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The mediating role of anthropomorphism in adopting the intentional stance towards humanoid robots

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Abstract

Evidence from cognitive psychology showed that cultural differences influence human social cognition, leading to a different activation of social cognitive mechanisms. A growing corpus of literature in Human-Robot Interaction is investigating how culture shapes cognitive processes like anthropomorphism or mind attribution when humans face artificial agents, such as robots. The present

paper aims at disentangling the relationship between cultural values, anthropomorphism, and intentionality attribution to robots, in the context of the intentional stance theory. We administered a battery of tests to 600 participants from various nations worldwide and modeled our data with a path model. Results showed a consistent direct influence of collectivism on anthropomorphism but not on the adoption of the intentional stance. Therefore, we further explored this result with a mediation analysis that revealed anthropomorphism as a true mediator between collectivism and the adoption of the intentional stance. We conclude that our findings extend previous literature by showing that the adoption of the intentional stance towards humanoid robots depends on anthropomorphic attribution in the context of cultural values.

1 Introduction

There is an increasing trend to introduce robots in human' environments in daily contexts such as school, eldercare (for a review see Wykowska, 2020). As humans become exposed to robot presence, it is crucial to examine how robots are represented in the human mind, and how robot actions are perceived and interpreted. (for a review see Wykowska, 2021). Previous studies have shown that people differ in the degree of anthropomorphism [3], [4] and in the likelihood of attributing intentionality to robot actions (Marchesi et al., 2019; Bossi et al., 2020, Hegel et al., 2008; Thellman & Ziemke, 2020). Apart from inter-individual differences such as personality traits [7]–[10], or, as reported by Ghiglino and Wykowska (2020), level of education, also cultural values might be a factor influencing the degree to which robots are perceived as human-like. In the present study, we investigated how the cultural values of individualism and collectivism may influence the anthropomorphic representation of robots (i.e., the attribution of human characteristics to a non-human system) and consequently, the likelihood of adopting the intentional stance towards robots [11]¹. Cultural values such as individualism or collectivism are defined as the core norms and principles shared by a community to organize social life [12]) The importance of cultural values

¹ The concept of intentional stance has been introduced by Dennett (1989) to denote the strategy that people use to explain behaviour of others in intentional terms, that is, by reference to mental states. For example, when observing someone grasping a glass of water, one might explain this behaviour as “reaching for water, because s/he wants to drink”. S/he “wants” is a mental state assumed to underlie the observed behaviour. For more elaborate description, see par. 1.3.

Cultural values influence our general attitudes towards others and social exclusion/inclusion behaviours. For example, Varnum and colleagues [13] report that people from Eastern countries adopt a more holistic approach and are more prone to interdependency (i.e. the tendency to value more relational harmony rather than the individual [14]) compared to people from Western countries. Indeed, several authors reported differences in collectivistic and individualistic values between Eastern and Western countries, leading to the conclusion that collectivism and individualism are “Cultural Syndromes” (for a review see Trandis, 1993). According to Trandis (1993), a Cultural Syndrome is defined when constructs (such as collectivism/individualism) are: 1 – organized around a theme, a value; 2 – the differences within-culture are smaller than across cultures and 3- these constructs are clustered in line with geographic regions (not necessary countries). Therefore, individualism and collectivism can coexist in the same country. Cultural Syndromes are internalized by individuals, thus each person has an individual tendency to adhere to collectivism or individualism and this individual tendency influences our choices in everyday life, especially when we socially interact with other humans and shape the way we present ourselves to others (Bandura, 2002; Markus & Kitayama, 1991; Vygotskji, 1979).

1.1 Anthropomorphism

A second pivotal concept in our study is anthropomorphism in the definition given by Epley and colleagues (2007). The authors describe anthropomorphism as the attribution of human physical or mental characteristics to non-human agents (of any kind or form). Anthropomorphism can be elicited by three factors: 1- the availability of physical characteristics of the agent that can activate knowledge and heuristics related to humans; 2- the possibility of fulfilling the human need for connection and sociality; 3- individual traits [18]. While the first two factors depend on the agent and how much it activates the "human model" [19], the third relies on each individual, and researchers showed that different personality phenotypes have different tendencies to anthropomorphize [7].

1.2 The intentional stance

The third concept core to the present work is the concept of intentional stance. Dennett (1989, 2009) defines the intentional stance as the strategy humans spontaneously adopt when interpreting the

behaviors of other agents with reference to mental states (she desires, he wishes, etc.). Interestingly, according to Dennett, this process takes place towards all agents that fulfill the epistemological requirement of being treated as rational. When this latter requirement is not met, humans can switch to the adoption of a different stance that allows a better explanation of the agent behavior, such as the design stance, defined as interpreting the agent's behavior with reference to how it is designed to behave. Several authors showed that the adoption of intentional stance can take place towards biological and non-biological agents [20]–[22]. As adoption of intentional stance relies on the attribution of human traits (mental states) to agents, it can be considered one aspect of a broader construct of anthropomorphism [8], [23]–[25].

