Ethnical Anthropomorphism in Human-Robot Interaction: Personalized Robot Tutors

Annemae van de Hoef, Sam Leewis, Koen Smit,
Łukasz Miętkiewicz, Emirhan Tala,
Fábio Seiji Sakai Iwashima, Berk Tahir Kiliç,
Mirjam de Haas

HU University of Applied Sciences Utrecht, Digital Ethics, Utrecht, Netherland
annemae.vandehoef@hu.nl, sam.leewis@hu.nl, koen.smit@hu.nl,
lukasz.mietkiewicz@hu.nl, emirhan.atal@hu.nl, fabio.sakaiiwashima@hu.nl,
berk.kilic@hu.nl, mirjam.dehaas@hu.nl

Social robots are becoming increasingly relevant in education, for example, by using them as tutors. To create a more empathetic and engaging learning environment, it is important to consider the anthropomorphism of these social robots. However, an ethnic perspective on the use of anthropomorphization is still lacking when it comes to improving learning gains. Therefore, this research focuses on whether personalized, ethnicity-based anthropomorphization of a robot can enhance learning gains. To this end, history lessons were tutored with a Furhat robot, with groups of participants interacting with a Furhat whose face matched the ethnicity of the participants, in an experimental setting. Our results showed that participants who interacted with the robot displaying the personalized, ethnicity-based anthropomorphization learned more than participants interacting with a robot displaying a robotic appearance. These findings highlight the importance of incorporating cultural diversity into educational technologies to foster more effective and inclusive learning environments.

Keywords: human-robot interaction, social robot, personalized, education, ethnicity

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1 Introduction

In today's world, technological advances offer a plethora of opportunities to improve many aspects of our lives (Bello et al., 2021; Nordrum, 2023). Using advanced technologies in various fields reflects a larger movement toward digital transformation (Baker, 2014). Among these technologies, social robots have the potential due to their ability to interact and engage with humans, creating a richer learning environment (Ayoko, 2021). Social robots have the potential to adapt themselves to each individual, capable of performing various educational tasks, from tutoring in specific subjects to facilitating language learning (e.g., Belpaeme, Kennedy, et al., 2018; Vogt et al., 2019). Moreover, they can provide opportunities for personalized learning, where robots adjust their teaching strategies to cater individual needs and learning styles of each student, thereby creating a shift toward digital, inclusive, and student-centered education (Belpaeme, Kennedy, et al., 2018; Cailloce, 2017).

To potentially improve the robot's performance, anthropomorphism (i.e., how much the robot's attributes resemble a human) is applied in their design (Alves-Oliveira et al., 2016; Belpaeme, Kennedy, et al., 2018; Liew et al., 2022). For example, Mohd Tuah et al. (2016), propose an anthropomorphism design to guide better human-computer interactions. In addition, Eysell & Kuchenbrandt (2012) used anthropomorphism to investigate whether a robot's ethnicity affects the participants' social categorization. Furthermore, concerning ethnicity, Makatchev et al. (2013) investigated how a robot can be more ethnically accurate not in terms of appearance but in verbal and non-verbal communication. Little research has been found, however, on the impact of anthropomorphism on learning gains when applying personalized ethnicity to a tutoring social robot. Indeed, research indicates that students often achieve higher learning gains when taught by teachers of the same ethnicity (Gottfried et al., 2023; Redding, 2019), suggesting a similar potential effect between students and robot tutors. Moreover, research showed that when humans interact with robots, homophily (i.e., having something in common) correlates with building trust in human-robot interaction (HRI) (Salek Shahrezaie et al., 2021). Therefore, this research paper describes a study that examines whether you can improve student performance by ethnically anthropomorphizing a social robot. Accordingly, the following research question is raised: "*To what extent does a*

tutoring robot enhance the performance of its learners when using personalized and ethnicity-based anthropomorphization?"

