Anthropomorphism in Social Robotics and Negative Attitudes, Sociability, Animacy, Agency, and Disturbance: A Pilot Study - EV

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Abstract

Designing a social robot that meets the acceptability requirements of the target end-users represents a challenge. The process is iterative and requires continuous improvements and optimization over time. One key aspect in designing an acceptable social robot is anthropomorphism. Social roboticists have developed assessment tools to evaluate different perception aspects. In this study, we evaluate the attitude of children toward four robots with different degrees of anthropomorphic traits. Questionnaires based on the Negative Attitude toward Robots Scale (NARS) and the Human-Robot Interaction Evaluation Scale (HRIES) were used to acquire the responses of 33 participants. To identify any changes due to interactions, a pre-test questionnaire was given prior to the interaction with a robot that was then followed by a post-test questionnaire. Statistical tests were used to analyze the effects of gender (i.e., males vs females), test (i.e., pre-test vs post-test), and four robots, on the perception of the robots. Statistical differences were found between the four robots in the subscales of HRIES, namely, Sociability, Animacy, and Disturbance. The preferences of the children were leaning toward the humanoid robot (i.e., Alpha) with the moderate anthropomorphic traits in the Disturbance subscale. Low to moderate correlations were found between the subscales of NARS and HRIES. The finding of this work highlights the importance of careful selection of anthropomorphic traits in designing social robots and the potential of integrated assessment tools to evaluate attitudes toward robots.

1 Introduction

Robots are being integrated in every aspect of our lives, most notably is the integration of robots in healthcare applications such as in surgery and prosthetics and also in close proximity to humans such as in rehabilitation and elderly care (20)(3)(21). The advances in sensors and wearable technologies are allowing the detection of different physiological variables, such as heart rate, which can be used by social robots during interactions to detect different forms of behaviors (4)(1)(38)(25)(5).Social robots are agents that are meant to interact directly with users to communicate, display and perceive emotions, establish relationships, and understand natural cues (31)(14)(15). The interest in using social robots has been extended to cover sensitive applications such as in the therapy of children with autism and special needs (18)(28). Previous studies reported the success of social robots in therapy sessions, which has allowed for many possibilities in early intervention (23)(37)(36). The design, shape, size, interaction scenario, embedded sensors, and functionality of social robots have varied depending on the intended goals, purposes, and investigations (24)(22)(19)(6)(2)(9). While it has made great strides, the research in social robotics is still lacking and in need to tackle challenges in different areas such as safety, design optimization, user acceptance, and interaction dynamics (30)(10)(11)(12)(7)(8)(13).

Unlike other forms of technologies, social robots will set foot into our personal spaces and have a more salient presence (43). The impression and perceived perception of a social robot plays an important role on the interactions and acceptability. Social robot design variables and factors such as the size, shape, gestures, sound, and anthropomorphism affect user's acceptance (33). To investigate the influence of different variables, various psychometric scales were developed to evaluate the acceptance of social robots based on different attributes (30). These scales rely on behavioral and physiological measures of robot acceptance using self-reported questionnaires (26)(39). Comfort, disturbance, animacy, warmth, anxiety, sociability,

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likeability, and intentionality are some of the scales that were considered in the elements of these questionnaires (35)(40). The outcomes of these questionnaires are analyzed using statistical methods to identify significant factors that affect attitudes toward social robots and influence acceptability (16).

Anthropomorphism, which is the attribution of human characteristics or traits to non-human entities, is widely adopted in social robotics. Developers and roboticists have projected anthropomorphism in different ways and at various degrees into their social robots designs. While having human-like attributes are desirable in social robots, going beyond a certain threshold might trigger eerie and unease feelings (i.e., Uncanny Valley Theory (34)). Assessment tools were developed to measure the effects of anthropomorphism and anxiety toward robots. The Negative Attitude toward Robots scale (NARS) was developed to evaluate users' attitudes toward a robot during interactions (35). The English version of this scale consists of 14 questions that are further categorized into three subscales pertaining situations, social influence, and emotions (Table. 1). NARS scale uses 5-points Likert scale of agreement. The Human-Robot Interaction Evaluation Scale (HRIES) is another scale that was recently developed based on anthropomorphism traits that was derived from de-humanization theory (40). HRIES uses 7-points Likert scale and consists of 16 items that are further categorized into four factors, namely, Sociability, Animacy, Agency, and Disturbance (Table. 1).