1.3 Cultural differences, anthropomorphism, and the adoption of intentional stance in human-robot interaction (HRI)

Recent literature in HRI investigated the influences of cultural differences when humans face artificial agents (for a review see [26]). The cultural background seems to influence HRI regarding several features of social interaction: likeability, trust, and engagement [27], proxemics [28], recognition of facial expressions [29], and preferred style of communication [30]. On the one hand, findings from social psychology show a higher in-group bias for cultures with high collectivist values (Y. R. Chen et al., 2002; Yamagishi et al., 1998). For instance, Kuchenbrandt and colleagues reported that in-group bias influence people's evaluation of robots [31]. That is because robots are not members of the human (in-) group, and thus, collectivist cultures could be less prone to anthropomorphize them. In addition, Kovačić found that individualistic cultures present a more positive attitude toward technology (compared to collectivist cultures). Kovačić argues that individuals perceive technology as a potentially useful tool to help them perform better [32]. As positive attitudes tend to result in a more positive evaluation, the consequence could be the attribution of positive (human-like) characteristics such as warmth or sociability [33], [34]. Nevertheless, to the best of our knowledge, no study empirically investigated how individual cultural values and specifically, the individual tendency towards collectivism/individualism, shapes the adoption of the intentional stance towards a humanoid robot or anthropomorphism (and a fortiori the interaction between intentional stance and anthropomorphism).

1.4 Assessment of the intentional stance in HRI and the relationship with anthropomorphism

Recently, researchers have investigated whether the intentional stance can be adopted towards humanoid robots [38]–[40] (see also [41] for a review). Marchesi et al. (2019) created the InStance Test (IST), a novel tool to assess the adoption of the intentional stance. The IST consists of a set of scenarios, depicting the iCub humanoid robot [42] involved in several activities (Fig.1). Below each scenario, two sentences are displayed as possible descriptions of the scenario. One description addresses the scenario with reference to a mental state (i.e., intentional stance) and the other with reference to a mechanistic explanation (i.e., design stance). Marchesi and colleagues asked participants to choose which sentence fits best as a description of the scenario by moving a button along a slider. The authors report that indeed there are individual differences in the adoption of the intentional stance, which called for a deeper investigation of the relation between the individual likelihood to adopt the intentional stance towards a robot and the individual tendency to anthropomorphize non-human systems. Indeed, Marchesi et al. (2021) report that the individual differences in anthropomorphism are associated with different levels of individual tendency to adopt the intentional stance towards robots (a higher tendency to anthropomorphize is associated with a higher tendency to adopt the intentional stance to explain the behavior of a humanoid robot) [43].

1.5 Aim of the present research

State-of-the-art research suggests that humans do adopt the intentional stance towards humanoid robots under some circumstances. Moreover, individual traits and other factors might differentiate individuals regarding their likelihood of adopting the intentional stance. Other biases and heuristics such as our tendency to anthropomorphize and individual cultural values such as collectivistic or individualistic attitudes might influence the individual differences. As differences in the level of individualism/collectivism can lead to a higher/lower tendency to anthropomorphize artificial agents . the present paper aims to disentangle the relationship between culture, the various dimensions of anthropomorphism, and the adoption of the intentional stance towards humanoid robots.

To address the aims of our study, we asked participants to complete a battery of questionnaires to model the relationship between the above-mentioned constructs: Cultural Values Scale (CVSCALE, [44], [45]) to measure individual adherence to cultural values; the Human-Robot Interaction scale (HRIES, [46]) to measure anthropomorphism; and the InStance Test (IST, [39]) to measure the degree

of adopting the intentional stance. Our hypotheses were two-folded: first, cultural values should influence anthropomorphism [47][48] [49], and second, building on the results of Marchesi et al (2021), anthropomorphism should positively mediate the causal relationship between the individual tendency towards collectivism and the adoption of the intentional stance.

2 Methods and measures

2.1 Participants

Six hundred – and - one participants from Singapore/Malaysia; the United States of America (USA), the United Kingdom (UK); Germany, Spain, and Italy have been recruited from Prolific. com. We selected these countries to access different levels of individualism-collectivism values and therefore to reach a representative sample (see table 1 for demographics of each country) in return for a payment of 3.3 £. The study was approved by the local Ethical Committee (Comitato Etico Regione Liguria) and was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki). Each participant provided written informed consent before taking part in the experiment by clicking on the “accept” button at the beginning of the survey. All participants were naïve to the purpose of this experiment.

Table 1 Demographic description of the sample

Country	n	Male	Female	Non-Binary	Prefer Not to Answer	M _{age}
USA	100	56	42	2		36.5
UK	100	31	70			38.4
Italy	100	54	42	4		25.8
Spain	100	71	27	1	1	27.7
Germany	100	68	29	2	1	31.0
Singapore/Malaysia	101	32	68	1		27.2

2.2 Task procedure and measures

Participants completed a series of questionnaires tailored to assess different variables that according to our hypothesis, may influence the adoption of the intentional stance toward a humanoid robot. The order of presentation was as follows: Cultural Values Scale, InStance Test, and the Human-Robot Interaction Scale. All questionnaires were administered in English. To guarantee that the respondents would have sufficient knowledge of the English language to understand the task, and the items of the questionnaires, we administered the LexTALE test [50], which provides a measure of the individual level of English proficiency.

Cultural values measure. Hofstede (2011) developed a framework to describe cultural values with a five-dimension model that encompasses power distance, collectivism, uncertainty avoidance, masculinity vs. femininity, and long-term orientation vs. short-term orientation. Power distance refers to how much individuals accept and expect that power is distributed unevenly. Collectivism refers to the extent to which people rely on themselves (individualism) or their group (collectivism). Uncertainty avoidance refers to how much tolerance individuals have for ambiguity. Masculinity vs. femininity refers to how the inequalities between genders are perceived in society and how individuals internalize these inequalities. Finally, long-term orientation refers to the temporal orientation of a society, meaning to what extent individuals feel pressured to plan their life with a long-term mindset.

