Review Article

PERR
PSYCHO-EDUCATIONAL RESEARCH REVIEWS

Psycho-Educational Research Reviews
11(*3*), 2022, 751-773
www.perrjournal.com

Human-Social Robot Interaction, Anthropomorphism and Ontological Boundary Problem in Education

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Keywords

Education
Social Robot
Human-Social Robot Interaction
Anthropomorphism
Psychological Anthropomorphism
Ontological categories

Article Info:

Received : 12-06-2022
Accepted : 07-11-2022
Published : 10-12-2022

DOI: 10.52963/PERR_Biruni_V11.N3.11

Abstract

Artificial intelligence and robotics technologies do not manufacture robots only for industrial use, but also for healthcare, marketing, tourism and accommodation industries where social interaction is prevalent. Service robots are social robots that interact directly with individuals and to fulfill the physical, cognitive, emotional and social needs of individuals. Recently, it was observed that the number of studies on the employment of social robots in education has increased. These studies reported positive findings on the employment of social robots in educational settings; however, they also indicated certain problems. One of these problems was the ontological boundary problem due to the anthropomorphic design of these robots. Certain studies on human-social robot interaction demonstrated that the human-machine distinction has blurred, humans started to attribute anthropogenic traits to these robots such as intention, emotion and purpose, while these studies categorized these robots as live or hybrid. Anthropomorphizing the robots and the ambiguity of their ontological category could lead to problems such as excessive attachment, social isolation, and violation of privacy, and perceptions of the individuals about their existence could be altered. The present article aimed to provide information about the studies conducted on the employment of social robots in education, analyze the advantages and disadvantages of human-social robot interaction based on anthropomorphism and ontological boundary problem. Finally, certain recommendations are presented about the employment of social robots in education.

To cite this article: Gültekin, M. (2022). Human-social robot ınteraction, anthropomorphism and ontological boundary problem ın education. *Psycho-Educational Research Reviews, 11*(3), 751-773. doi: 10.52963/PERR_Biruni_V11.N3.11

INTRODUCTION

Recently, social robots (also called social assistants), designed to interact directly with individuals and provide physical, cognitive, social, emotional assistance, have been introduced in the service robot category (Breazal, 2003; Duffy, 2003; Kim et al., 2013; Shahid et al., 2014). The social robotics discipline was described as the science of developing and building robots that could be integrated into human groups and conduct complex social interactions, including communication and cooperation with humans (Dautenhahn, 2007; Fong et al., 2003). Breazal (2011) reported that social robots were designed to engage in social-emotional interaction with humans. Social robots generally engage in "meaningful interactions" with humans (Breazal, 2003). Another common definition described social robots as those that could interact with humans in a meaningful way, with a degree of autonomy based on their role in a social interaction (Sarrica, 2020). Asprino et al. (2022) reviewed the definitions of social robots in a recent article and identified three common properties: a) Physical body: Social robots have a physical body. b) Interaction with humans: Social robots can interact with humans by exhibiting human-like behavior and obeying the social rules associated with their roles. c) Autonomy: Sometimes, albeit limited, a social robot could decide independently. Social robots do not aim to perform a mechanical task, but directly interact with humans (Sheridan, 2016). Social robots are used in entertainment, health, home and workplace, tourism and accommodation, treatment, care and rehabilitation fields (Baraka et al., 2020). The increase in the prevalence of these robots has also been reflected in academic research. For example, more than 1600 studies have been published between 2000 and 2020 on social robot-human interaction (Stock-Homburg, 2021).

One of the areas where social robots have been investigated in recent years was education (Alam, 2021; Johal, 2020; Smakman et al., 2021). Although the findings on the employment of social robots in education have been promising, there are also various concerns and limitations (Belpaeme et al., 2018; Chalmers et al., 2022; Guggemos et al., 2022; Johal, 2020; Papadopoulos et al., 2021; Smakman et al., 2021; Woo et al., 2021). One of the sources of the above-mentioned concerns was associated with the design morphology of the robots and the humanoid features attributed to social robots.

