# Not all sizes matter. The perception of robots' age and mental abilities based on their physical dimensions


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## ABSTRACT

The study analyses differences in the perception of age and mental abilities of robots displayed as 3D models in an immersive VR room (CAVE), manipulating anthropomorphic variables such as height, head dimension, and limb length. Participants (N = 122) were randomly assigned to one of four experimental conditions where they interacted with a robot with a different combination of physical dimensions. After the interaction, participants had to fill in a post-test questionnaire where they were assessed for their tendency to anthropomorphise and their AI knowledge.

The results show that different combinations of physical appearance of the robots affect the perception of their age. In particular, the combination of robot size and parts dimension influences age perception but not the mental characteristics of the robots. These results might have implication for developing robots for specific functions, such child care or support in study activities.



## CCS CONCEPTS

• **Computer systems organization → Robotics**; • **Human-centered computing → Laboratory experiments**; **Empirical studies in HCI**.

## KEYWORDS

robot perception, anthropomorphism, robot age, mind perception, human-robot interaction




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## 1 INTRODUCTION

The interplay between the physical appearance of technologies, the tendency towards anthropomorphism, and the attribution of mental states implies that technologies are also given characteristics such as gender and age [21]. Many studies have analyzed the relationships between gender representations and, for example, attributing to robots the skills needed to perform a given role [4, 20]. Others have focused on the factors that determine whether a robot looks masculine or feminine [7, 26] and on the consequences that the attribution of gender stereotypes could have on possible discrimination or on perpetration of these stereotypes [10, 24].

There are fewer studies regarding age, however. Among the factors contributing to this, one could be the scarcity of child-like robots. In the Robo-Gap database [21], which includes ratings of the perceived age of 251 commercial robots, only 12 robots have an age less than or equal to 14. It is thus easy to claim that social robots are mainly designed to look like adults.

Focusing on childlike-looking robots, research has mainly focused on issues such as determining the effectiveness of robots as educational tools [2, 16]. Another line of research has instead explored the reactions that robots with the appearance of children can produce in individuals interacting with them [5, 17, 25, 29], highlighting how they generally elicit positive reactions, facilitating a relationship in which, among other things, they are not likely to be mistreated [6].

It is necessary to determine what makes a robot a technology that appears similar to humans but at a childlike stage of development. The study reported here addressed an issue that is still neglected by social robotics research in that it aimed to determine what features of the physical appearance of anthropomorphic robots might make them perceived as child-like. In more detail, the relationships between baby robots' perceived age and individual tendency to anthropomorphism, to attribute mental states to them, and the influence of participants' competence of the in relation to Artificial Intelligence systems were explored.

## 2 RELATED WORK

A considerable amount of research in the field of Human-Robot Interaction (HRI) has analysed the extent to which people perceive robots as human-like technology [9] and the effects that robot appearance and behaviour have on people's tendency to attribute mental states to them [1, 11, 23]. The attribution of human-like characteristics to social robots and other non-human entities, a bias towards anthropomorphism, has also been described as an extension of the theory of mind to non-human agents [3, 18, 19]. However, the overlap between the theory of mind and anthropomorphism is not so definite. As suggested by recent work [13] aimed at examining how and whether the individual tendency towards anthropomorphism can influence the brain activity implicated in the theory of mind (both as mind perception or mind ascription), there is no evidence of a clear relationship between dispositional anthropomorphism and the adoption of a theory of mind.

Several factors have been related to the tendency towards anthropomorphism. Some studies found that viewing a robot as an artefact or a mindful system depends mainly on contextual situations [22]. However, a study on the relationship between mental capacities perception and mind ascription to humanoid robots in different scenarios has highlighted how the perception of affective mental capacity is a significant predictor of mental state ascription to humanoid robots independently of context [14].

The perception of the ability to feel emotions influences mind ascription. People do not expect robots to be able to engage emotionally with the environment. Thus, when robots are perceived with affective capacities, this significantly triggers processes of mind ascription more than expected physical or agency capacities.

