions used aligned with the ones provided by Fischer (2021), i.e., anthropomorphic design and psychological anthropomorphism, there was no consensus in the reviewed study about a unique and comprehensive definition. That said, it is not surprising that we found no clear evidence of systematic variations in the research outcomes depending on the definition of the two variables of interest, i.e., i) culture and ii) anthropomorphism. In other words, results related to the effect of culture on anthropomorphism towards robots remain mixed, regardless of the definition (or lack of) given to both variables.

Regarding i) the definition of culture, none of the reviewed studies explicitly defined culture (see answer to RQ1 for more details). The only distinction was between studies explicitly referring to Hofstede's dimensions of culture, e.g. power distance (Li et al., 2024; Mehmood et al., 2024; Salem et al., 2014; Yu & Ngan, 2019) and studies in which culture is operationalized as participants' national-based identity. Considering the first group of studies, i.e. the ones explicitly referring to Hofstede's model of culture, they all found an effect of individuals' cultural values on their tendency to anthropomorphize robots. However, results are not comparable due to the diversity of the methods used (e.g., questionnaires to measure anthropomorphism). Considering the second group of studies, i.e., the ones that did not rely on an explicit definition of culture, they presented mixed results, namely that some of them observed an effect of individuals' culture (the way the author(s) of the study interpreted it) on anthropomorphism towards robots (e.g., Li et al., 2022), whereas some others did not (e.g., Liberman-Pincu et al., 2024).

A similar line of reasoning can be applied also when considering ii) the definition of anthropomorphism. Regardless of whether anthropomorphism- whose definition was mainly in line with the one provided by Epley et al. (2007)- was treated as an independent or a dependent variable, it led to heterogeneous results. For example, when anthropomorphism was considered as an independent variable, some evidence reported a relationship between individuals' culture and their likelihood to anthropomorphize robots (Bartneck, 2008; Castelo & Sarvary, 2022), whereas others did not (Muniz et al., 2024). The same occurred when anthropomorphism was considered a dependent variable, and thus it was addressed whether culture affected anthropomorphism (see answer to RQ3 for more details).

In summary, we cannot provide a clear answer to RQA, i.e., whether the definition of the two variables of interest (culture, anthropomorphism) significantly affects the results, as they are not comparable to each other. When considering i) culture, it is because of a lack of definition of culture, and diverse directionality of results (presence vs. absence of a relationship between culture and anthropomorphism). When considering ii) anthropomorphism, it is because in some studies it was treated as an independent vs. dependent variable, even though the definition of anthropomorphism was consistent across studies.

RQ4B. Do research findings vary depending on the methodological factors?

4.2.1. Participants' characteristics

As previously outlined, all studies involved a well-balanced sample (in terms of gender) of adult participants from the general population. The only exceptions were represented by a study recruiting a sample of children between 5 and 11 years of age (Ríos Rincón et al., 2022), and another study involving a sample of adult specialized participants (i.e., design students and professional designers; (Liberman-Pincu et al., 2024). It is worth noticing that this latter study was one of the three reviewed studies reporting a lack of effect of individuals' culture on anthropomorphism. One study is insufficient to argue that specialized adults, as compared to the general population, are not sensitive to cultural differences in anthropomorphism towards robots; however, participants' degree of prior exposure to robots (depending also on what type of exposure) should be taken into account during participants'

recruitment.

4.2.2. Robot's characteristics

Similarly to Thellman and colleagues' work (Thellman et al., 2022), we focused on three characteristics of robots that might influence the relationship (or lack of) between individuals' culture and their tendency to anthropomorphize robots: i) presentation (i.e., how the robot was introduced to participants in the study), ii) morphology (i.e., anthropomorphic vs. functional), and iii) behavior (i.e., whether the robot behaved socially with participants, or it displayed no behavior). Overall, we observed no systematic variations of the results as a function of robot characteristics; in other words, no variations in any of the selected robot characteristics significantly affected the results, both in terms of the presence/absence of the effect and its directionality (if any).

5. Discussion

The present review aimed to understand whether there is a relationship (and, if so, of what sort) between individuals' culture and their likelihood of anthropomorphizing robots, that is, people's tendency to attribute human-like features to nonhuman agents such as robots (Epley et al., 2007). To do so, we went through a rigorous step-wise process of literature review, which allowed us to obtain a final number of publications (N = 17) that were relevant to the scope of the review.