The goal of socializing the robots introduced the field of social robotics that aims to design not only cognitively, but also emotionally and physically human-like robots. As robots became more anthropogenic in appearance (i.e., hands, face, eyes) and behavior, people became susceptible to anthropomorphize robots (de Visser, 2016; DiSalvo et al., 2002). The tendency of humans to anthropomorphize social robots is a well-documented phenomenon (Arora, 2021; Bartneck et al., 2009; Blut et al., 2021; Crowell et al., 2019; Duffy, 2003; Eyssel and Reich, 2013; Eyssel and Kuchenbrandt, 2012); Fussel et al., 2008; Hegel et al., 2008; Song et al., 2021; Zlotowski et al., 2015). The implementation of more and more humanoid features to robots has raised the question of whether social robots would be perceived as a new ontological category by humans (Damiano & Dumouchel, 2018; de Graaf; 2016). On the one hand, social robots are almost an ontological species similar to humans, on the other hand, they are classified as "inanimate" since they are not "biological beings". It was argued that although social robots are not biological living beings, their appearance and skills would lead to a perception about these robots as humans or alive, which in turn would cause children to perceive them as a new species, a new ontological category. (Kahn & Shen, 2017; Severson & Carlson, 2010). Kahn et al. (2011) developed the "New Ontological Category" hypothesis based on a series of studies. The meanings that students attribute to social robots and the concerns that arise from the cognitive and emotional bond they develop with these robots have been mentioned in various studies on the employment of social robots in education (Kennedy et al., 2016; Newton & Newton, 2019; Serholt et al., 2017, Sharkey & Sharkey, 2011; Smakman et al., 2021), and these concerns also include other digital devices (Festerling and Siraj, 2021; Koike and Loughan, 2021; Pradhan et al., 2019).

Studies on the employment of social robots in education have focused on learning outcomes, system availability, multimedia synchronization, and the impact of social robots on learning skills (Stower, 2021; Tolksdorf et al., 2021). The current article aims draws the reader's attention to the problem of anthropomorphism and ontological boundaries in the "human-social robot" interaction, based on the study findings that the employment of social robots in education would be more popular in the future. The possible risks of these concerns in self-perception and social relations of individuals have been discussed in the literature. The position of educators in this discussion would affect the extent of the acceptance of social robots in education. The present study aimed to convey the benefits and risks of social robots in education and to provide a comprehensive framework for discussion.

In the first section, previous studies on the employment of social robots in education and related advantages and disadvantages are discussed. In the second section, the concept of anthropomorphism, the preference of anthropomorphic designs in social robotic architecture, and why people tend to anthropomorphize robots are discussed. In this section, Epley's three-factor anthropomorphism theory, which was the first theory that attempted explain anthropomorphism comprehensively in psychology, are addressed. In the third section, the ontological boundary problem, which was based on the human tendency to anthropomorphize non-human beings, and the new ontological category hypothesis are discussed. In the final section, the potential problems of anthropomorphism and ontological border problem are discussed, and certain recommendations about the employment of social robots in education are presented.

THE EMPLOYMENT OF SOCIAL ROBOTS IN EDUCATION

The interest in the employment of social robots in educational settings has increased in recent years (Leite et al., 2013). Although the first study on the employment of social robots in education was published in 1992 (Belpaeme, 2018), the number of studies has significantly increased especially since the 2000s (Johal, 2020). Lambert et al. (2020) investigated user experiences in social robotics in over 93 publications and reported that education was one of the most researched fields. They reported that the interest in social robots in education has increased since 2013 due to personalized learning opportunities (Johnson & Lester, 2016), the improvement in the job satisfaction of teachers (Shih et al., 2007), reduction of workload (Han, 2010), student satisfaction (Alemi et al., 2017) and motivation (Smakman et al., 2021) that social robots provide. Belpaeme et al. (2018) reviewed 101 papers on the employment of social robots in education published between 1992 and 2017 and reported that demographic and economic factors such as school budget limitations and the increase in the class population have increased the need for technological assistance in education. A study on the employment of social robots in psychological health services (Gültekin, 2022) reported that the employment of artificial intelligence technologies has been encouraged for cost reduction, improvement of work quality, reduction of the workload of experts and personnel, and provision of personalized services.