For the purposes of our study, we adopted the collectivism subscale of the Cultural Values Scale (CVSCALE,[45]), which has proven to be reliable in measuring Hofstede's dimensions of collectivism/individualism at the individual level² (6 items, e.g., Individuals should sacrifice their self-interest for the group; $\omega = .860$, $CI_{95\%} [.843, .877]$). In addition, as Hofstede posited a dimension named "indulgence", which addressed the extent to which a society values leisure time, moral discipline, happiness, and well-being (Enkh-Amgalan, 2016). Khans and Cox reported that indulgent cultures tend

² We administered and analyzed also the other subscales to control for covariance. The other subscales of the CVSCALE dimensions are power distance (6 items, e.g. People in higher positions should make most decisions without consulting people in lower positions; $\omega = .816$, $CI_{95\%} [.793, .839]$), uncertainty avoidance (5 items, e.g. It is important to closely follow instructions and procedures; $\omega = .862$, $CI_{95\%} [.845, .880]$), long-term orientation (6 items, e.g., Long-term planning is important; $\omega = .749$, $CI_{95\%} [.719, .780]$), and masculinity (4 items, e.g. It is more important for men to have a professional career than it is for women; $\omega = .831$, $CI_{95\%} [.808, .853]$).

to create new technology as a way to improve life, to value the expression of emotions and freedom of speech. To explore the indulgence dimension, we developed 5 items added at the very last of the CVSCALE questionnaire (e.g., Freedom of speech is important (see supplementary materials for the complete list of items); $\omega = .715$, $CI_{95\%} [.679, .751]$) [51], [52]. For each item participants had to indicate the extent to which they agree or disagree with the statement from 1 “Disagree strongly” to 7 “Agree strongly”.

Table 2. Descriptive Statistics of the filtered sample for the collectivism subscale (Yoo et al., 2011)

	COLLECTIVISM					
	Ger	Ita	Singa_Malay	Spain	UK	USA
Valid	95	96	95	94	98	94
Mean	4.248	4.115	4.394	4.723	4.296	4.314
Std. Deviation	1.006	1.064	1.024	0.934	1.120	1.281

Anthropomorphism measure. Spatola and colleagues (2020), created the Human-Robot Interaction Evaluation Scale (HRIES) to assess the individual tendency to anthropomorphize social robots. The authors report four subscales: Sociability (i.e., to what extent the robot is perceived as social, $\omega = .840$, $CI_{95\%} [.811, .865]$), Agency (i.e., to what extent the robot it perceived to have agency in its environment, $\omega = .767$, $CI_{95\%} [.727, .803]$), Animacy (i.e., to what extent the robot is perceived as having smooth movements, $\omega = .807$, $CI_{95\%} [.778, .833]$), and Disturbing (i.e., to what extent the robot is perceived as uncanny, $\omega = .883$, $CI_{95\%} [.863, .900]$). Participants were asked to evaluate how closely a series of adjectives would describe the robot (i.e., “Warm”, “Alive”, “Real”). The items were evaluated on a 7-point Likert scale (1: “Not at all”, 7: “Totally”).

Table 3a. Descriptive Statistics of the filtered sample for the HRIES (Spatola et al., 2020)

	HRIES_SOCIABILITY						HRIES_ANIMACY					
	Ger	Ita	Singa_Malay	Spain	UK	USA	Ger	Ita	Singa_Malay	Spain	UK	USA
Valid	95	96	95	94	98	94	95	96	95	94	98	94
Mean	4.921	4.589	4.734	4.987	4.316	4.779	3.634	3.469	3.639	3.489	3.028	3.596
Std. Deviation	1.100	1.046	0.963	0.859	1.471	1.103	1.092	1.213	1.356	1.274	1.367	1.363

Table 3b. Descriptive Statistics of the filtered sample for the HRIES (Spatola et al., 2020)

	HRIES_AGENCY						HRIES_DISTURBANCE					
	Ger	Ita	Singa_Malay	Spain	UK	USA	Ger	Ita	Singa_Malay	Spain	UK	USA
Valid	95	96	95	94	98	94	95	96	95	94	98	94
Mean	4.732	4.289	4.571	4.402	4.408	4.519	2.766	2.953	3.471	3.125	3.112	3.008

Table 3b. Descriptive Statistics of the filtered sample for the HRIES (Spatola et al., 2020)

	HRIES_AGENCY						HRIES_DISTURBANCE					
	Ger	Ita	Singa_Malay	Spain	UK	USA	Ger	Ita	Singa_Malay	Spain	UK	USA
Std. Deviation	0.969	1.216	0.992	1.080	1.247	1.165	1.411	1.380	1.422	1.399	1.617	1.632

Intentional stance measure. The InStance Test (IST) was developed by Marchesi et al. (2019) to assess the individual tendency of adopting the intentional stance towards a humanoid robot. Overall, it consists in 34 scenarios ($\omega = .880$, $CI_{95\%} [.867, .894]$), each one made of three static images depicting the iCub robot (Metta et al., 2010). Below, two sentences are presented (one mentalistic, thus representing the adoption of the intentional stance, and the other mechanistic, thus representing the adoption of the design stance) as possible descriptions of each scenario (Fig.1). Participants' task is to choose the sentence they consider a good fit for the depicted scenario by moving a button on a slider. The obtained score ranges from 0 (totally mechanistic, i.e., design stance) to 100 (totally mentalistic, i.e., intentional stance). For the complete list of items, refer to [39] Supplementary Materials.