Our primary finding was that the majority of the reviewed studies (14 out of 17 studies) reported a relationship between the two variables of interest, namely culture and anthropomorphism towards robots. In other words, these studies suggest that individuals' cultural background significantly affects their tendency to anthropomorphize robots. What is worthwhile noticing, however, is that the pattern of results was not consistent across studies. Indeed, some studies showed a stronger tendency to anthropomorphize robots in Eastern than in Western countries, whereas results of other studies went in the opposite direction, i.e., with people from Western countries anthropomorphizing robots more than people from Eastern countries. Not to mention that a small portion of the reviewed studies showed a lack of relationship between culture and anthropomorphism, namely, individuals' cultural background does not significantly affect their tendency to ascribe anthropomorphic traits to robots.

Although interesting, it is not a conclusive finding, since the results were highly mixed. First, some studies showed a relationship between people's culture and anthropomorphism towards robots, whereas others did not. Second, within the cluster of studies reporting a significant effect of culture on anthropomorphism, the direction of the effect is not consistent across studies, as previously outlined.

That said, our subsequent step was to investigate whether the mixed findings of our review were due, at least in part, to theoretical and/or methodological factors. With the former, we referred to the conceptualization and definition of the two variables of interest (culture and anthropomorphism). With the latter, we referred to the methods used to investigate the relationship between them, and related to both participants and the robot involved. To help readers follow the flow of arguments, in the next sections we will discuss them separately.

5.1. How theoretical factors affect the relationship between culture and anthropomorphism in HRI

5.1.1. Definition of culture

Regarding the definition of culture, we observed that none of the reviewed studies clearly defined the concept of culture. Conversely, they assumed the equivalence of “culture” with the concept of national-based identity, according to which individuals' culture overlaps with the culture of their country of origin. Only one study (Spatola et al., 2022) adopted a broader definition of culture, thus assessing also people's individual cultural values. In some studies (e.g., (Li et al., 2024; Yu & Ngan, 2019), culture has been conceptualized with explicit reference to the cultural model of Hofstede (2011), for example to the dimension of power distance; however, the model remains a country (national)-based perspective on culture. One possible explanation for the lack of clarity in the definition of culture is that the majority of studies investigating culturally mediated anthropomorphism have been published in journals and conference proceedings associated with the computer science and robotics communities (see Section 3), whereas the concept of ‘culture’ is traditionally discussed and defined in fields such as anthropology and philosophy. While this cannot be a conclusive explanation, this consideration supports the idea that a deeper exchange between the technological and humanistic research communities may lead to a more nuanced understanding of the concept of ‘culture’ and a richer analysis of how culture mediates anthropomorphism in HRI.

In any case, there are grounds for arguing that the national perspective on culture that is most often found in the literature is outdated. Two important aspects need to be considered: (i) the complexity of the society in which we live, and (ii) the emergence of acculturation phenomena. These two aspects suggest that a nation-based concept of ‘culture’ is too rigid and essentially inadequate to fully understand the cultural mediation of anthropomorphism in HRI.

Regarding the first aspect (i), the nationally-based definition as postulated by Hofstede (2011) poses at least two problems (Ornelas et al., 2023). First, it does not consider that individuals or groups, due to their personal history and experiences, can deviate from their country (and thus culture) of origin, which means that individuals or groups who do not fit into the definition of their traditional national culture are automatically neglected and more easily excluded (as in the case of refugees and immigrants). Second, the focus on national culture obfuscates the complexity, and various nuances, of culture, for example, subcultures and minority groups. These two issues raise awareness of the fact that culture as the individual's national identity does not fully reflect the complexity of society as it is, risking being divorced from the psychological and social reality of how cultural behavior emerges (Ornelas et al., 2023). Therefore, the conception and adoption of a broader definition of culture, which embeds also more individual psychological and sociological traits other than their country of origin, might be beneficial not only for the HRI domain but also to other research domains (e.g., psychology, anthropology, sociology). In turn, this might help to better operationalize culture in empirical studies. Already two decades ago, UNESCO made a substantial step in this direction, defining culture as a set of distinctive spiritual, material, intellectual, and emotional features of a society or social group. However, other features such as daily practices and individual behavior should be included to enhance and complete the definition of cultural identity (UNESCO, 2002), which would then incorporate not only a national but also an individual (and thus subjective) dimension of culture.