THE ROLE OF SOCIAL ROBOTS IN EDUCATION

Social robots generally play three roles in education are: teacher/assistant-teacher, peer and student (Ceha et al., 2021; Guggemos et al., 2022; Hood et al., 2015; Levinson et al., 2021). Certain comprehensive studies reported that social robots are predominantly employed as teachers/assistant teachers, followed by peer/co-learner, and finally as (novice) students (Ceha et al., 2021). Chen et al. (2020) reported that pedagogical robots are designed either as an instructor or as a teacher playing the role of a student who reinforces learning and argued that both robot types supported learning. However, the authors stated that a peer-like design would further promote the learning and emotional engagement of the students. In a study where 59 5-7 years old public school children participated in a vocabulary learning activity, Chen et al. (2020) demonstrated that the Tega social robot, designed as a peer robot, improved children's vocabulary learning and affective skills and student participation better when compared to an intermediary such as a teacher or a peer. In the meta-analysis conducted by Belpaeme et al. (2018), it was reported that social robots supported learning in all three roles; however, the authors did not compare the effectiveness of different robot types. The authors determined that 48% of the social robots played the role of a teacher, 38% played the role of an assistant teacher, and 9% played the role of a peer or student in the study.

THE EDUCATIONAL LEVELS THAT EMPLOYED SOCIAL ROBOTS

Research on the employment of social robots in education were mostly conducted with preschool and primary school children (Woo et al., 2021; Donnerman et al., 2020; Johal, 2020). Other studies were conducted with high school and college students (Ahmad et al., 2021; Bainbridge et al., 2011; Björling et al., 2020; Donnerman et al., 2020). Björling et al. (2020) reported that although several studies have been conducted with children, adults and the elderly, the number of studies conducted with young adults were insufficient. Woo et al. (2021) also argued that in 23 studies reviewed by them, 11 were conducted with primary school students, 6 with kindergarten or pre-school students, and 3 with secondary school students. Smakman et al. (2021) investigated the attitudes of 4 stakeholder groups towards the employment of social robots in education and reported that children generally had a positive attitude towards social robots in various countries and cultures. Young children's openness to learning and interaction with social robots, and the attractiveness of social robots (Chen et al., 2020) could be among the reasons why children were preferred in studies. Woo et al. (2021) reported that it was clear that robots motivated students in the classroom in a meta-analysis. Other studies indicated that robots significantly excited the children, and their motivation increased their interest in the course (Majgaard, 2015). Furthermore, it was reported that social robots, the content and behavior of which were personalized for children, and that employ nonverbal social cues, high social interaction skills, and adequate feedback, could improve learning and participation of the children (Kory-Westlund & Breazal, 2019).

THE MOST STUDIED TOPICS IN SOCIAL ROBOTICS RESEARCH

Social robots are mostly employed in the education of children with autism spectrum disorder and second language learning (Woo, 2021). Kanero et al. (2018) conducted a comprehensive study on the effectiveness of social robots in second language learning and determined that social robots were promising in this field; however, they could report evidence to suggest their superiority to human educators. In a study conducted by Özdemir and Karaman (2017), the interaction between students with moderate intellectual disorders and a humanoid robot was investigated based on feedback types, and it was observed that students welcomed robot feedback (such as physical and vocal feedback) with admiration and excitement, and it was determined that teachers also reported positive views on robot-assisted education. Also, social robots could improve math (Ahmed et al., 2020), multiplication table (Konjin & Horn, 2020), reading (Gordon & Breazal, 2015) instruction and sign language skills (Köse et al., 2015), and promote scientific curiosity (Shiomi et al., 2015). It was also reported that social robots contributed to writing, reasoning and problem solving skills (Newton and Newton 2019). Papadopoulos et al. (2020) reviewed 21 studies on the employment of social robots in education and investigated the impact of social robots on learning outcomes in 10 studies and reported that 7 studies were conducted on language development. The authors emphasized that only two studies were on mathematics education and social robots have not been adequately studies in mathematics and science instruction.