2 Background and Related Work

Research has shown that social robots can have many benefits in the education field (Alves-Oliveira et al., 2016; Belpaeme, Kennedy, et al., 2018; Belpaeme, Vogt, et al., 2018; Donnermann et al., 2022; Gleason & Greenhow, 2017; Ramachandran et al., 2016; Rosenberg-Kima et al., 2020; Smakman et al., 2020; van den Berghe et al., 2019; Vincent et al., 2015). For example, social robot tutors can be beneficial, as suggested by research in which social robots were used to assist children in learning a second language (e.g., Vogt et al., 2019) or solving fraction problems (Ramachandran et al., 2016). Here, the robot acted as a language tutor, providing personalized vocabulary lessons and feedback. The results of this research showed that children who interacted with the robot showed improvement compared to those who did not receive vocabulary lessons. However, the effect of the robot on their performace was not clear (Vogt et al., 2019). On the other hand, gestures by a robot seem to have a positive effect on children's engagement (de Haas et al., 2020).

Most research involving robots in an educational setting has concentrated on one-on-one interactions. Nevertheless, group settings could also impact learning gains positively. For example, the use of social robots in small group activities helped manage learning by introducing tasks, ensuring proper time management, and encouraging group discussions between students (Rosenberg-Kima et al., 2020). In addition, another study has implemented an adaptive robot tutor to support students with exam preparation (Donnermann et al., 2022). They found that students interacting with a robot with a personalized and more human-like behavior scored higher on the exam and had an increase in intrinsic motivation related to the course content in general compared to students who interacted with a robot that did not adapt itself to the participants. Other research came to a similar conclusion that designing the educational robots as more anthropomorphic, or at least fitting their demographic (i.e., children), results in better learning rates and positive social interactions (Belpaeme, Vogt, et al., 2018; van den Berghe et al., 2019; Vincent et al., 2015). Furthermore, some papers have shown results that an anthropomorphic social robot encourages responses that are beneficial for learning because it invites social interaction with the robot (Belpaeme, Kennedy, et al., 2018). A more general

example is that human-robot interaction puts a great emphasis on psychology and behavior for a more engaging and communicative interaction (Alves-Oliveira et al., 2016).

Beyond the traditional education roles of social robots, there is an interesting implementation of robots to enhance the benefits of social robots: robots featuring ethnical anthropomorphism. For example, the same ethnicity between students and teachers results in students receiving fewer negative behavior ratings and being perceived as more favorable in terms of academic ability, especially among Black and Latino/Latina students (Redding, 2019). Furthermore, students achieved higher scores in, e.g., math and reading (Gottfried et al., 2023) when taught by teachers of the same ethnicity. In contrast, some studies found no significant positive relationship between ethnic similarity and learning gains (Driessen, 2015; Hughes et al., 2005; Tom & Cronan, 1998). A review by Driessen (2015) reports that the results of 24 quantitative studies were mixed, and the article suggests that even if the studies found some positive results, these were more related to subjective teacher evaluations than to objective achievement outcome measures.

While there are mixed opinions on the benefits of having the same ethnicity as a teacher on student performance, the effect of students' interaction with a personalized ethnic social tutoring robot on students' learning gains has not yet been studied. However, research has been conducted on ethnic anthropomorphism and robots. For example, Eysell & Kuchenbrandt (2011) concluded that German participants found a robot that represented the majority (in this case, a German ethnicity) more favorable (e.g., felt closer to or received more warmth from) than a robot that represented the minority (in this case, a Turkish ethnicity). Another angle explored how verbal and non-verbal communication can be used to represent ethnicity through a robot rather than a potentially offensive ethnic appearance (Makatchev et al., 2013). In addition, Mohd Tuah et al. (2016) proposed an anthropomorphism design scale, from anthropomorphism to animism, to guide a better understanding of how anthropomorphism can be used. Given the research on ethnicity and education and the current state of (ethnic) anthropomorphisms in research, it is suggested that an effect observed in human-*human* interactions may differ when similar approaches are applied in human-*robot* interactions. Therefore, this research aims to investigate whether social robots that implement ethnic anthropomorphism increase the history knowledge of students at an University of

Applied Sciences. We hypothesize that a robot that adapts its appearance to participants' ethnicity improves history knowledge in a setting where it tutors history lessons to groups of participants (H1).

3 Research Method

The experiment is conducted with the Furhat robot made by Furhat Robotics and students at an University of Applied Sciences. The robot's face is projected onto a facial mask, making it possible to adapt its face based on the participants' ethnicity. The faces used to represent certain ethnicities are pre-made by Furhat Robotics (as shown in Figure 1).

