

# The Effect of 3D/VR on the Perception of Robot Humanlikeness\*

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**Abstract**— Humanlikeness is a quality possessed by social robots tasked for human interaction. This quality has remained ambiguously defined in literature, despite the notion that social robots with humanlike qualities tend to be better received by users. Currently, the Anthropomorphic Robot (ABOT) Database serves as a validated resource for robot designers and researchers to reference a robot’s humanlikeness score. However, one of the limitations of this database is that the scores are based on 2D images of the robots, rather than based on the actual embodied robots. To combat this limitation, the current study aims to research if having the robots in a 3D Virtual Reality (VR) space makes a difference in the humanlikeness scores. This current study focuses on collecting the humanlikeness scores of robots in VR, and further aims to compare the scores with the scores that are currently listed in the ABOT Database. To accomplish this, 16 robot models were put in a VR environment where participants rated the humanlikeness of each robot. All the robots were previously rated in the current ABOT database so the scores from the VR environment and the ABOT database could be compared. Results from 11 participants show no significant difference between 2D humanlikeness scores and 3D/VR humanlikeness scores. The results of this paper will validate the progression of continuing to build a 3D visualized database of humanlike robots while providing further context for how perceptions of humanlikeness differ throughout 2 and 3-dimensional spaces.

## I. INTRODUCTION

Anthropomorphism is the process of ascribing human features to non-human agents or objects. Humanlikeness is the degree to which a nonhuman object or agent resembles a human being and is an important aspect in human-robot interaction, as it affects how people respond to robots in different contexts [1]. Previous literature has established how the preferred humanlikeness (from low to high score) varies depending on the context in which the robot is being used, where a low score may be preferred in an industrial setting vs. a high score in a social setting. However, the ability to systematically quantify a robot’s humanlikeness has previously been nonexistent, as designers and companies have relied on primarily instinctive judgment to produce new humanlike social robots [3]. The Anthropomorphic Robot (ABOT) Database provided one such solution to this problem by systematically quantifying over 251 real-world robot’s humanlikeness scores based on three dimensions: body-manipulators, face, and surface look. The original ABOT study gathered data from over 1,250 participants and asked them to rate their humanlikeness on a scale of 0-100 [4]. As a

result, researchers and designers can utilize this data by way of the database’s predictor tool, which allows for a robot to be given a predicted humanlikeness score based on a provided 2D image.

Though a step in the right direction, one current limitation of the ABOT database is that the data available is based solely on 2D images of social robots. In an ideal world, data on the real-life physical robots judged in a real-life setting would provide a high degree of ecologically valid data. However, as social robots are consistently being added to the database, it would be extremely costly and inefficient to judge these robots in person. In this study, we explore a possible solution to this - by bringing ABOT to 3D in virtual reality (VR). VR has been established as an effective way to collect ecologically valid data in a simulated space and has been utilized in studies requiring a high sense of immersion [5]. Due to technological advances in simulation graphics, we hypothesize that VR will be shown to be an effective means of measuring robot humanlikeness. Another benefit of VR is that 3D models are far cheaper than their real-life counterparts and can be continually added as more robots are made available in 3D form, like that of the original ABOT work.

One concern that has been raised about VR is that models (especially those made available by third parties) will not be accurate to their real-life counterparts. Since we chose models based on availability, we expect some minor differences to appear in translation to 3D. Despite this, models largely remain true to their design and can provide a more holistic view over viewing a 2D image. Another concern about VR is that participants will experience a degree of motion sickness, which may pose a risk of harm. To combat this, we will have participants take a pre-screening test for VR sickness and ask that they remain seated throughout the duration of the experiment. Participants will be given the option to opt-out of the study based on the score they receive or for any reason. We understand the need

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for accessibility and have attempted to prioritize participant comfort in our study design.

Though concerns have been raised about model accuracy and access to a diverse selection of robots, we remain confident that VR is a reliable means of measuring humanlikeness perception in 3D. Additionally, to remain consistent with the original ABOT work, participants will answer the same questions about robot humanlikeness. We conclude, with consideration to the above, that VR will be a cost-effective and ecologically valid option for viewing robots in 3D. In this study, we address the limitations of the original ABOT study by using VR technology to examine how scores are affected when robots are viewed in 3D.

## METHODS

### A. Participants.

11 participants were recruited from the George Mason University participant recruitment system for undergraduate students. Initial screening processes required participants to be over the age of 18 with normal to corrected vision. For their participation, participants were awarded research credit towards completing their undergraduate class requirements. All 11 participants' data was used during analysis. The average age of the participants was 23 years old, with age ranges from 19-29. 9 participants identified as male, 1 identified as female, and 1 identified as neither male nor female.