Table 1: The subscales and the notations for the Negative Attitude toward Robots scale (NARS) and Human-Robot Interaction Evaluation Scale (HRIES) that were adopted in this study.

NARS subscales		HRIES subscales	
NS1	Negative Attitude toward Situations of Interaction with Robots	HC1	Sociability
NS2	Negative Attitude toward Social Influence of Robots	HC2	Animacy
NS3	Negative Attitude toward Emotions in Interaction with Robots	HC3	Agency
		HC4	Disturbance

In this study, we evaluated the children's perceived perception of four robots with different anthropomorphic traits using the NARS and HRIES scales. We identified the effects of anthropomorphism traits in four robots on children and investigated the children's attitudes toward the robots. This paper is organized as follows. Section 2 presents related work. Section 3 describes the methodology. Section 4 presents the results while Section 5 provides the discussion. Section 6 concludes the study.

2 Related Studies

Studies investigating perceptions and attitudes toward robots have varied. One study investigated the effects of touch from a robot on humans (29). A humanoid robot that interacted with 48 students was considered in laboratory settings. The study assessed the students' attitudes toward the robot using NARS scale and their fears using the Robot Anxiety Scale (RAS). The results showed that a touch from the robot has affected the participants positively. Another study investigated cross-cultural differences (i.e., USA and China) in relation to ambivalent attitudes toward robots exhibiting different mental (i.e., mindful vs mindless) capabilities (27). Based on questionnaire methods, the study identified key differences between the tested population samples due to robot's different mind capabilities.

The perception of a robot requesting help was investigated in another study (42). Various variables, such as lights, expressions, and politeness levels, were tested with 139 participants using web and video approaches. Questionnaires were used to acquire the participants' responses and the negative attitudes toward the robot. The study reported significant differences for the measured effects such as perceived politeness and help intention. Another study investigated the relation between the anthropomorphism of a robot trainer and user acceptance in physical rehabilitation scenarios (32). Three illustrations of fictional scenarios depicting three trainer robots with different levels of anthropomorphism (i.e., low, medium, and high) were consider to acquire the participants' attitudes. The results showed that the level of anthropomorphism affected the patients' attitude toward robots positively.

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3 Methods

3.1 Participants

Thirty-six participants aged between 3–18 years old were recruited in Qatar for this study. 64% of the participants were females while 36% of them were males. A written consent was obtained from the parent of each participant to conduct the study. The procedures for this work did not include invasive or potentially hazardous methods and were in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

3.2 Robots

In this study, four robots were considered representing different degrees of anthropomorphism. The robots considered in this study were Professor Einstein Robot (Hanson Robotics, Hong Kong), Alpha (UBTECH Robotics, China), Cozmo (Anki, United States), and RVR (Sphero, United States). These robots were selected based on the degree of their human-like characteristics with Einstein robot having the most anthropomorphistic traits followed by Alpha, Cozmo, and lastly RVR, which is with the least traits (Fig. 1).

Figure 1: The four robots that were considered in this study. Ordered from left to right Einstein, Alpha, Cozmo, and RVR.

3.3 Procedures

3.3.1 Questionnaire items

The questionnaire consisted of 30 items adopted from the Negative Attitude toward Robots scale (NARS) and the Human-Robot Interaction Evaluation Scale (HRIES) (35)(40). The items in HRIES were presented as questions (e.g. Is the robot trustworthy?). The items for both NARS and HRIES were randomized (Table A1 and Table A2). These two scales were used in the questionnaire to measure the participants already existing bias or perception toward robots in general in the pre-test questionnaire and to measure any changes to their perception toward the robots after the interaction sessions in the post-test questionnaire. The 30 questionnaire items were reduced to 7 subscales (Table. 1). The subscales were then used in the analysis.

3.3.2 Experiments

Participants took part in two surveys: pre-test and post-test. Between the pre-test and post-test surveys, the participants interacted with one robot for around three minutes (Fig. 2). During these interactions, each robot performed a demo showing a different set of behaviors based on their respective capabilities.