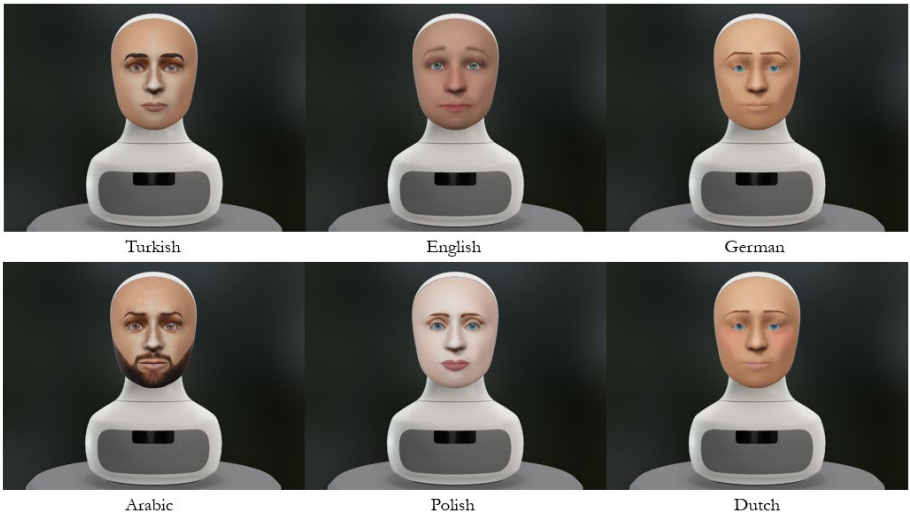

Figure 1: Furhat Robotics Pre-made Faces
Source: Adapted from Furhat Robotics: Furhat Robotics. (2024). *Furhat SDK* (Version 2.7.2) [Software]

Researchers assigned faces to the robot based on the ethnic population the participants wanted to represent themselves with. The participants identified themselves as Dutch, American, Brazilian, European, Turkish, German, Syrian, Finnish, Tunisian, Arabic, Surinamese, Austrian, Afghan, Caribbean, French, and/or Angolan. The participants were divided into two groups: one with a robotic face (control) and the other with an appearance based on the participant's ethnic identity (treatment), as shown in Figure 2. The control and treatment groups were then

divided into smaller groups of five participants. These groups of five were formed by the researchers based on random sampling, and congruent ethnicity and gender. If there were groups of participants with mixed ethnicities, they were placed in the control group. The participants in the treatment group were grouped based on the ethnicity they had specified beforehand and according to the available faces as shown in Figure 1. This way, the face of the robot matched the ethnicity of each participant in the treatment group.

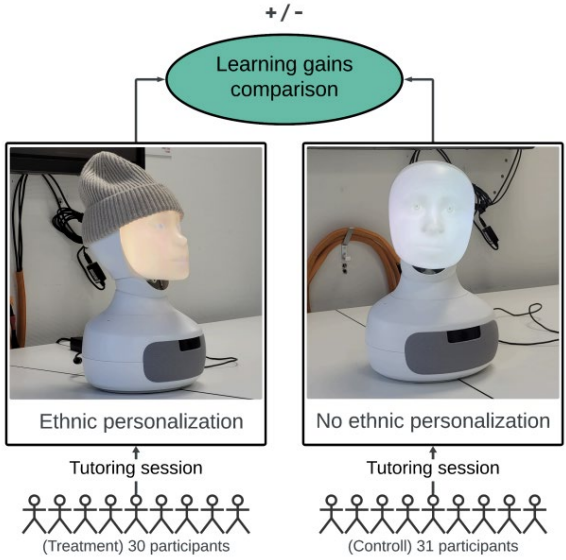

Figure 2: Experiment Design Visualization
Source: Own

The experiment took place at HU University of Applied Sciences Utrecht where the control group consisted of 31 participants and the treatment group of 30 participants. The robot automatically changed its attention from one participant to another during the tutoring session, with each participant receiving equal attention. The robot in the control group did not make human-like head movements, had no human-like features, and had a robotic face. In contrast, the robot in the treatment group did make human-like head movements, wore a hat to appear more human, and changed its voice (e.g., male or female) and face to match the participants' ethnic identity. Both before and after a tutoring session, each participant is asked about their confidence on the topic from 0 (No confidence) to 10 (Fully confident) (e.g., How confident are you about your knowledge of the Osman Pasha who fought in