### B. Design.

This study took 16 robot models + 3 foil models (e.g., models of a human and 2 featureless "smart" devices) and placed them within a 3D environment for viewing in VR. Foils were used to establish clear anchors and detect abnormalities in participant data (e.g., the participant rates robots carelessly or fails to understand the task). Models were chosen based on availability in Unity package format, but more models will be added in the future. As a result of availability-based selection and difficulty translating some extremely humanlike robots to 3D, most robot models used tended towards low and medium humanlikeness (e.g., Jibo, Kuri, and UR3). Participants were tasked with viewing each robot (presented in randomized order) and rate their perceived physical humanlikeness on a scale of 0-100 for consistency with prior ABOT research. Participants were able to see each robot as scaled to realistic size, rotate robots 360 degrees, and adjust their proximity to the robot in the virtual environment for a holistic view, as desired. After each robot was rated, data was funneled to an external spreadsheet for data analysis. An independent samples T-Test was performed in SPSS to compare the humanlikeness scores between VR and the 2D ABOT Database. Average humanlikeness scores of the 16 robots in VR were compared to their 2D humanlikeness scores.

Some concern has been raised over the extended use of VR and the propensity to experience sensations of motion sickness [6]. To address this risk, participants took an initial

screening questionnaire, the Virtual Reality Sickness Questionnaire (VRSQ), prior to the experiment. The VRSQ has been established as an effective way of measuring the possibility of experiencing motion sickness when using VR [7]. Participants took the questionnaire and were shown their score (low to high risk of experiencing motion sickness) and were given the option to opt-out of the study based on this risk or for any reason. Participants remained seated during the duration of the experiment for comfort and to reduce motion sickness. As VR is a relatively new technology that has yet to receive broad use or recognition within the field of psychology, we decided to include an additional index measure to examine responsiveness to new technologies. For this, we decided to use the Technology Readiness Index (TRI 2.0) to measure people's propensities for experiencing new technologies [8]. Scores from the TRI were recorded for examination purposes only and did not affect the participant's ability to participate in the experiment.

## MATERIALS AND MEASURES

### C. VR Headset and Environment.

An HTC Vive Pro 2 Headset was used for viewing robots in the 3D environment, which was created in Unity VR by the experimenters.

### D. Images of Robots and Foils.

16 3D models of the robots and 3 foils were purchased from multiple stores online for this experiment. These robots were compared with the ABOT Database to ensure that their 3D humanlikeness scores can be compared to the 2D humanlikeness scores.

### E. ABOT Database Scores.

The humanlikeness scores of the robots in the ABOT Database were used to compare the effect of having 3D models in VR on humanlikeness scores.

### F. Virtual Reality Sickness Questionnaire.

The Virtual Reality Sickness Questionnaire is a measure to score the likelihood that someone will experience motion sickness while in a VR environment. (Kim et al., 2018). Total score ranges from 0-50. 0-2 points are interpreted as "light susceptibility to motion sickness", 3-7 points as "moderate susceptibility to motion sickness", 8-15 points as "extreme susceptibility to motion sickness", and values above 16 are "definitive motion sickness".

### G. Technology Readiness Index 2.0.

The Technology Readiness Index (TRI 2.0) measures people's propensity to utilize new technology, and has four dimensions: 1. Optimism, 2. Innovativeness, 3. Discomfort, and 4. Insecurity.

## PROCEDURE

After participants consented, they were given a basic demographics survey, followed by the Virtual Reality Sickness Questionnaire (VRSQ) and Technology Readiness Index (TRI 2.0) on Qualtrics. After completing the VRSQ,

participants were given a score (light, medium, moderate, and high susceptibility to experience motion sickness), and were given the option to cease participation. The participants then were seated in the middle of surrounding VR base stations on a chair and fitted into the VR headset and given remote controls. Participants were instructed to remain seated for the duration of the experiment to assist in reducing potential symptoms of motion sickness, though choosing to sit or stand did not affect the field of view (FOV) participants were able to see. After calibrating into the VR environment, participants read instructions from within VR on a text screen and were then shown the series of robots. Participants rated robots by using the HTC Vive Pro 2 hand controllers to change the value of a slider from 0-100 based on their judgements of the robots' physical humanlikeness. Finally, after the experiment concluded, participants were assisted in removing the VR headset and controls and thanked for their time.

## RESULTS

An independent samples T-Test was performed to compare the humanlikeness scores between VR and the 2D ABOT Database. To do this, the average humanlikeness scores of the 16 robots in VR were compared to their 2D humanlikeness scores.