3.4 Analysis

Cronbach's alpha test was used to determine the internal consistency of the questionnaire items. Multivarate ANOVA test was used on all the factors and the subscales of the questionnaire items. A Pearson's correlation analysis was performed between the NARS and HRIES subscales. The statistical tests were conducted using Minitab (v18.1, Minitab Inc., USA) at a statistical significance level of $p < 0.05$.

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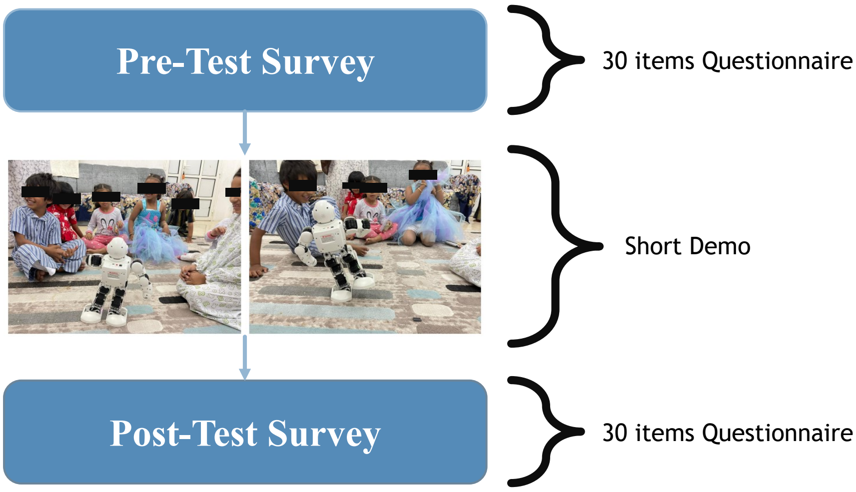

Figure 2: An overview of the experimental procedures that were considered in this study.

Table 2: The mean and standard deviation for the participants' responses based on the subscales and categorized based on the factors.

	Gender		Test		Robot			
Factor	Female	Male	Pre-test	Post-test	Alpha	Cozmo	Einstein	RVR
NS1	15.2 (4.4)	13.2 (3.9)	15.3 (4.4)	13.6 (4.1)	15.7 (3.7)	12.6 (5.4)	14.7 (2.7)	14.4 (5.1)
NS2	14.7 (4.3)	13.7 (4.1)	15.1 (4.6)	13.6 (3.8)	12.4 (3.5)	14.1 (3.5)	14.8 (4.1)	16.5 (4.8)
NS3	9.9 (3.2)	11.4 (3.0)	9.6 (3.0)	11.3 (3.1)	9.8 (2.7)	11.7 (3.5)	11.5 (2.6)	9.2 (3.5)
HC1	18.3 (5.4)	19.2 (5.2)	17.6 (5.5)	19.6 (4.9)	15.6 (3.7)	21.9 (5.4)	19.9 (4.2)	18.3 (6.0)
HC2	12.9 (6.6)	15.8 (6.3)	12.4 (5.8)	15.4 (7.2)	11.4 (5.6)	17.3 (4.1)	18.8 (4.6)	9.4 (4.4)
HC3	18.3 (4.8)	19.1 (4.0)	18.5 (4.3)	18.7 (4.7)	19.2 (4.1)	19.7 (3.2)	17.8 (4.6)	17.7 (5.8)
HC4	9.0 (4.9)	9.7 (5.4)	9.9 (5.6)	8.7 (4.5)	6.7 (3.5)	8.5 (4.8)	12.3 (5.6)	10.1 (5.1)

3.5 Results

To determine the internal consistency, a reliability test was performed on all the questionnaire items. Cronbach's alpha test was used and an acceptable score of 0.71 was achieved (17).

The mean and standard deviation for the responses of the participants based on the subscales and factors were tabulated (Table. 2). For NS1, the highest score achieved was for Alpha robot while the lowest was for Cozmo robot. As for NS2, the highest score was for the pre-test while the lowest was for the Alpha robot. The RVR robot achieved the lowest score for NS3 while Cozmo robot the highest. For HC1, Cozmo scored the highest while alpha robot the lowest. Einstein robot obtained the highest score in HC2 while RVR robot the lowest. For HC3, Cozmo robot has the highest score in HC3 while RVR the lowest. Alpha robot achieved the lowest in HC4 while Einstein robot the highest.