Regarding the second aspect (ii), acculturation is an important concept that should be more embedded into the HRI domain. Berry (2005) defined it as the dual process of cultural and psychological change that occurs as a result of contact between two or more cultural groups and their members. At the individual level, it involves changes in a person's behavioral repertoire; at the group level, it involves changes in social structures, institutions, and cultural practices (Berry, 2005). In short, what is important is to conceptualize, and then adopt, a more flexible definition of culture, which involves not only individuals' national identity but also encompasses other levels of analysis.

In summary, we observed that most of the studies reported a relationship between culture and anthropomorphism, suggesting that individuals' cultural background significantly affects their tendency to anthropomorphize robots. However, it seems that this relationship does not systematically vary as a function of the definition of culture, that is, the way the notion of “culture” was used in the reviewed studies did not systematically affect the results (and their heterogeneity). However, it is important to be cautious with this, as we also observed that none of the authors provided an explicit- least of all, unitary- definition of culture; thus, it is extremely difficult to conclude whether the definition of

culture significantly affected our results.

5.1.2. Definition of anthropomorphism

Regarding the definition of anthropomorphism, what we observed was that, transversely to the reviewed studies, the most used definition was the one provided by Epley et al. (2007), according to which anthropomorphism is the tendency to attribute human-like traits to nonhuman agents such as robots. As for culture, it seems that our findings did not systematically vary as a function of the definition of culture; however, we cannot draw any definitive conclusion on that, especially considering that anthropomorphism was treated differently across studies (i.e., independent vs. dependent variable). However, we do believe that this distinction between the roles that a variable of interest can assume might be relevant for future research, and thus might be taken into consideration.

5.2. How methodological factors affect the relationship between culture and anthropomorphism in HRI

As previously outlined, it seems that the mixed findings we obtained in our review were not systematically due to theoretical factors, i.e., the definition of the two concepts of interest (culture and anthropomorphism). However, we also sought to investigate whether methodological factors, i.e., methods used to investigate the relationship between culture and anthropomorphism (related to both participants and the robot involved), played a role in modulating this relationship.

Specifically, we focused on three specific factors: (1) measures of the two variables of interest, namely culture (a) and anthropomorphism (b), (2) factors related to participants, and (3) factors related to the robots involved in the studies.

Concerning measures of culture (1a), we observed that none of the reviewed studies adopted a specific measure to quantify culture. Instead, based on the assumption that culture corresponds to individuals' national culture, all the studies recruited participants based on a priori criteria of national identity, such as country of origin or mother tongue. The only exception was one study (Spatola et al., 2022), in which the authors collected information related to participants' cultural values at the individual level through the corresponding questionnaire (CVS; Yoo et al., 2011). In some cases, where culture was explicitly identified with one or more dimensions of Hofstede's cultural model (for example, individualism vs. collectivism or power distance), the corresponding subscales of the questionnaire by Hofstede and Minkov (2013) were used. However, our findings did not vary as a function of the methods used to measure culture; in other words, the existence or the lack of effect of culture on anthropomorphism towards robots, as well as the directionality of the effect (if any), did not systematically vary as a function of the measures of culture adopted in the reviewed studies.

A similar observation can be made when focusing on the measures of anthropomorphism towards robots (1b). As described above, the definition of anthropomorphism was rather consistent across studies, since the author(s) mainly referred to the definition of Epley et al. (2007). More in detail, they adopted it to various degrees, ranging from those who stuck to that to those who more implicitly referred to it, perhaps reworking that (see Supplementary Materials, Table SM.2., p. 5, for a summary of definitions of anthropomorphism). Similarly, the measurements adopted for anthropomorphism were rather consistent across studies. They were predominantly verbal, which means that anthropomorphism towards robots was mainly measured by Likert-like scales, being either questionnaires that were extensively used already (e.g., the IDAQ questionnaire from Waytz et al. (2010), or the Godspeed questionnaire by Bartneck et al. (2009) or new methods such as the anthropomorphism index (Dang & Liu, 2023). Given their consistency, in terms of types of measures adopted across the reviewed studies, they did not systematically affect our findings, in terms of both 1) the presence or absence of the effect of culture on anthropomorphism, and 2) the directionality of the effect, if any. Notably, the same analysis also applied when considering anthropomorphism as an independent vs. dependent variable.