There is a scarcity of studies that examine the factors which drive the perception of the age of a robot, and how much the perception of age can influence other processes, such as the attribution of mental states, that is, agency and communion, to anthropomorphic robots.

## 3 THE STUDY

Determining the factors affecting the perception of the age of robots is particularly relevant. Firstly, this may make person-robot interactions easier for those types of individuals who may prefer interactions with systems that resemble them. In fact, children may prefer to interact with robots that look like children [2, 16]. Furthermore, determining whether the perception of a given age is matched by relevant characteristics, such as being in possession of more or less developed mental capacities, could alter the consideration of the behavioural and relational possibilities recognised in the robot. Robots with less agency and communion could be perceived as less skilled and also less responsible if they commit unethical actions [12]. In addition, being able to clearly determine what induces the perception of a robot's age can lead to and highlight those 'dark patterns' [8, 15] that can maliciously leverage the perception of an infantile system to pursue unacceptable goals. Considering these issues, this study is based on the following hypotheses.

RQ1 - *Do robots' size (RQ1.1) and head/limbs-to-body proportions (RQ1.2-3) affect their perceived age?*

HP1.1 Taller and larger-sized robots should be considered older than smaller ones, given that in humans, general height and size correlate with age.

HP1.2 A robot with a larger head-to-body ratio should be considered younger than a robot with a smaller head-to-body ratio since the head-to-body ratio decreases with age, and a large head-to-body ratio is strongly associated with neoteny.

HP1.3 A robot with a smaller limbs-to-body ratio should be considered younger than a robot with a larger limbs-to-body ratio since the limbs-to-body ratio increases with age.

RQ2 - *Are the level of agency and experience attributed to the robots influenced by their size and head/limbs-to-body proportions?* This is an exploratory question related to the possible relationship between age and agency and experience. It is possible to hypothesise that the robots that were perceived as younger would also be perceived as having a higher level of sensitivity (i.e., more experience) (HP2.1) and less agency (HP2.2) than the older robots.

## 4 METHODS

### 4.1 Sample characteristics

One hundred twenty-two participants took part in the experiment, mainly students from the University of Siena, who received a compensation of €8.00. The mean age was 23.3 years old ($SD$ = 2.32), and the sample was almost gender-balanced, with 70 women (57.4%) and 51 men (42.8%); only one participant declared to identify as a non-binary gender.

### 4.2 Design and procedure

Before the experiment began, participants were informed about the objective of the study. They were assured of their right to terminate the interaction and withdraw from the study at any point without the need to provide a justification. They were then invited to sign an informed consent to participate. Participants were randomly assigned to one of four experimental groups. In one group (1 - control robot), which served as a control group, the robot's height was 170 cm, whereas in the others (2, 3 and 4), it was around 120 cm, but we varied the proportions of some crucial parts of the robot (the head and/or the limbs). In one group (2 - small robot), the proportions of the body parts were the same as in the control group (the robot was simply a scaled version of the control robot). In the other groups, we increased the head-to-body ratio by increasing the size of the head by 30% from the small robot condition (3 - small robot + HBR), and in the last group (4 - small robot + HBR – LBR) we also decreased the size of the limbs by 20% (see Figure 1).

The robots were presented in a VR setting called CAVE (Cave Automatic Virtual Environment) in the University of Siena VR lab. The CAVE is a cube-shaped room with video projectors that creates a 3D VR environment projecting images onto the walls and the floor. The participants wear special shutter glasses that allow