A multivariate ANOVA test was conducted on all the subscales, factors, and their interactions (Table. 3). A statistical significance was found for the Test factor in the case of NS3 and HC2 subscales at $p<.05$. For the robot factor, a statistical significance was found in the case of HC1, HC2, and HC4 at $p<.05$. A post hoc Tukey test in the case of HC1 showed that Alpha robot differed significantly compared to Cozmo and

Table 3: The ANOVA test results for all the subscales, factors, and their interactions.

	Gender		Test		Robot		Interaction	
Factor	F-value	p-value	F-value	p-value	F-value	p-value	F-value	p-value
NS1	2.91	0.09	0.87	0.36	1.78	0.16	0.32	0.81
NS2	0.66	0.42	2.22	0.14	1.97	0.13	0.2	0.89
NS3	0.94	0.34	4.17	0.046*	1.72	0.18	0.62	0.61
HC1	0.5	0.48	2.4	0.13	5.11	0.004*	0.09	0.96
HC2	0.1	0.76	4.86	0.032*	8.93	0.0*	0.49	0.69
HC3	1.76	0.19	0.75	0.39	0.6	0.62	0.78	0.51
HC4	0.74	0.4	0.12	0.73	3	0.04*	1.73	0.17

$^{*}p < 0.05$

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Table 4: The Pearson's correlation analysis between the subscales of NARS and HRIES scales.

	NS1	NS2	NS3	HC1	HC2	HC3
NS2	0.431*					
NS3	-0.413*	-0.241				
HC1	-0.45*	0.017	0.573*			
HC2	-0.253*	0.068	0.531*	0.633*		
HC3	-0.223	-0.181	0.49*	0.494*	0.333*	
HC4	0.369*	0.164	-0.348*	-0.185	0.004	-0.171

$^{*}p < 0.05$

Einstein robots. In the case of HC2, a post hoc Tukey test showed that Alpha and RVR robots differed significantly compared to Einstein and Cozmo robots. For the HC4 subscale, Einstein robot differed significantly compared to Alpha based on a post hoc Tukey test. No statistical significance was found for the interaction between the subscales and factors.

A Pearson's correlation analysis was performed between the NARS and HRIES subscales (Table. 4). A total of eleven significant correlations were found at $p<.05$. NS1 was found to be positively low correlated with NS2 and HC4 while negatively low correlated with NS3, HC1, and HC2. NS3 was found to be moderately positively correlated with both HC1 and HC2, positively low correlated with HC3, and negatively low correlated with HC4. For HC1, a moderate positive correlation was found with HC2 and a low positive correlation with HC3. HC2 and HC3 were found to have low positive correlation.

4 Discussion

Studying the effects of being human-like with desirable anthropomorphic features in social robotics represents a major challenge. Nonetheless, it is an essential step toward developing social robots that meet the minimal acceptability among the target end-users. The differences in preferences due to gender is another factor that affects the perception of robots. For example, a study reported that females are more accepting of humanoid robots (41). However, the results in our study did not show any significance for the gender factor. This discrepancy could be attributed to mismatch in the number of participants based on their gender. Another factor that could affected the preferences is the wide range of anthropomorphic traits across different robotic designs that made the responses of participants more evenly distributed. Interacting with the robots have altered some aspects of children's perceived perceptions. For example, significant difference was found for the test factor (i.e., pre-test vs post-test) in two subscales, namely emotions in interaction (i.e., NS3) and Animacy (i.e., HC2). Seeing the robots alive and in action might have made the children more relaxed and comfortable around robots, hence, affected their perceptions of the presented robots positively.

The participants' perceptions of the four robots have varied and showed discrepancy in the subscales. While no differences were found in NARS, the HRIES reported statistical significant differences in Sociability (i.e., HC1), Animacy (i.e., HC2), and Disturbance (i.e., HC3). Cozmo and Einstein were rated as the best in terms of Sociability compared to other robots. This could be attributed to their engaging interactions. Einstein scored the highest in terms of Animacy, which could be attributed to its facial expressions and hand gestures. In contrast, RVR scored the least in Animacy characteristics and that could be due to the lack of expression capabilities and minimal anthropomorphic traits. In terms of Disturbance, Einstein has scored the highest (i.e., worse) while Alpha the lowest (i.e., best). Some aspects of anthropomorphism in Einstein might be going beyond the safe threshold in the uncanny valley, hence, affecting the responses of the children negatively.