Figure 1: Example item from the IST (Marchesi et al., 2019)

Table 4. Descriptive Statistics of the filtered sample for the InStance Test (Marchesi et al., 2019)

	INSTANCE TEST					
	Ger	Ita	Singa_Malay	Spain	UK	USA
Valid	95	96	95	94	98	94
Mean	36.672	36.005	43.365	37.827	32.445	37.923
Std. Deviation	14.825	16.775	13.910	15.790	17.382	17.430

213

214 **3 Analyses and results**

215 **3.1 Filtering procedure**

216 Participants with missing values and values that resulted over or below 2.5 SD on the variable of
217 interests were considered as outliers, leading to a total sample of $N = 572$ participants
218 (Singapore/Malaysia $n = 95$; USA $n = 94$; UK $n = 98$; Germany $n = 95$; Spain $n = 94$; Italy $n = 96$). All
219 the analyses were performed with R (version 4.0.2 [53]) and JASP v.0.14.1 (2020), using the SEM
220 package.

221

222 **3.2 Comparison across Countries on IST and HRIES subscales**

223 To explore differences in the collectivistic tendency, in the adoption of the intentional stance and
224 in the tendency to anthropomorphize across Countries, we performed non-parametrical Kruskal-Wallis
225 test on the collectivism, IST and HRIES subscales scores. Results showed a significant difference in
226 the collectivism subscale of the CVSCALE [$\chi^2 = 16.84$, $df = 5$, $p = .004$, $\epsilon^2 = .029$] and in the IST [χ^2
227 $= 21.42$, $df = 5$, $p < .001$, $\epsilon^2 = .037$]. Moreover, statistical significance emerged also for the Sociability
228 subscale [$\chi^2 = 17.11$, $df = 5$, $p = .004$, $\epsilon^2 = .029$], Animacy subscale [$\chi^2 = 15.52$, $df = 5$, $p = .008$, $\epsilon^2 =$
229 $.027$] and Disturbance subscale [$\chi^2 = 12.69$, $df = 5$, $p = .026$, $\epsilon^2 = .022$] of the HRIES. No statistical
230 significant effect emerged for the Agency subscale of the HRIES [$\chi^2 = 8.56$, $df = 5$, $p = .127$, $\epsilon^2 = .014$].
231 Post-Hoc comparison with Tukey HSD correction are reported in the supplementary materials.

232 To further explore the relationship between collectivistic tendency, adoption of the intentional
233 stance, and anthropomorphic attribution we performed a path model analysis.

234

235 **3.3 Structural Equation Model**

236 First, to explore the structural relationship between our variables, we conducted a path model
237 analysis. We defined our model introducing all the subscales from the CVSCALE (to control for
238 covariance) as first-order variables, all the subscales from the HRIES as second-order variables, and
239 the IST as the outcome variable. We controlled for covariance between same-level variables. In

addition, to account for possible differences in the knowledge of the English language, we added the LexTALE test [50] as a covariate (see Supplementary Materials for all model parameters). All 95% Confidence Intervals were calculated with a bias-corrected percentile bootstrap analysis with 10,000 samples [54], with a Maximum Likelihood estimator, that has been proven to provide more precise model fit indices and less biased parameters, compared to other estimators such as Generalized Least Squares and Weighted Least Squares [55]. All variables were z-score corrected. The model fit indices and Information Criteria are reported

respectively in Figure 2.

3.4 Structural Equation Model Results

Figure 2 represents all the significant paths that emerged from the path model, revealing a consistent direct influence of collectivism on the anthropomorphism constructs (specifically on the Sociability, Agency, and Animacy subscales) but not on the IST. Given our initial hypothesis, we further explored the indirect relationship between collectivism and IST (collectivism → anthropomorphism → intentional stance) with a mediation model, considering the above-mentioned variables as the predictor, mediator, and outcome, respectively. All paths' parameters are reported in the supplementary materials.

Figure 2. Panel A: Model path. We reported the significant (in black) and non-significant (in grey) paths with the associated b statistics. Panel B: Fit indices of our model.

3.5 Indirect effects

As a second step, building upon the significant paths in the path model analysis, we tested the mediating effect of anthropomorphism between the individual collectivism tendency and the adoption of the intentional stance. As in the previous analysis, all data points were z-score corrected. The strategy to calculate the 95% Confidence Intervals was kept constant (a bias-corrected percentile bootstrap analysis with 10,000 samples), as the Maximum Likelihood estimator.

The indirect effects of collectivism on IST through the HRIES scale were significant when mediated by the Sociability subscale [$b = 0.025$, $\text{bootSE} = 0.011$, $z = 2.253$, $p = 0.024$, $\text{bootC.I. 95\%}$

(0.006; 0.054)], the Animacy subscale [$b = 0.016$, $\text{bootSE} = 0.008$, $z = 1.996$, $p = 0.046$, $\text{bootC.I. 95\%}$ (0.003; 0.039)] and the Agency subscale [$b = 0.023$, $\text{bootSE} = 0.010$, $z = 2.424$, $p = 0.015$, $\text{bootC.I. 95\%}$ (0.007; 0.047)]. No indirect effect of collectivism on IST mediated by the Disturbing subscale ($\text{bootC.I. included } 0$, see Table 2) was observed.