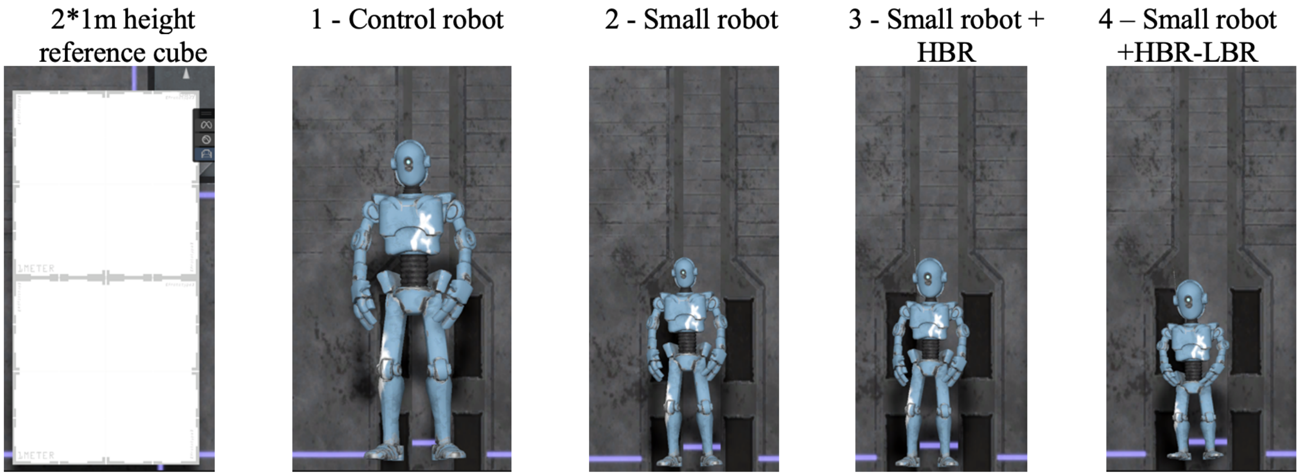


**Figure 1: The four robots which participants interacted with within the CAVE. Two white squares with sides of one meter are presented as references for dimensions of the robot, in particular the height (170 cm in condition 1, around 120 in the others).**

to deliver slightly different images to each eye, enabling stereoscopic vision. Infrared cameras allow to track the head position and orientation of participants, in order to dynamically update the projections. In this way participants were projected into a virtual world they could explore by walking and rotating their heads. An experimenter explained the study, how the CAVE works and how to use the controller to interact with the robot. The experimenter was always present to provide help if needed. The study procedure was approved by the IRB of the University (CAREUS, act n. 68/2022).

The robot inside the CAVE guided the entire experiment through written instruction. Another experimenter supervised all the processes in a separate room with a remote PC (and he could stop the experiment at any time). Through a 3D graphic interactive interface, the robot asked the participant 19 questions. The first 18 questions concerned the robot's mental skills [11], and referred to two main dimensions of mind perception: the experience level (conceived as the ability to feel feelings and emotions; investigated by the first 11 questions and the agency level (conceived as the ability to make things happen, to intervene into reality), last seven questions. Lastly, the participants had to give the robot an age based on their impression on a scale from 1 to 100 years, where one meant "new-born" and 100 meant "very old". The robot then thanked the participant. The 3D interaction with the robot lasted, on average, five minutes.

Then, the participant was invited to complete an online questionnaire through Google Forms. The questionnaire had four sections. The first one aimed at gathering information about the socio-demographic characteristics of the participants, including 3 questions about the participants' familiarity with information systems, robots and IA tools, and sci-fi cultural products answered on a 7-point agreement scale. In the other sections, two standardised scales were administered to measure: 1) the tendency to anthropomorphism, i.e. attributing human-like characteristics to technological systems, was measured using 5 items taken from the Individual Differences in Anthropomorphism Questionnaire (IDAQ) [28], and rated on an 11-point scale from 0 "not at all" to 10 "very much"; 2) the knowledge and usage of smart tools and AI (12 items grouped in four domains "Awareness", "Usage", "Evaluation" and "Ethics" by means of the Artificial Intelligence Literacy Scale (AILS) [27], with a 7-point Likert scale from 1 "Completely disagree" to 7 "Completely agree".

## 5 RESULTS

We computed initially the internal consistency of the measures of robot perception and individual characteristics. Reliability for robot perception measures was good for experience ($\alpha$ = .89), and poor for agency ($\alpha$ = .62). For individual scales internal consistency was acceptable for familiarity with technology ($\alpha$ = .73), IDAQ ($\alpha$ = .75) and AILS ($\alpha$ = .78). The mean scores of participants on individual scales showed no significant difference between the conditions, and no differences emerged in the participant's age and gender.