Concerning participant-related factors (2), we considered the composition of the sample sizes recruited for each study both in terms of age (adults vs. children) and expertise towards robots (general population vs. specialized participants). Regarding age, only one study involved a sample of children (Ríos Rincón et al., 2022), whereas all the others involved adult participants; thus, it is not sufficient to draw any conclusion about whether age modulates the relationship between culture and anthropomorphism towards robots, and in which direction. Regarding expertise, only one study (Liberman-Pincu et al., 2024) involved specialized participants, i.e., design students and professional designers; all the others recruited participants from the general population (or, at least, no information was given regarding participants' expertise). It is worth noting that this study was one of the few reporting a lack of effect of culture on participants' tendency to anthropomorphize robots. It is not sufficient to conclude that specialized participants from various cultures have a comparable tendency to anthropomorphize robots; however, future studies should address this issue, to understand what is the role of expertise (if any) in cross-cultural HRI studies.

Concerning robot-related factors (3), overall, we did not find a systematic variation of the results as a function of the characteristics of the robot(s) involved in the reviewed studies. However, we would like to make some considerations. Regarding the robot presentation, the reviewed literature provides mixed results (presence/absence of the effect of culture on the anthropomorphism towards robots) regardless of whether the robot was presented via a verbal description, a video, or it was physically sharing the same space of participants during the experiment. However, we noticed that the majority of no results (where "no results" stands for a lack of relationship between culture and anthropomorphism towards robots) emerged when participants were provided with a verbal description of the robot (robot presentation == [text]; (Liberman-Pincu et al., 2024) or when the presentation was mixed, i.e., when two modalities were combined and one of them was the verbal description (e.g., [text + image] as in (Muniz et al., 2024); or [video + physical] as in (Fraune et al., 2020). At present, we are not able to say whether, and how, it affects our results; however, it was worthwhile to mention, as it might be taken into account in future research and properly tested in further experiments.

Regarding robot behavior, another point that we would like to raise is that when the reviewed study comprised a direct social interaction between the robot and the participants (e.g., Evers et al., 2008; Salem et al., 2014) results are consistent with each other, namely, they all show that participants' culture modulates anthropomorphism towards robots, and in the same direction (i.e., Eastern cultures are more disposed towards anthropomorphism than Western cultures). On the contrary, when the robot displayed no behavior (for example, because the robot was presented in the form of pictures(, then the results were mixed, both in terms of i) presence/absence of the effect and ii) directionality of the effect (if any). Again, there is too little evidence to conclude that the behavior (or lack of behavior) of the robot significantly modulates the effect of participants' culture on their tendency to anthropomorphise robots. This could therefore be an interesting topic for future research.

6. Conclusions and limitations

What prompted us to conduct this review regarding the potential role of individuals' cultural background in anthropomorphism towards robots is the relevance that this latter started to gain in the HRI field. As Fischer (2021) precisely pointed out, anthropomorphism can have a double meaning. It can be seen as a *property of robots* (what Fischer calls "anthropomorphic design"), which can trigger an anthropomorphizing behavior. In other words, designing robots with human-like features (in terms of both physical appearance and behavior) might trigger people to respond to robots similarly to how they do with other humans. However, anthropomorphism can be seen as the people's tendency to attribute

human-like characteristics to robots; in this sense, it is crucial to understand what factors might contribute to ascribing "humanness" to robotic agents. In this context, anthropomorphism is more akin to a psychological phenomenon, and this is what interested us. Moreover, we decided to focus on culture, in terms of individuals' cultural background, as a factor potentially affecting people's likelihood of anthropomorphizing robots. It is a relevant factor, given that robots (and especially *social robots*) are increasingly present in human societies. Thus, it is imperative to understand how to design robots well-tailored to humans' attitudes and needs, including culture, and what factors are affecting the use of robots by humans.