Plevna?). In this manner, participants who were too knowledgeable about this topic were excluded in advance and it was clear afterward whether participants understood the topic. The session consisted of a monologue by the Furhat robot about the history of the Battle of Plevna and a test with 10 multiple-choice questions (e.g., Why did Russian troops want to capture Plevna? (A) Because it was rich in resources (B) It was a key place to move towards Istanbul (C) Gazi Osman Pasha was born there (D) It was the capital of the Ottoman Empire). No pre-test is conducted for the 10 multiple-choice questions as this could affect the post-test results and the little knowledge of the topic during the pre-test might demotivate the participants. The topic of the experiment is chosen due to the researchers' familiarity with it and the low chances of participants having prior knowledge of it. The variable used to represent the learning gains is the total number of correct answers scored by each participant on the test.

Upon arrival, participants signed a consent form and were asked two questions about their confidence level in the subject before the tutoring session (mean ≈ 0.1, median = 0, range = 1 for the treatment group, mean ≈ 0.4, median = 0, range = 5 for the control group). The researchers then made the participants sit in chairs in front of the Furhat robot, which stood on top of a table so that it could see all the participants' faces. While participants waited for the tutoring session to start, the Furhat robot uttered its idle lines every 15-20 seconds, e.g., "Just waiting till everyone is set" or "Take your time." When the session started, the robot greeted the participants, introduced itself, and showed the participants that it could change its face, voice, and language. From here, the Furhat robot's script changed based on the control and treatment conditions. The Furhat robot operator then changed the robot's face and voice to match the ethnicity the participants identified themselves with beforehand. Then, participants in both conditions were informed by the Furhat robot that they would be tested regarding the information they would receive during the 30-minute tutoring session. The Furhat robot would then give information about Gazi Osman Paşa and the Plevna's war. At the end of the tutoring session, it thanked everyone for participating in the experiment and informed the participants that they were not allowed to cheat or choose random answers. Participants were asked to leave the answer blank if they did not know the answer. After answering two questions about their confidence in the subject after the tutoring session (mean ≈ 5.6, median = 6, range = 9 for the treatment group, mean ≈ 5.2, median = 5, range = 6 for the control group), the participants took the multiple-choice test.

4 Data Analysis and Results

Data analysis was performed on the provided answers to the multiple-choice test. In addition, the furhat robot was programmed using Python 3 where the following modules were used: Scipy, Pandas, Seaborn, Pylab, and Matplotlib. A t-test was considered, but two assumptions could not be met. The Barlett's test confirmed that there were no significant differences between the variances of the test results of the two groups (p-value ≈ 0.64). Furthermore, the data were not normally distributed. Therefore, it was chosen to conduct a non-parametric test Mann-Withney U test. Data analysis results revealed that participants scored higher in the treatment condition (median = 7, range = 10) than in the control condition (median = 5, range = 7). As Figure 2 shows, the result of the Mann-Whitney U-test (W = 601, effect size = 0.29, p-value = 0.048) indicated a statistically significant positive effect of the treatment variable, meaning that participants scored higher when interacting with the robot adapting its appearance to the participants' ethnicity.

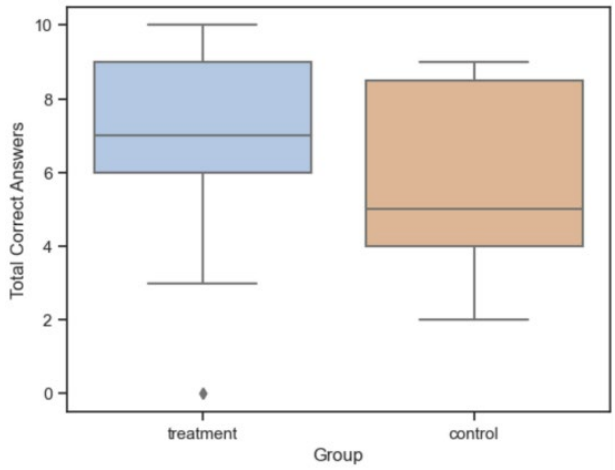

Figure 3: Difference between the control and treatment group
Source: Own

Moreover, the groups consisted of approximately 65% males and 35% females. However, their performance (mean ≈ 6.5, median = 7, range = 10 for males, mean ≈ 6.3, median = 7, range = 8 for females) did not reveal significant results.