Table 2 - Indirect effects

							95% Confidence Interval			
							Lower	Upper		
			Estimate	Std. Error	z-value	p				
CV_COLL	→	HRIES_SOC	→	IST	0.025	0.011	2.253	0.024	0.006	0.054
CV_COLL	→	HRIES_AN	→	IST	0.016	0.008	1.996	0.046	0.003	0.039
CV_COLL	→	HRIES_AG	→	IST	0.023	0.010	2.424	0.015	0.007	0.047
CV_COLL	→	HRIES_DIST	→	IST	0.001	0.005	0.280	0.780	-0.009	0.015

Note. Delta method standard errors, bias-corrected percentile bootstrap confidence intervals, ML estimator. NB: Not all bootstrap samples were successful: CI based on 9998 samples.

Following Zhao and colleagues' classification (Zhao et al., 2010), anthropomorphism seems to play the role of a true mediator between the individual collectivism tendency and the adoption of the intentional stance towards a humanoid robot. This seems particularly true for the mediation role of the perceived level of Sociability, Animacy, and Agency of the robot, while the Disturbing dimension seemed not to mediate the effect. Nonetheless, the total indirect effect of Collectivism on the IST is significant [$b = 0.065$, $\text{bootSE} = 0.018$, $z = 3.623$, $p = <.001$, $\text{bootC.I. 95\%}$ (0.029; 0.104)], indicating the total mediating role of attributed anthropomorphism on the relationship between the individual tendency towards collectivism and the individual likelihood of adopting the intentional stance towards a humanoid robot (Table 2). The higher the level of collectivism, the higher the anthropomorphic attribution, and the higher the likelihood of adopting the intentional stance towards a humanoid robot.

3.6 Exploratory analyses

In addition, to confirm that our model was indeed the best to describe the relationship between the constructs of interest, we post-hoc compared our mediation analysis with a second model that considered the adoption of the intentional stance as mediator (collectivism → intentional stance → anthropomorphism). Results showed that there is no mediation effect of the intentional stance on the considered anthropomorphism constructs (model parameters are reported in supplementary materials).

This showed that the tendency towards collectivism influenced the tendency to anthropomorphize and, only through anthropomorphism, collectivism influenced the tendency to adopt the intentional stance towards humanoid robots.

4 Discussion

In the present paper, we aimed at disentangling the relationship between cultural values, the tendency to anthropomorphize, and the tendency to adopt the intentional stance towards a humanoid robot. To address this aim, we first built a structural model to test whether our hypothesized relationship between the variables (and relative sub-constructs) would hold: differences in cultural values should influence anthropomorphism and the adoption of the intentional stance. Results showed that cultural values, in particular the level of individualism/collectivism, directly influence anthropomorphism, but not the adoption of the intentional stance. The higher the collectivism, the higher the anthropomorphism. Our second step was to investigate whether anthropomorphism would play a mediating role between collectivism and the adoption of the intentional stance. The mediation results showed that when considering the role of anthropomorphism as a mediator between culture (as a predictor) and the adoption of the intentional stance towards robots (as the outcome), the relationship was significant. In particular, our results showed that the Agency, Sociability, and Animacy subscales of the HRIES were positive mediators between collectivism and adoption of the intentional stance. Interestingly, the “disturbing” subscale of HRIES (i.e. negative appraisal) seems to rely on a parallel process, as it is not influenced by collectivism. However, it still has a positive effect on Intentional Stance. The higher the score on the disturbing subscale, the higher the IST. A tentative interpretation of this result could rely on the distinctiveness threat hypothesis discussed by Ferrari et al. (2016). The authors argue that individuals could feel threatened by the increased (imaginative) similarity of robots' appearance and capacities to humans [56]. In this context, the observer does not adopt a design stance but on the contrary, overestimates the abilities of the robot, attributing to the artificial agent humanlike characteristics such as intentions. In other words, the distinctiveness threat results in an overestimation of the human-like properties of the robot (as a negative expectation). This result is consistent with previous literature, where collectivistic cultures are reported to have more negative attitudes towards robots and do not perceive them as part of their in-group (Bartneck et al., 2007, Wang et al., 2010, Marchesi, Roselli and Wykowska, 2021).

More generally, the model showed a strong influence of collectivism on anthropomorphism and – through anthropomorphism – on the adoption of the intentional stance towards a humanoid robot. The relationship in the reverse direction (intentional stance → anthropomorphism) was not observed. In other words, cultural values, in particular collectivism, influence our perception of robots in terms of anthropomorphic attributions. This result is in line with previous literature that shows how collectivistic cultures tend to anthropomorphize, like more and trust more, anthropomorphically-shaped or zoomorphic robots (for a review see Lim, Rooksby, and Cross, 2020). The present results extend the previous findings by demonstrating that the adoption of the intentional stance towards robots depends on anthropomorphism in a context of cultural values. Therefore, interpretation of the robot's actions would depend on prior attribution of anthropomorphic characteristics. This attribution would be influenced by the cultural values adopted by the observer.

Future experiments should attempt to create a vaster and more comprehensive theoretical model of how these variables and their facets interact with each other when humans predict the behaviour of a robot. Moreover, more theoretical and empirical investigations should explore the presence of new variables that may play a role in the adoption of the intentional stance towards humanoid robots.

5 Author Contributions

SM and AW designed the task. SM performed data collection, SM and NS performed data analysis, SM, NS, and AW discussed the data. SM, NS, and AW wrote and edited the manuscript. All authors contributed to reviewing the manuscript and approved it.

