User Acceptance of Social Robots

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Abstract— **A mismatch between the user's expectations and the actual reality of social robots may negatively impact the acceptance and use of the robot. Given that the use of personal robots may be expected to become a part of people's everyday lives, it is critical to understand and consider the factors that may increase acceptance and adoption when robots are designed and introduced. How the robot is accepted by end users may be influenced by factors, such as: 1) the role assigned to the robot (i.e., robot function), 2) the robot's social capabilities or skills such as the robot's social intelligence and emotions expressions, and 3) the robot appearance. In this paper, an experiment is conducted to investigate, understand and identify the potential impact of these factors on user's acceptance and adoption of social robots. The experiment is conducted in a culture night event where some of the attendances are voluntarily interacted with the robot and filled out a questionnaire. The questionnaire is designed to measure their expectations and impressions before and after interacting with the robot (i.e., to assess robot's social skills), their preferences regarding the robot appearance (i.e., machine-likeness or human-likeness appearance) and finally to assess the need for a secondary interactive touchscreen display on the robot chest to facilitate interface and hence improve the robot's functionality. The goal of this paper is to understand the impact of these factors on user's acceptance and adoption and giving the users a more effective role in the design of this type of technology.**

Keywords-human robot interaction (HRI); personal robots; iSocioBot;

I. INTRODUCTION

Due to the continuing technological advancements, robots have been increasingly designed for personal use to perform simple servant-like tasks (e.g., the robotic vacuum cleaner), assisting and caring for elderly people [1], providing therapy and teaching autistic children new life skills to improve their social behaviors [2]-[4], at homes and in classrooms for education [5]-[7], or to be used purely for entertainment [8], [9]. It is expected that personal robots may become a part of people's everyday lives and therefore, it is critical to understand the factors that may increase its acceptance, adoption and use when designed and presented to its end-users. Despite the ever-growing development and public interest in robotics, a theoretical model specific to robot acceptance has not developed yet [10]-[12]. Acceptance has been widely studied for other forms of technology other than robotics such as the Technology Acceptance Model (TAM) [13], the Unified Theory of Acceptance and the Use of Technology model (UTAUT) [14], and the Chain Model (TPC) [15]. These models differ in complexity and content, however, their goals are to understand, explain and predict variables that contribute to user acceptance of various types of technologies. With the advent of technology acceptance models that can provide guidance for understanding the variables that influence robot acceptance, robot developers will be able to design robots that are more likely to be adopted. The goal of this paper is to identify the impact of some potential factors that might predict user acceptance of personal and social robots. These variables have been identified in the literature as potentially impacting acceptance; robot function, robot social capabilities, and robot appearance [10], [14], [15]. Functionality of the robot includes control and interface issues, such as the appropriateness of the control method for the task, the ease of use, and suitability and easiness of user interface. Social interactive skills, social intelligence, emotion expression, and dialogue system may influence the user expectations about the robot's social capabilities. A mismatch between the user's expectations and the actual social intelligence of the robot may negatively impact the acceptance and use of the robot [10]. Robot appearance is also expected to influence acceptance. The robot physical shape, such as the human-likeness, animal-likeness, machine-likeness, and robot's gender are expected to influence perceptions of and attitudes of end-users towards robots. It has been believed that deep understanding of these factors may lead robot designers to develop personal robots that will be widely accepted and adopted. In addition to a believable appearance, the design of a social robot requires a sensory apparatus able to perceive the social and emotional world, and a control system able to generate fast and acceptable responses [16], [17].

This paper is organized as follows; an introduction to user acceptance and a review of literature is given in Section I. Section II gives a brief introduction to the build in-house robot's platform called iSocioBot which will be used in the experiment, human-robot interaction system, factors impacting robot acceptance, and finally data collection process and the questionnaire. Results and the discussion of results are given in Section III. Concluding remarks are presented in Section IV.

II. Materials and Methods

A. Robot Platform (iSocioBot)

The autonomous robot platform used in this experiment is a newly developed in-house intelligent social robot (iSocioBot) using off-the-shelf standard components [18]. The main goal behind building iSociobot is to attempt to make service robots socially intelligent and capable of establishing durable relationship with their end-users [19]. iSociobot is designed to work side-by-side with people and therefore its body shape is built to resemble that of the human body, as it is shown in Figure 1. The robot is 1.49m tall, which is very close to the worldwide average human female height, 1.7m. This height makes its users more comfortable in interaction with it and gives the robot cameras, on top of it, a wider field of view (FOV) for more optimal and robust face detection and recognition. The human-like body frame, round face and nick of the robot is supported by a round face and a neck built on top of a low cost TurtleBot base able to move and turn around at a speed close to human speed [20]. The face is equipped with 32×32 RGB matrix LED array to enable the robot to display different types of facial expressions, and three Pololu RGB LED strips for ears and necklace.