Designing an acceptable social robot is an iterative process that requires many refinements and improvements over time. The appearance of a social robot is one of the most important aspects in the initial stages of the designing process. Social roboticists have developed many assessment tools to evaluate different perception aspects. In this study, the Negative Attitude toward Robots scale (NARS) was used in conjunction with the newly introduced the Human-Robot Interaction Evaluation Scale (HRIES). Low to moderate statistically significant correlations were found between the items of these two scales. Interestingly, the negative items or positive items for each scale correlated positively with the respective ones of the other scale. This implies the possibility of developing a more comprehensive assessment tool that considers items from different scales.

The investigations conducted in this study were limited to 33 participants. To acquire more generalizable findings, a larger sample size is needed. Additionally, the participants should be divided into age groups to analyze its effects. Four robots were used throughout the surveys. However, more robots can be used to investigate different aspects of design and their effects on acceptability and perceived perceptions. The questionnaire items in this study were limited to the adopted from the two scales (i.e., NARS and HRIES). Nevertheless, more items can be incorporated from other scales to study more aspects.

5 Conclusion

The appearance of a social robot plays an essential role on its acceptance among the target end-users. This study investigated attitudes toward four robots of different forms and with different anthropomorphic traits. Using ANOVA tests, this study analyzed the relation between three factors (i.e., gender, test, and robot) and seven subscales derived from two assessment tools (i.e., NARS and HRIES). Based on the descriptive statistical results, all robots scored closely, hence, no robot can be ranked as the best or most acceptable to all the participants. Of the three robots, results showed that the attributes of RVR robot has the least Agency and Animacy. Unexpectedly, the Einstein robot, which is the most anthropomorphic robot among the four, scored the highest in Disturbance. The elements of the two scales (i.e., NARS and HRIES) correlated and provided new insights about the overall assessment.

This study represents first of its kind to be conducted in the region, which is interesting to identify cross-cultural differences. Future work should consider having children of different cultural backgrounds interacting with the robots multiple times to identify any changes due to repeated exposure. Furthermore, it should consider a variety of robots with different features and characteristics to examine their effects on children's perceptions.

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APPENDIX

Table A1: The randomized Negative Attitude toward Robots scale (NARS) items and their respective subscales that were considered in this study.

N.	NARS Question	Subscale
1	I would feel uneasy if robots really had emotions.	S2
2	Something bad might happen if robots developed into living beings.	S2
3	I would feel relaxed talking with robots.	S3
4	I would feel uneasy if I was given a job where I had to use robots.	S1
5	If robots had emotions, I would be able to make friends with them.	S3
6	I feel comforted being with robots that have emotions.	S3
7	The word “robot” means nothing to me.	S1
8	I would feel nervous operating a robot in front of other people.	S1
9	I would hate the idea that robots or artificial intelligences were making judgments about things	S1
10	I would feel very nervous just standing in front of a robot.	S1
11	I feel that if I depend on robots too much, something bad might happen.	S2
12	I would feel paranoid talking with a robot.	S1
13	I am concerned that robots would be a had influence on children.	S2
14	I feel that in the future society will be dominated by robots.	S2

Table A2: The randomized Human-Robot Interaction Evaluation Scale (HRIES) items and their respective subscales that were considered in this study.

N.	HRIES Question	Subscale
1	Is the robot weird?	HC4
2	Is the robot likeable?	HC1
3	Is the robot alive?	HC2
4	Is the robot intelligent?	HC3
5	Is the robot warm?	HC1
6	Is the robot self-reliant?	HC3
7	Is the robot trustworthy?	HC1
8	Is the robot creepy?	HC4
9	Is the robot human-like?	HC2
10	Is the robot uncanny?	HC4
11	Is the robot rational?	HC3
12	Is the robot friendly?	HC1
13	Is the robot real?	HC2
14	Is the robot intentional?	HC3
15	Is the robot scary?	HC4
16	Is the robot natural?	HC2

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