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352 **7 References**

- 353 [1] A. Wykowska, “Social Robots to Test Flexibility of Human Social Cognition,” *Int. J. Soc.*
354 *Robot.*, vol. 12, no. 6, pp. 1203–1211, 2020, doi: 10.1007/s12369-020-00674-5.
- 355 [2] A. Wykowska, “Robots as Mirrors of the Human Mind,” *Curr. Dir. Psychol. Sci.*, vol. 30, no.
356 1, pp. 34–40, 2021, doi: 10.1177/0963721420978609.
- 357 [3] H. Cullen, R. Kanai, B. Bahrami, and G. Rees, “Individual differences in anthropomorphic
358 attributions and human brain structure,” *Soc. Cogn. Affect. Neurosci.*, vol. 9, no. 9, pp. 1276–
359 1280, 2013, doi: 10.1093/scan/nst109.
- 360 [4] M. G. Chin, V. K. Sims, B. Clark, and G. R. Lopez, “Measuring Individual Differences in
361 Anthropomorphism toward Machines and Animals,” *Proc. Hum. Factors Ergon. Soc. Annu.*
362 *Meet.*, vol. 48, no. 11, pp. 1252–1255, 2004, doi: 10.1177/154193120404801110.
- 363 [5] F. Hegel, S. Krach, T. Kircher, B. Wrede, and G. Sagerer, “Understanding social robots: A user
364 study on anthropomorphism,” *Proc. 17th IEEE Int. Symp. Robot Hum. Interact. Commun. RO-*
365 *MAN*, pp. 574–579, 2008, doi: 10.1109/ROMAN.2008.4600728.
- 366 [6] S. Thellman and T. Ziemke, “Do You See what I See? Tracking the Perceptual Beliefs of
367 Robots,” *iScience*, vol. 23, no. 10, p. 101625, 2020, doi: 10.1016/j.isci.2020.101625.
- 368 [7] N. Spatola and A. Wykowska, “The personality of anthropomorphism: How the need for
369 cognition and the need for closure define attitudes and anthropomorphic attributions toward
370 robots,” *Comput. Human Behav.*, vol. 122, p. 106841, 2021, doi: 10.1016/j.chb.2021.106841.
- 371 [8] G. Airenti, “The development of anthropomorphism in interaction: Intersubjectivity,
372 imagination, and theory of mind,” *Front. Psychol.*, vol. 9, no. NOV, pp. 1–13, 2018, doi:
373 10.3389/fpsyg.2018.02136.
- 374 [9] A. Waytz, J. Cacioppo, and N. Epley, “Who sees human? The stability and importance of
375 individual differences in anthropomorphism,” *Perspect. Psychol. Sci.*, vol. 5, no. 3, pp. 219–
376 232, 2010, doi: 10.1177/1745691610369336.

- 377 [10] A. D. Kaplan, T. Sanders, and P. A. Hancock, "The relationship between extroversion and the
378 tendency to anthropomorphize robots: A Bayesian analysis," *Front. Robot. AI*, vol. 6, no. JAN,
379 2019, doi: 10.3389/frobt.2018.00135.
- 380 [11] J. Haugeland and D. C. Dennett, "True Believers: The Intentional Strategy and Why It Works,"
381 *Mind Des. II*, 2020, doi: 10.7551/mitpress/4626.003.0003.
- 382 [12] H. C. Triandis, *Individualism and collectivism*. 2018.
- 383 [13] M. E. W. Varnum, I. Grossmann, S. Kitayama, and R. E. Nisbett, "The origin of cultural
384 differences in cognition: The social orientation hypothesis," *Curr. Dir. Psychol. Sci.*, vol. 19,
385 no. 1, pp. 9–13, 2010, doi: 10.1177/0963721409359301.
- 386 [14] S. Kitayama, M. Karasawa, K. B. Curhan, C. D. Ryff, and H. R. Markus, "Independence and
387 interdependence predict health and wellbeing: Divergent patterns in the United States and
388 Japan," *Front. Psychol.*, vol. 1, no. SEP, pp. 1–10, 2010, doi: 10.3389/fpsyg.2010.00163.
- 389 [15] A. Bandura, "Social cognitive theory in cultural context," *Appl. Psychol.*, vol. 51, no. 2, pp.
390 269–290, 2002, doi: 10.1111/1464-0597.00092.
- 391 [16] H. R. Markus and S. Kitayama, "17. Markus & Kitayama (1991)," *Psychol. Rev.*, vol. 98, no. 2,
392 pp. 224–253, 1991.
- 393 [17] S. T. Parker, : *Mind in Society: The Development of Higher Psychological Processes* . L. S.
394 Vygotsky., vol. 81, no. 4. 1979.
- 395 [18] N. Epley, A. Waytz, and J. T. Cacioppo, "On Seeing Human: A Three-Factor Theory of
396 Anthropomorphism," *Psychol. Rev.*, vol. 114, no. 4, pp. 864–886, 2007, doi: 10.1037/0033-
397 295X.114.4.864.
- 398 [19] E. Wiese, G. Metta, and A. Wykowska, "Robots as intentional agents: Using neuroscientific
399 methods to make robots appear more social," *Front. Psychol.*, vol. 8, no. OCT, pp. 1–19, 2017,
400 doi: 10.3389/fpsyg.2017.01663.
- 401 [20] F. Happé and U. Frith, "Theory of Mind in Autism," *Learn. Cogn. Autism*, pp. 177–197, 1995,
402 doi: 10.1007/978-1-4899-1286-2_10.