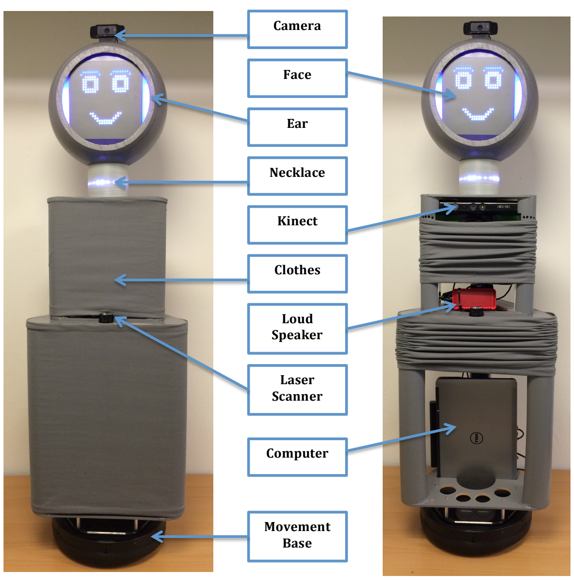

Figure 1. iSocioBot.

With the aid of the face and ears, the robot can simulate expressions such as listening, thinking and speaking. Due to the limited payload capacity of the robot base, which is maximum 5kg, it is decided to build the body frame from light materials such as plastic and wooden sticks and covering it with acoustic clothes to allow sounds to reach the acoustic devices and for the robot to look more feminine and friendly. The robot is also equipped with a range of sensors and actuators including encoders, laser range scanner, gyro, bumpers, Xbox Kinect, color camera, microphone array, loudspeaker, Wi-Fi module, two-wheel drive (2WD), etc., which can give the robot massive capabilities to sense the environment, able to localize, mapping, and navigate, avoid collision, simulate human's emotional and facial expressions, and have a dialogue system to verbally communicate with human end-users. iSocioBot software system is based on Robot Operating System (ROS) and Ubuntu. The software is a set of open source and newly written software frameworks running as a set of ROS-based processes. When all software modules are running, the robot is only limited by the capability of the onboard computer battery, which is around one hour, before the need for recharging.

B. Human-robot interaction using speech

In this section, we present our ongoing work in building and integrating technologies for natural and long-term human-robot interaction. The robot's ability for establishing simple and natural interaction with its users is of central importance for all kind of applications of personal robots. The system consists of spontaneous automatic speech recognition (ASR), audio-visual perceptual system, speaker localization and tracking, dialogue system, and speech synthesis. When a user speaks to the robot while they are not facing each other, the robot tends to slowly spin around until it can clearly face him/her. These components have been integrated on iSocioBot for real-time and long-term user interaction.

Although the robot has a more sophisticated artificial intelligence (AI)-based dialogue with natural language understanding system, which is able to respond to users in a more human and natural manner, in this experiment and for the sake of providing all users with the same conditions, a very primitive, flexible, and answers-independent dialogue script is used. The dialogue script consists of a set of ordered groups of sentences and questions. In the experiment, the robot randomly chose a sentence or a question from each group in order. Detecting when the user starts and stops talking timely control the transition between each script item. The dialogue starts by greeting the user using one of the welcome statements, asking about his/her name, a few sentences and questions to discuss the cultural night event, and then it ends by wishing him/her a pleasant event. The dialogue was conducted in Danish. An English translation of a part of the Danish script is shown in Table I.

C. Data collection and questionnaire

Data will be collected through a paper-based questionnaire [21]. The questionnaire consists of a number of questions assessing the views and impressions of participants regarding the factors that could potentially impact robot acceptance and adoptions. These factors include robot functionality, robot social capability, and robot appearance. The questionnaire will also collect some demographic data

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about participants such as gender, age group and previous experience in interacting with personal robotics. For children or adults with a low literacy rate, it was allowed to fill out the questionnaire verbally with the help of a staff member or parents.