6 Discussion and Future Research

This research aimed to check for the difference in knowledge about the history of the Battle of Pevna between participants interacting with an ethnically personalized face robot and a robotic face robot, hypothesizing that an ethnically personalized robot could enhance knowledge by improving the educational environment. The results revealed that participants who interacted with the ethnically personalized robot performed significantly better than participants in the control condition. The results may indicate that the effects observed in previous research, where students achieve higher scores in, e.g., math and reading (Gottfried et al., 2023), also occur when students interact with robots with an ethnically personalized face. The same holds for more positive academic skills among Black and Latino/Latina students when taught by teachers of the same ethnicity. In other words, it could mean that personalizing a robotic tutor's appearance to match students' ethnic identity leads to better learning outcomes. However, the effect could also be attributed to the treatment robot's more anthropomorphic appearance. It is possible that would, in turn, indicate that anthropomorphism influenced the result (Alves-Oliveira et al., 2016; Belpaeme, Kennedy, et al., 2018; Liew et al., 2022) more than ethnic personalization.

Several limitations were observed in the study. Firstly, a few participants reported being more focused on the robot's head movements than on its speech. While it may have caused some of them to score lower, the issue was unlikely to influence the between-group difference as it occurred in both groups. Secondly, we placed participants with different ethnicities in the control group, which could have influenced the dynamic of these groups and could have influenced the results. Furthermore, the quality of Furhat's faces and voices left a lot to be desired. Making the faces more detailed as well as improving the quality of the voices could increase the treatment variable's impact or show other effects. Finally, the multiple-choice test consisted of 10 questions. Moreover, the results of this study are consistent with positive results on higher learning gains as stated by Gottfried et al. (2023) and Redding (2019), however are not consistent with the mixed results on learning gains as stated by Driessen (2015). A more comprehensive test should be conducted in the future to further validate the results. Moreover, future research could expand on the results of this research in many ways. Analyzing the outcomes of such research would help assess whether the difference in the target variable was caused more by

anthropomorphization than ethnic-personalization or vice versa. Furthermore, focusing on participants' ethnicity instead of identity could lead to completely different findings and mitigate difficulty in interpreting their answers. By considering a participant's ethnicity (e.g., urbanicity (Jang, 2020) or social characteristics), a deeper understanding is gained of how such a social robot can be personalized even more to further improve learning gains. Finally, it would also be beneficial to experiment with an alternative subject of teaching. For example, how a more visual subject, such as art or mathematics, affects students' learning gains when taught by a social robot. We argue that extending the research on the use of a social robot to tutor multiple subjects contributes to a more general solution and knowledge about the advanced customization of social robots in practice.

7 Conclusion

The purpose of this research was to examine the difference in history knowledge between people interacting with a Furhat tutor with a robot face and a Furhat tutor with an ethnically personalized face, which raised the following research question: "*To what extent does a tutoring robot enhance the performance of its learners when using personalized and ethnicity-based anthropomorphization?*" An experiment was conducted where a history tutoring session with the Furhat was given to a treatment and control group. Here, the treatment condition would interact with a more human-like Furhat with an ethnically personalized face and the control condition would interact with a more robot-like Furhat. After the tutoring session, the groups would take a multiple-choice test on the subject of teaching and submit the results, from which their knowledge could be assessed. The results revealed that participants interacting with an ethnically personalized appearance during the tutoring session did receive better outcomes than those interacting with a robot with a robotic appearance. The result suggests that, in this study's context, personalized ethnical anthropomorphization implemented in robotic tutors could increase the knowledge about the subject of their users. Furthermore, the results revealed that biological sex does not seem to significantly influence the outcome, in the context of this study. From a theoretical point of view, this research contributes to the body of knowledge of social robotics, as well as that it provides initial insights into the use of ethnic anthropomorphization in social robots used in education. From a practical point of view, this research contributes to the practical application of social robots in education and

demonstrates that social robots can be personalized towards someone's ethnicity to boost knowledge as compared to social robots without ethnicity personalization.

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