Since the main and the exploratory hypotheses were centred on perceived age, before analysing the data we inspected the distribution of the age ratings in the different conditions. The distribution showed some possible outliers, so we filtered those participants which in each condition attributed an age 1.5 times the interquartile range below the first quartile or above the third quartile. 25 participants were excluded in this way, 9 in condition 1, 8 in condition 3, 6 in condition 4 and 2 in condition 2. The analyses reported below are relative to data from 97 participants.

We compared the mean age and levels of agency and experience attributed to the robots across conditions using 1-way ANCOVAs including all the individual scales as covariates (centred on the mean). Pairwise comparisons of the means were adjusted with Tukey's method. The results are presented in the following paragraphs.

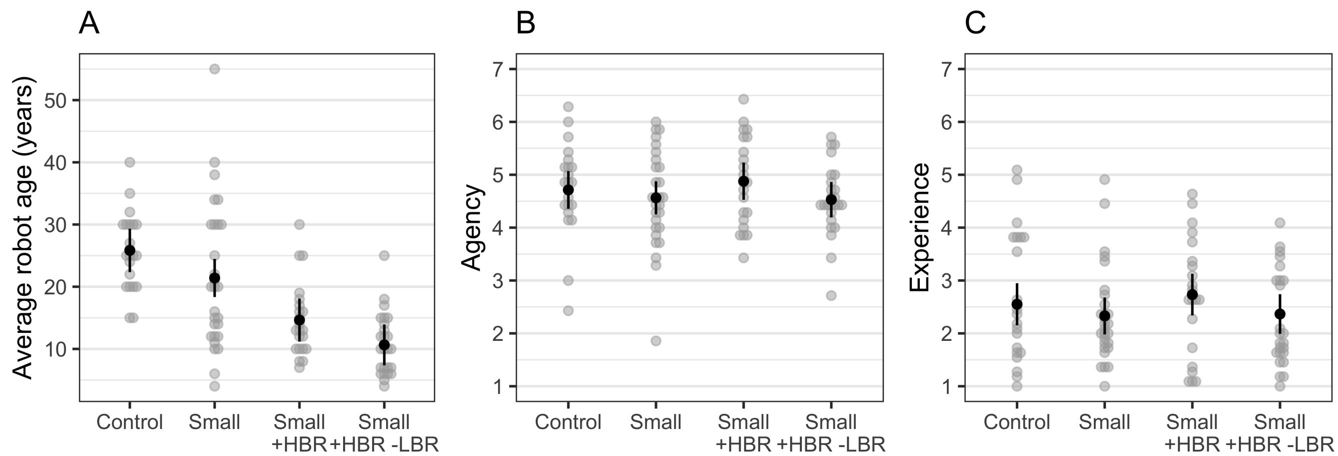


**Figure 2: Plots of the average perceived robot (A) age, (B) agency and (C) communion across the experimental conditions. HBR = Head-to-Body Ratio, LBR = Limbs-to-Body Ratio. Error bars represent 95% confidence intervals for the means. Grey dots represent individual evaluations.**

## 5.1 Perceived age

The analysis of the perceived age showed significant differences between the means in the different conditions ($F(3, 89) = 15.51; \eta_p^2 = .343, p < .001$). None of the covariates were significant. Figure 2A shows the mean ages across the conditions. As can be seen, the lowest age was attributed to conditions 3 (+HBR, $M = 14.6, SE = 1.74$) and 4 (+HBR −LBR, $M = 10.6, SE = 1.65$). Pairwise comparisons showed that participants rated the robot as significantly younger in these conditions than in the control ($M = 25.8, SE = 1.76$, +HBR: $t(89) = 4.53, p = .0001$, +HBR −LBR: $t(89) = 6.19, p < .0001$) and in the small robot conditions ($M = 21.4, SE = 1.54$, +HBR: $t(89) = 2.90, p = .024$, +HBR −LBR: $t(89) = 4.74, p < .0001$). The perceived age of the robots in conditions 3 and 4 was not significantly different from each other ($t(89) = 1.67, p = .348$), and neither it was the perceived age in the control and in the small robot conditions ($t(89) = 1.90, p = .237$).