TABLE I. DIALOGUE SCRIPT

No.	iSocioBot's Dialogue Script
1 2 3	Hello. Welcome to the cultural evening. I am SocioBot from Aalborg. What is your name? Hello. Welcome to this glorious event. My name is SocioBot and I come from Aalborg. What is your name? Hi there. Welcome to Culture Night. My name is SocioBot, and I come from Aalborg University. What is your name?
1 2 3	Great to see you. Nice to meet you. Om, it is nice to be with you.
1 2	Where are you from? Where do you live?
1 2	It's a good place. I have heard very well about it. It sounds like a nice place. I would like to visit it one day.
1 2	What made you decide to attend the cultural evening? Why are you here tonight?
1 2	I am glad you are here. There is much to see. I hope to get time to look around later, but so far I have to stand here and greet people. It is great that you are here. I have heard that there are many different exhibitions and stands around, so I hope to get time to try them later. For now, I greet people, when they come.
1 2	How many people do you think there are here tonight? How many do you think there comes to culture tonight?
1 2	It is a great event. I guess around 3000 visitors. Yes, it's a great event. My best guesses are that there will be about 3000
1 2	What do you think about my appearance in general? What do you think of the way I look like?
1 2 3	It's good to hear. Thank you. Thank you, your opinion is important to me. I would probably just consider it. Thank you, it's good to hear your opinion. I way just think about it.
1 2	It was nice to talk to you. I hope you get a lovely evening. It's been exciting to talk to you. I wish you a fun night. '

Before interacting with the robot, each participant has been given an introduction to iSocioBot, design, functions and its possible applications. They are also given a brief explanation about what kind of data the questionnaire will collect, why it is collected and how it will be used. A staff member provided explanations and guidance before and throughout the experiment to participants.

The paper questionnaire consists of four main questions with a set of standard answers, a section for demographic information, and three illustrative pictures. The first two questions are addressing the social intelligence skills of the robot by assessing the user's impressions and views before and after interacting with the robot, the third question is about the user's preferences of the robot appearance by asking whether they would prefer the human-likeness or machine-likeness of the robot and how this can affect their engagement with and acceptance of the robot, and finally the fourth question is addressing the robot functionality by assessing the need for a touchscreen display on the robot's chest to facilitate robot's control and user interface issues and how this can affect robot acceptance.

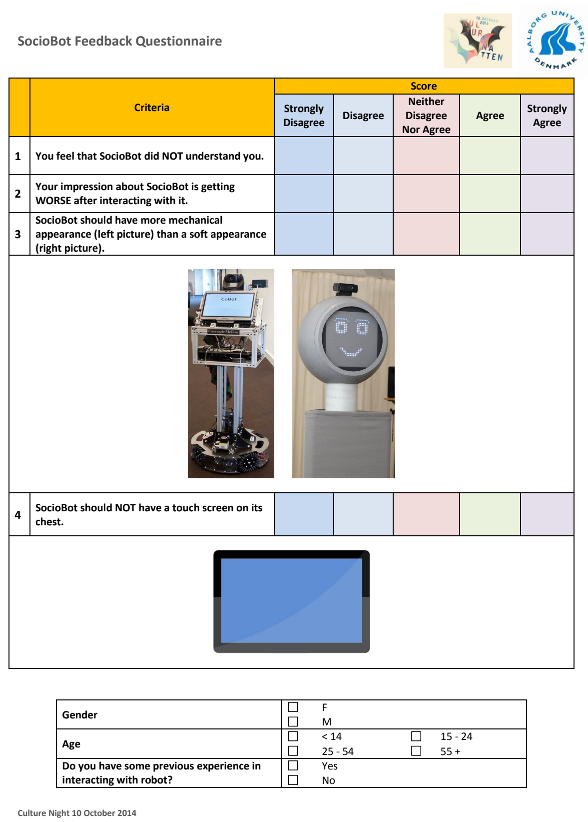

Figure 2. Paper questionnaire is designed to evaluate robot's acceptance.

For these types of questions, participants are provided with a set of categorical answers (i.e., Strongly Agree (SA), Agree (A), Neither Agree Nor Disagree (NAND), Disagree (D), Strongly Disagree (SD)) where he/she is supposed to choose only one answer for each question. Due to the fact that different age groups, genders, and educational and cultural background are expected to have different views on any given subject, and to get an idea of what kind of social, age, and gender groups are giving answers, the questionnaire asks each participant to identify his/here gender (i.e., male/female), choose an age group (less than 14, 15-24, 25-54, and above 55 years old), and answer whether he/she has previously experienced a kind of interaction with social robots. Identity of each participant he been left anonymous.