- 403 [21] F. Heider and M. Simmel, "University of Illinois Press <http://www.jstor.org/stable/1416950> .,"
404 *Am. J. Psychol.*, vol. 57, no. 2, pp. 243–259, 1944.
- 405 [22] J. Zwickel, "Agency attribution and visuospatial perspective taking," *Psychon. Bull. Rev.*, vol.
406 16, no. 6, pp. 1089–1093, 2009, doi: 10.3758/PBR.16.6.1089.
- 407 [23] M. Dacey and M. Dacey, "Anthropomorphism as Cognitive Bias Mike Dacey," no. 2002, pp.
408 1–19, 1957.
- 409 [24] A. Waytz, N. Epley, and J. T. Cacioppo, "Social cognition unbound: Insights into
410 anthropomorphism and dehumanization," *Curr. Dir. Psychol. Sci.*, vol. 19, no. 1, pp. 58–62,
411 2010, doi: 10.1177/0963721409359302.
- 412 [25] J. Złotowski, E. Strasser, and C. Bartneck, "Dimensions of anthropomorphism: From humanness
413 to humanlikeness," *ACM/IEEE Int. Conf. Human-Robot Interact.*, pp. 66–73, 2014, doi:
414 10.1145/2559636.2559679.
- 415 [26] V. Lim, M. Rooksby, and E. S. Cross, "Social Robots on a Global Stage: Establishing a Role
416 for Culture During Human–Robot Interaction," *Int. J. Soc. Robot.*, 2020, doi: 10.1007/s12369-
417 020-00710-4.
- 418 [27] P. L. P. Rau, Y. Li, and D. Li, "A cross-cultural study: Effect of robot appearance and task," *Int.*
419 *J. Soc. Robot.*, vol. 2, no. 2, pp. 175–186, 2010, doi: 10.1007/s12369-010-0056-9.
- 420 [28] M. S. Remland, T. S. Jones, and H. Brinkman, "Proxemic and haptic behavior in three European
421 countries," *J. Nonverbal Behav.*, vol. 15, no. 4, pp. 215–232, 1991, doi: 10.1007/BF00986923.
- 422 [29] R. E. Jack, C. Blais, C. Scheepers, P. G. Schyns, and R. Caldara, "Cultural Confusions Show
423 that Facial Expressions Are Not Universal," *Curr. Biol.*, vol. 19, no. 18, pp. 1543–1548, 2009,
424 doi: 10.1016/j.cub.2009.07.051.
- 425 [30] I. Papadopoulos and C. Koulouglioti, "The Influence of Culture on Attitudes Towards
426 Humanoid and Animal-like Robots: An Integrative Review," *J. Nurs. Scholarsh.*, vol. 50, no. 6,
427 pp. 653–665, 2018, doi: 10.1111/jnu.12422.
- 428 [31] D. Kuchenbrandt, F. Eyssel, S. Bobinger, and M. Neufeld, "When a Robot's Group Membership
429 Matters: Anthropomorphization of Robots as a Function of Social Categorization," *Int. J. Soc.*

- 430 *Robot.*, vol. 5, no. 3, pp. 409–417, 2013, doi: 10.1007/s12369-013-0197-8.
- 431 [32] Z. J. Kovačić, “The impact of national culture on worldwide eGovernment readiness,” *Informing*
432 *Sci.*, vol. 8, pp. 143–158, 2005, doi: 10.28945/492.
- 433 [33] J. K. Swencionis, C. H. Dupree, and S. T. Fiske, “Warmth-Competence Tradeoffs in Impression
434 Management across Race and Social-Class Divides,” *J. Soc. Issues*, vol. 73, no. 1, pp. 175–191,
435 2017, doi: 10.1111/josi.12210.
- 436 [34] C. Bartneck, T. Suzuki, T. Kanda, and T. Nomura, “The influence of people’s culture and prior
437 experiences with Aibo on their attitude towards robots,” *AI Soc.*, vol. 21, no. 1, pp. 217–230,
438 2007, doi: 10.1007/s00146-006-0052-7.
- 439 [35] T. Chaminade *et al.*, “How do we think machines think? An fMRI study of alleged competition
440 with an artificial intelligence,” *Front. Hum. Neurosci.*, vol. 6, no. MAY 2012, pp. 1–9, 2012,
441 doi: 10.3389/fnhum.2012.00103.
- 442 [36] H. L. Gallagher, A. I. Jack, A. Roepstorff, and C. D. Frith, “Imaging the intentional stance in a
443 competitive game,” *Neuroimage*, vol. 16, no. 3 I, pp. 814–821, 2002, doi:
444 10.1006/nimg.2002.1117.
- 445 [37] C. Özdem, E. Wiese, A. Wykowska, H. Müller, M. Brass, and F. Van Overwalle, “Believing
446 androids–fMRI activation in the right temporo-parietal junction is modulated by ascribing
447 intentions to non-human agents,” *Soc. Neurosci.*, vol. 12, no. 5, pp. 582–593, 2017, doi:
448 10.1080/17470919.2016.1207702.
- 449 [38] A. M. Abu-Akel, I. A. Apperly, S. J. Wood, and P. C. Hansen, “Re-imaging the intentional
450 stance,” *Proc. R. Soc. B Biol. Sci.*, vol. 287, no. 1925, pp. 1–9, 2020, doi:
451 10.1098/rspb.2020.0244.
- 452 [39] S. Marchesi, D. Ghiglino, F. Ciardo, J. Perez-Osorio, E. Baykara, and A. Wykowska, “Do we
453 adopt the intentional stance toward humanoid robots?,” *Front. Psychol.*, vol. 10, no. MAR, 2019,
454 doi: 10.3389/fpsyg.2019.00450.
- 455 [40] S. Thellman, A. Silvervarg, and T. Ziemke, “Folk-psychological interpretation of human vs.
456 humanoid robot behavior: Exploring the intentional stance toward robots,” *Front. Psychol.*, vol.