In summary, what we observed was that, in the majority of the reviewed studies, a significant relationship emerged between culture and anthropomorphism. In other words, participants' cultural profile modulated their likelihood of attributing anthropomorphic traits to robots. However, results are mixed, both in terms of (i) presence/absence of this relationship, and (ii) directionality of it (if any). Because of that, we sought to assess whether the mixed nature of our results was due, at least in part, to theoretical and/or methodological factors. Regarding theoretical factors, namely the definition of culture and anthropomorphism provided in the reviewed papers, we observed that they do not vary our results systematically. Furthermore, we consistently noticed that the definition of culture is often not provided or lacks clarity. This may be due to the lack of cross-fertilization between the communities of computer scientists and roboticists, on the one hand, and the communities of anthropologists and philosophers, on the other, in which the very concept of 'culture' is defined, discussed, and problematized. We also noted that the nationally dependent definition of culture as postulated by Hoftstede's cultural model (Hofstede, 2011) is somewhat outdated, and it does not reflect anymore the complexity of the cultural context people are immersed in. In these modern times, in which both societal and environmental events (wars, job crises, climate change, etc.) force people to move from one place to another, it is not plausible anymore to stick to a definition of culture that overlaps with the concept of national identity. Or, at least, it would be important to expand the concept of culture beyond national identity, incorporating also other aspects. One example might be to consider also as individual cultural values overcoming the traditional, binary distinction between Eastern and Western countries, or the boundaries between one geographical nation and another. If we can keep this in mind, it would be easier to operationalize culture, and thus select the appropriate instruments to study it in empirical research (not only limited to the HRI domain).

Conversely, the concept of anthropomorphism is usually well-defined, and in the context of our study we observed that researchers tend to stick to one definition (i.e., the one from Epley et al., 2007). Therefore, there is more consistency in how the concept of anthropomorphism is described as compared to culture, as well as in terms of its operationalization. However, also in this case it is important to be cautious. A recent paper by Heyselaar (2023) replicated the first seminal CASA study published (Nass et al., 1994), in which the authors showed that participants mindlessly apply with artificial agents (specifically, computers) the same social behaviors that they use with other humans. However, in Heyselaar's study the original results were not replicated, i.e., participants no longer interact with computers as if they were humans. One explanation that the author gave was that, in the past few years, technology and its role in human society changed drastically and quickly, and thus people got more used to being surrounded by (and using) various kinds of artificial agents (Heyselaar, 2023). In the context of our study, what is worthwhile noticing is that, if these results were further replicated, it would become less meaningful to study factors modulating anthropomorphism towards artificial agents, including social robots. At present, however, the application of the CASA theory is still valid, especially in the context of emerging technologies (Heyselaar, 2023). Therefore, it is still important to address whether, and how, people attribute human-like characteristics to robots.

Another important issue to raise is that our mixed results might be due to several limitations that critically influenced the findings. One is more theoretical, and- as outlined above- it largely depends on the lack of clarity when defining the two variables of interest, namely culture. From the reviewed paper it is evident that, in most cases, researchers took for granted that individuals' culture fully overlaps with the culture of their country of origin. Although informative this definition closes the door to a broader definition, which might better describe the complexity, and various nuances, of culture.

However, there are other (more methodological) limitations. First, the methods used in the reviewed studies are predominantly verbal, i.e. both variables of interest (culture and anthropomorphism towards robots) were mainly measured via Likert-like scales which asked participants to provide explicit answers/ratings. Although informative, explicit measures envisage a high degree of control by people, for various reasons (i.e., social desirability, conformity to social norms, etc.). On the contrary, implicit measures are performance-based instruments that assess mental contexts indirectly and thus are less influenced by intentional control. That said, in future research it might be worthwhile to combine both types of measures, to have a more comprehensive overview of the phenomenon (and, hopefully, more consistent results). Second, the majority of the reviewed studies were run online, which means that researchers were not physically sharing the same space as participants during the experiment. It might be an issue because experimenters do not know precisely what happens during the completion of the task, as well as they cannot be entirely sure of whether participants fully understood the instructions- in short, they do not have full control over the experimental setting, which in turn might affect the quality of collected data. Based on this, it might be helpful to conduct more rigorous studies, or to find alternative methodologies that might ensure a higher control over the experimental setup.

Moreover, since the results are highly mixed, it leads to lower replicability and thus generalizability of findings. Last but not least, the number of the reviewed studies is rather low (N = 17). Therefore, we could not draw any definitive conclusions on the relationship between culture and anthropomorphism. However, as researchers, we cannot neglect anymore the importance of cultural factors, and how they contribute to shaping people's tendency to ascribe anthropomorphic traits to robots.

CRediT authorship contribution statement

Cecilia Roselli: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Conceptualization. **Leonardo Lapomarda:** Writing – review & editing, Conceptualization. **Edoardo Datteri:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Funding acquisition, Conceptualization.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.104871.

Data availability

No data was used for the research described in the article.

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