## 5.2 Agency and experience

The analysis of the agency and experience levels assigned to the robots has not shown any significant difference between the means in the different conditions ($F_{ag}(3, 89) = 0.85; p = .47; F_{exp}(3, 89) = 0.94; p = .42$). Among the covariates, IDAQ was positively associated with experience ($F(3, 89) = 19.60, \eta_p^2 = .178; p < .001$) and marginally with agency ($F(3, 89) = 3.66, \eta_p^2 = .040; p = .059$). Means scores in different conditions are shown in Figures 2B and 2C, respectively. Participants attributed more agency than experience to the robots, as shown in the graphs. This difference resulted significantl in the analysis of a t-test paired sample ($t(96) = 22.68; p < .0001$).

# 6 DISCUSSION AND CONCLUSIONS

The main research questions addressed by this study concerned the factors affecting the perceived age of a robot (RQ1). We tested the hypothesis (HP1.1) that a smaller size would make the robot look younger, within an immersive VR environment which allowed to make size directly perceivable. The results of the study confirm this hypothesis, but also showed that a smaller size is not sufficient to appear younger, since the age attributed to the control robot (170cm) and to the small robot (120cm) with the same proportions were not significantly different. We expected (HP1.2) that a larger head-to-body ratio would make the robot look younger, and more childlike. The results confirmed this hypothesis: in both the conditions in which the head of the robot was increased in size to yield a higher HBR the perceived age of the robot was significantly lower than the control robot and, more importantly, also than the small robot. The average perceived age in these conditions ranged between 10 and 15 years. We must also notice that in both conditions the variability of the age attributed was smaller than in condition 1 and 2. Our third hypothesis was that a lower LBR lead to younger perceived age. The robot in this condition, which also was small and had increased HBR, was indeed the robot with the lowest average age (10.6 years). However, the results showed that in the condition with reduced LBR the robot was judged significantly younger than both the control robot and the small robot, but not significantly younger from the other robot in condition 3, which also was small and had increased HBR, but had normal LBR. Overall, these results suggests that a higher HBR is necessary to convey impressions of a child robot, although they cannot tell us whether it is also sufficient, since we did not have a control condition of a big sized robot with increased HRB. Further studies should thus investigate this.

Lastly, we hypothesized that age could influence the perception of a mind in the robot (RQ2), so that the younger robots might be attributed less agency (HP2.1) and more experience (HP2.2). Neither of these predictions was confirmed, as no significant effect of condition was found in the agency and experience ratings. We did find a significant weak correlation between the age and the agency of the robot, but the same was not found between age and experience. Overall, therefore, our study suggests that manipulation of the robot size and proportions, which influence the perceived age of the robot, do not also affect the mental characteristics attributed to it. It is possible, however, that to influence the perception of the mind, the age attributed to must be lower than the one attributed to the robot in the conditions in which it was judged young. Further studies should test this hypothesis by including more childlike (and possibly infant-like) robots.

In conclusion, our study has shown that the size and proportions of a robot can strongly influence the age the robot appears to have, and that it is possible to make anthropomorphic robots look like children, by simultaneously reducing their overall size and increasing their head-to-body ratio. Decreased limbs-to-body ratio might even strengthen the impression of child-likeness, although our study did not bring conclusive evidence about the effect of this factor. Making a robot look like a child opens the possibility of taking advantage of the favourable impression produced by a younger age, and young robots might also be considered more suitable for certain roles or tasks, an hypothesis which further studies should investigate.

## 6.1 Limitations

The study has some limitations that should be acknowledge. First of all, after removing the outliers based on the age attributed to the robot, the sample size in each condition was relatively small. Further studies with a larger sample and more statistical power are thus needed to verify our findings, and possibly extend them. Secondly, we did not include a control condition in which the robot was tall but had an increased HBR. Further studies including these controls should be conducted to understand better the role of proportions in determining the perceived age of a robot.

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