The 16 robots scores in VR ( $M = 26.24$ ,  $SD = 23.67$ ) and the same 16 robots scores in the 2D ABOT Database ( $M = 18.07$ ,  $SD = 13.19$ ) were not significantly different from each other,  $t(30) = 1.206$ ,  $p = .098.B$ .

## DISCUSSION

The ABOT database created a way for researchers and designers to predict their robot's humanlikeness with a feature-focused tool that calculates a humanlikeness score based on participant data. Currently, the database is limited to calculating humanlikeness scores in 2D. One limitation of this is that participants can only make judgements based on one image, without seeing a holistic view of the robot which may influence their perception of the robot. The current study attempted to resolve this by showing robots in 3D for the purpose of obtaining a higher degree of ecologically valid data to expand upon prior ABOT research regarding human perception of robot humanlikeness.

One reason that 3D data would be beneficial over 2D is due to the ability to view the robot holistically. In 3D, the participant can rotate the robot 360 degrees and view the shape, size, and components of the robot from different angles. As these robots would be used in a real-life setting, it is important to understand how their overall humanlikeness score is impacted from the perspective the robot is viewed from. Another reason we chose to visualize robots in 3D is the ability to add additional functionalities in the future, such as robot face and body animations. Additionally, a 3D environment provides the capability to change the scene which the participant views the robot in, which may influence the perception of the robots' humanlikeness. Researchers visualizing the robot in 3D could examine how people respond when robots are in settings such as a

hospital, care facility, or industrial factory. Thus, we decided to perform a study based solely in 3D/VR.

The results from the data analysis show that there was no significant difference between 2D and 3D humanlikeness scores. This demonstrates that robots rated in VR tended to be rated similarly to that of their 2D image counterparts. One possible interpretation of this result is establishing that the ABOT Database is a valid way of quantifying robot humanlikeness. This may contribute evidence for researchers and designers who are looking to confirm if using the ABOT database's predictor tool is indeed a valid way to assess their designs humanlikeness. Another possible interpretation is that the perception of overall humanlikeness does not change whether the robot is presented in 3D vs 2D. This would help expand the breadth of what is known about the perception of humanlikeness in multiple dimensions and give way to potential follow-up studies to narrow the concept further. However, given our low sample size and limited robot availability, more data is needed as follow up to these findings.

While viewing the 3D model of the robots on a computer screen could have been an alternative to using VR, there were several critical benefits of VR that made us choose VR. The primary reason for this is that VR provides a more realistic experience due to the participant's immersion in the environment compared to using a computer. When the participant is in the VR environment, they are experiencing a scenario comparable to how the robot would be interacted with in real life. Another advantage of VR is that the participant can come "face to face" with the robot compared to viewing it from a 3rd person perspective. As more studies demonstrate the benefit of using VR as a tool in psychological research, we expect more research on human-robot interaction and humanlikeness in VR to become available. Though we attained a null result, we are nevertheless excited by the potential benefits of continuing to conduct research on robot humanlikeness in VR.

## LIMITATIONS

There are several limitations to this study that should be considered. First, compared to the ABOT databases over 250 robots, there were only 16 robots for this study. While this number was chosen based on availability, the 16 robots might not be representative of how other robots' humanlikeness will be different or similar when viewed in virtual reality. This was due to the limited availability of 3D models of robots for research use. An additional limitation of using available robots from online stores (not provided by the designers or companies themselves) was slight difference in robot appearance (e.g., colors and certain textures). While we attempted to scale each robot to its realistic size, adjustments were imperfect and may not reflect the actual size of the robot as perceived in real life.

Though this is a limitation of the present study, we hope that this study encourages researchers and designers to make their robots available in 3D format in the future. Second,

while VR does offer a more realistic view of robots, it is still not the same as viewing robots in person. Third, the robots remain static in VR without any movement aside from participant rotation and proximity adjustment, which was a limitation of the original ABOT study. Lastly, our study is limited by its low sample size of only 11 participants. While the participants were able to access some degree of manipulation for viewing each robot, the robots do not possess the full range of motion they would have in person.

#### FUTURE DIRECTIONS

This study is the first step to a series of studies that will expand on investigating the applicability of robots in VR. In the future, we plan to add more robots from the ABOT database to the VR environment and collect more data on people's perception of these robots in VR. We would like to reiterate our desire to expand our database with 3D models of robots and would ask the community to contribute models if possible. Additionally, adding movement capabilities, animation, and robot voices would potentially increase the accuracy and realism of 3D robots. Potential steps forward could include testing the efficacy of tasks typically requiring a physical social robot with the robot's VR model. As this is only the start of the long-term goal of analyzing human likeness in 3D/VR and creating an additional tool for social robot researchers and designers.

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