- 8, no. NOV, pp. 1–14, 2017, doi: 10.3389/fpsyg.2017.01962.
- [41] J. Perez-Osorio and A. Wykowska, “Adopting the intentional stance toward natural and artificial agents,” *Philos. Psychol.*, vol. 33, no. 3, pp. 369–395, 2020, doi: 10.1080/09515089.2019.1688778.
- [42] G. Metta *et al.*, “The iCub humanoid robot: An open-systems platform for research in cognitive development,” *Neural Networks*, vol. 23, no. 8–9, pp. 1125–1134, 2010, doi: 10.1016/j.neunet.2010.08.010.
- [43] S. Marchesi, N. Spatola, A. Wykowska, and J. Perez-Osorio, “Human vs humanoid. A behavioral investigation of the individual tendency to adopt the intentional stance,” *ACM/IEEE Int. Conf. Human-Robot Interact.*, pp. 332–340, 2021, doi: 10.1145/3434073.3444663.
- [44] G. Hofstede, “Dimensionalizing Cultures: The Hofstede Model in Context,” *Online Readings Psychol. Cult.*, vol. 2, no. 1, pp. 1–26, Dec. 2011, doi: 10.9707/2307-0919.1014.
- [45] B. Yoo, N. Donthu, and T. Lenartowicz, “Measuring hofstede’s five dimensions of cultural values at the individual level: Development and validation of CVSCALE,” *J. Int. Consum. Mark.*, vol. 23, no. 3–4, pp. 193–210, 2011, doi: 10.1080/08961530.2011.578059.
- [46] N. Spatola, B. Kühnlenz, and G. Cheng, “Perception and evaluation in human-robot interaction: The Human-Robot Interaction Evaluation Scale (HRIES) – a multicomponent approach of anthropomorphism,” *Int. J. Soc. Robot.*, 2020, doi: 10.1007/s12369-020-00667-4.
- [47] N. Epley, A. Waytz, S. Akalis, and J. T. Cacioppo, “When we need a human: Motivational determinants of anthropomorphism,” *Soc. Cogn.*, vol. 26, no. 2, pp. 143–155, 2008, doi: 10.1521/soco.2008.26.2.143.
- [48] N. Epley, S. Akalis, A. Waytz, and J. T. Cacioppo, “Creating social connection through inferential reproduction: Loneliness and perceived agency in gadgets, gods, and ghreyhounds,” *Psychol. Sci.*, vol. 19, no. 2, pp. 114–120, 2008, doi: 10.1111/j.1467-9280.2008.02056.x.
- [49] F. Eyssel, D. Kuchenbrandt, S. Bobinger, L. De Ruiter, and F. Hegel, “‘If you sound like me, you must be more human’: On the interplay of robot and user features on human-robot acceptance and anthropomorphism,” in *HRI’12 - Proceedings of the 7th Annual ACM/IEEE*

International Conference on Human-Robot Interaction, 2012, pp. 125–126, doi:
10.1145/2157689.2157717.

[50] K. Lemhöfer and M. Broersma, “Introducing LexTALE: A quick and valid Lexical Test for
Advanced Learners of English,” *Behav. Res. Methods*, vol. 44, no. 2, pp. 325–343, 2012, doi:
10.3758/s13428-011-0146-0.

[51] R. Khan and P. Cox, “Country Culture and National Innovation,” *Arch. Bus. Res.*, vol. 5, no. 2,
2017, doi: 10.14738/abr.52.2768.

[52] A. L. Prim, L. S. Filho, G. A. C. Zamur, and L. C. Di Serio, “The Relationship Between National
Culture Dimensions And Degree Of Innovation,” *Int. J. Innov. Manag.*, vol. 21, no. 1, 2017,
doi: 10.1142/S136391961730001X.

[53] A. Bunn and M. Korpela, “A language and environment for statistical computing,” *Found. Stat.
Comput.*, vol. 2, pp. 1–12, 2013.

[54] X. Zhao, J. G. Lynch, and Q. Chen, “Reconsidering Baron and Kenny: Myths and truths about
mediation analysis,” *J. Consum. Res.*, vol. 37, no. 2, pp. 197–206, 2010, doi: 10.1086/651257.

[55] S. V. T. & R. D. H. Ulf Henning Olsson, Tron Foss, “Structural Equation Modeling : A The
Performance of ML , GLS , and WLS Estimation in Structural Equation Modeling Under
Conditions of Misspecification and Nonnormality,” vol. 7, no. August 2012, pp. 37–41, 2009.

[56] F. Ferrari, M. P. Paladino, and J. Jetten, “Blurring Human–Machine Distinctions:
Anthropomorphic Appearance in Social Robots as a Threat to Human Distinctiveness,” *Int. J.
Soc. Robot.*, vol. 8, no. 2, pp. 287–302, 2016, doi: 10.1007/s12369-016-0338-y.

8 11 Data Availability Statement

The datasets for this study will be available upon acceptance in the following OSF repository
[NAME OF REPOSITORY] [LINK].

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