Due to the expected diversity of participants' age and educational background, questions are formulated in the most simplest way and the questionnaire is provided with a number of illustrative pictures to help respondents to get directly to the subject of each question. An English translation of the Danish questionnaire is shown in Figure 2. The experiment has been conducted during the annual culture night event organized by the Danish Ministry of Higher Education and Sciences in the city of Copenhagen. In this event, doors are opened for children and adults of all ages to experience new technology beside a massive of other cultural activities [22]. Interested attendees were asked to voluntarily take part in a dialogue with the robot and optionally fill out the questionnaire thereafter. Among hundreds of attendees, a total of 97 persons decided to participate.

III. Results & Discussion

97 participants in total have decided to take part in a dialogue with iSocioBot and fill out the questionnaire with a response rate above 98% (2 participants decided not to fill in the questionnaire). It has been believed that the experiment participants were a fair representative sample of the cultural night's attendees. In the following sub-sections, the collected data will be statistically analyzed.

A. *Participants' analysis*

It is believed that age, genders, and cultural background may have a certain impact on the answers of each individual participant. Therefore, we will analysis the group participants and break it down into response groups according to gender, age, and cultural background, as follows:

- *Gender*: among the 97 participants there are 40 females (around 41.24%) and 57 males (around 58.76%), as it is shown in Table II.
- *Age*: 86.60% of the participants are less than 14 years old, 1.03% from 15 to 24 years old, 9.28% from 25 to 54 years old, and 3.09% of the participants are above 55 years old, as it is shown in Table II.
- *Cultural background*: 88 participants (around 90.72%) of the sample have no previous experience in personal and social robots beforehand. Only 9 participants (around 9.28%) of the sample have experienced personal robots before. Therefore, the participant's previous experience in robotics will be considered insignificant in this study.

It is obvious, as it is shown in Table II, that the majority of the experiment participants are children under 14 years old and this indicates that young generations are more curious for testing and experiencing new and sophisticated technologies including personal and social robots. This also implies that personal and social robots are capable of attracting children and this can open the door for more applications of these robots in areas such as in education as an effective learning tool in homes and in classrooms and in useful entertainment as well [23][24].

TABLE II. Age vs. Gender Groups of Participants

Age (years)	Gender		Total
	Female	Male	
<14	35	49	**84 (86.60%)**
15-24	-	1	**1 (1.03%)**
25-54	3	6	**9 (9.28%)**
>55	2	1	**3 (3.09%)**
Total	**40 (41.24%)**	**57 (58.76%)**	**97**

B. *Questionnaire analysis*

In this section, data collected through the experiment will be summarized and analyzed, as it is shown in Table III. The three factors that might affect robot acceptance and adoptions will be analyzed through the following 4 questions:

Q1: do you feel that that iSocioBot did not understand you?

Q2: your impression is getting worse after interacting with iSocioBot?

Q3: iSocioBot should have more machine-likeness than a human-likeness appearance?

Q4: iSocioBot should not have a touchscreen display on its chest?

1) Social Intelligence of the robot: Questions 1 and 2 are used to ask participants about their views and impressions about the social skills of the robot. The first question asks whether the participant has the feeling that iSocioBot can understand him/her. This question implies evaluating the ability of the employed ASR system and the dialogue system to provide appropriate and logical answers corresponding to the user's answers. The second question asks the participant whether he/she still has the same impression about social robot or it is getting worse after interacting with the robot. This question, in addition to assessing the social skills of the robots, it also assess the user's previous believes and expectations of such kind of technology and to what degree its behavior matches its humanoid appearance. Participants' answers (%) are shown in Table III.

TABLE III. Statistical Results of the Questionnaire

Labels	Frequency of questionnaire answers			
	Q1	Q2	Q3	Q4
SA	9 (9.28%)	4 (4.12%)	7 (7.22%)	12 (12.37%)
A	23 (23.71%)	10 (10.31%)	2 (2.06%)	20 (20.62%)
NAND	13 (13.40%)	22 (22.68%)	7 (7.22%)	19 (19.59%)
D	34 (35.05%)	29 (29.90%)	27 (27.84%)	15 (15.46%)
SD	18 (18.56%)	32 (32.99%)	54 (55.67%)	31 (31.96%)

From Table III, 53.61% of the sample are disagree and strongly disagree on the hypothesis that iSocioBot cannot understand them compared to 32.99% who either agreeing or strongly agreeing that the robot cannot understand them clearly. 62.89% of the sample either disagree or strongly disagree that their impression about social robots is getting worse after interacting with iSocioBot. It could be concluded that the sample users are strongly satisfied about the current social skills of the robot and that there is a satisfactory matching between robot's humanoid appearance and its social skills. In other words, the majority of the participants strongly agree that the robot looks like human and is able to behave similarly by identifying and reacting to human communications using voice and facial expressions.

2) Robot appearance: Compared to industrial robots which are specifically designed for doing some specific tasks such as welding steel in specifically designed car factory or workshop, humanoid robots, on the other side, are designed for use by humans in daily life activities and in an unstructured and dynamic environment, therefore, these robots have to be adapted to the world in which humans are already live. However, It is not adequate that these robots would likely be designed to look like one of us, or just have a pleasing looking but it should be designed specifically for its intended function. Despite the reality that the majority of humanoid robots would have no use for their humanoid appearance and because people are naturally used to communicate and interact with other humans, people would be more accepting of these robots if they appeared and operated in a much more human manner. In this experiment, question number 3 is about user preferences regarding the robot appearance. It asks participants whether they would prefer the machine-like or human-like appearance of the robot? The majority of the participants in the interaction decided that they would prefer the human-likeness of the robot. 83.51% of the sample were either disagreeing or strongly disagreeing on the hypothesis that social robots should have a more machine-like appearance.

3) Robot functionality: To improve robots acceptance and use, question 4 is used to ask participant their views whether the robot should not have a touchscreen display on its chest. 47.42% of the participants group either disagreeing or strongly disagreeing on that hypothesis compared to 32.99% who see that it is not necessary for the robot to have a touchscreen display on its chest. Touchscreen would be used to facilitate communication with the robot and improve safety. Answers of participants are given in Table III.

IV. CONCLUSIONS

Creating robots which look, communicate and maneuver like humans has partially become a reality. These robots are now able to adequately communicate with human users using voice, identify human communications patterns and reacts accordingly, simulate human's facial expressions, and maneuvering like humans, however, it is still far to achieve the deep and complex level of human-to human communication and interaction. These robots are designed to be used by humans and in the world in which humans are actually live. In this regards, an experiment is conducted to measure the impact of some variables that are believed very effective for user acceptance and adoption of these robots. Data analysis showed that children less than 14 years old are more interested in interacting with robots. This complies with previous studies that indicated that young generations are more likely willing to experience and use new and sophisticated technologies specially robots. The success of the robot in attracting children is a signal of the usefulness of these technologies and it opens the door for employing this technology to work directly with human and operate in a variety of applications such as educating and entraining children at homes and in classrooms. If children will be major consumer of personal robots, they also should be given more effective role in designing these new technologies.

Despite the reality that the majority of robots would have no use for its humanoid appearance, results showed a strong support for the human-likeness appearance of personal robots. Because people are naturally used to communicating and interacting with other humans, it would be ideal situation for any one trying to use a personal robot. If we can design a robot which is able to react and communicate in a similar way to humans, it would no longer be thought as a machine by its user, and people would naturally be more engaged and accepting it if it appeared and operated in a much more human manner. For user acceptance and adoption, a strong matching between the humanoid appearance of the robot and its behavior must be achieved, and vice-versa. Results showed a strong support for humanoid robots to have a secondary mean of user-interface and communication rather than the natural human communication by voice. A touchscreen display on the robot's chest might give the robot's users a better feeling of safety in case the ASR system failed to work properly.

From this study, we can summarize the following concluding remarks; 1) in the area of social and humanoid robots, it is crucial to achieve a kind of matching between robot appearance and actions, if a robot's designer will go for the human-likeness appearance, a satisfying degree of robot's social intelligence and skills must be achieved, and vice versa, 2) in addition to the voice communication between the robot and its users, a secondary way, such as a touchscreen display on the robot's chest, to communicate with the robot in emergency cases or in case of ASR failure is crucial, 3) children are more interested in experiencing new technology and therefore they should be given a more effective role in the design and development of such kind of technology, and finally, 4) personal robots are very well accepted product and therefore it can be employed to work with humans in very challenging environments such as in classrooms for educating children and in nursery homes for elderly care giving.

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