THE EFFECTIVENESS OF SOCIAL ROBOTS IN EDUCATION

Previous studies indicated that the findings on the employment of social robots in education have been generally promising. Belpaeme et al. (2018) reviewed 309 findings reported in 101 articles and proceedings in a meta-analysis and determined that social robots led to both cognitive (knowledge, comprehension, application, analysis, synthesis, assessment) and affective (attentiveness, receptiveness, sensitivity, reflectiveness and curiosity) achievements; however, affective achievements were more significant. Johal (2021) extended the meta-analysis conducted by Belpaeme et al. (2020) and argued that the studies conducted after 2016 reported both cognitive and affective achievements and social robots had a real potential in education. Other meta-analyses reported that social robots were promising in education, despite certain limitations and ethical concerns (Papadopoulos et al., 2020; Woo et al., 2021). Belpaeme et al. (2018) indicated that social robots have the potential to participate in the educational infrastructure such as paper, whiteboard and computer tablets and social robots were inevitable in education, and they were hopeful about the benefits of social robots.

ROBOT TYPES EMPLOYED IN EDUCATION

Belpaeme et al. (2018) reported that physical social robots have three advantages over other digital/virtual devices (i.e, tablets, videos, computers): a) These could be employed in curricula and populations (e.g., visually impaired individuals, toddlers) that require physical interaction (e.g., handwriting or basketball), b) The interaction between students and a physical robot improves social behavior that is beneficial for learning (e.g., robots are more interesting and fun), and c) It improves student learning outcomes. For example, physical robots led to effective learning with puzzles that required cognitive skills when compared to robot videos and audio instruction (Powers et al., 2007). Li (2015) reviewed 38 empirical studies that compared physical robots and remote-control or virtual agents (avatars) and reported that physical robots were more effective. Konjin and Horn (2020) reported that robots have some advantages and disadvantages when compared to human teachers. These advantages included patience, inability to exhibit anger, equal behavior towards all students, and impartiality. Disadvantages included technical problems (e.g., maintenance), lack of educational versatility, limited skills, and inability to manage the classroom.

Previous meta-analyses also reviewed studies on social robot types, and it was reported that the anthropomorphic robot NAO was the most common social robot (Belpaeme et al., 2018; Guggemos et al., 2022; Woo et al., 2021). Belpaeme et al. (2018) argued that that all robots have anthropomorphic features such as a head, eyes, a mouth, arms or legs, except the "Heathkit HERO" employed in a study by Draper and Clayton (1992). A meta-analysis on the relations between children and social robots reported that anthropomorphic robots were the most common types (64 out of 86 studies) and 40 out of 64 studies were conducted with NAO (van Straten et al., 2020). A contextual study (conducted between 2009 and 2019) on the employment of social robots in psychological health services for children reported that the two most employed robots were NAO and PARO (Kabacinska et al., 2021). Lambert et al. (2020) established that NAO was the most common among 35 robots employed in 93 studies conducted in different fields. NAO is 58 cm tall and approximately 5 kg robot produced by Aldebaran Robotics in 2008. It is an anthropomorphic social robot. It has two legs, two arms, two hands, a head, and two LED eyes. NAO is furnished with two cameras, seven tactile sensors, four directional microphones and speakers that allow interaction with the environment. It can walk, speaking, listen, and communicate with others (Gelin, 2019; Robaczewski et al., 2021). Apart from NAO, anthropomorphic robots such as Pepper, Robovie, Zeno, iRobiQ, PaPeRo have been used in educational research (Belpaeme et al., 2018; Özdemir and Karaman, 2017; Woo et al., 2021) Certain studies reported that anthropomorphic robots were more preferred by the users (Diaz, 2011; Hegel et al., 2009). Anthropomorphic robots such as NAO and Pepper have been preferred since their appearance does not lead to the "uncanny valley" problem (Li et al., 2010; Woo et al., 2021).

There is no linear correlation between the anthropomorphic look of the robots and positive emotional responses. The decrease in the curve of the correlation between anthropomorphic robots and positive emotional response is called the uncanny valley effect (Yin et al., 2021). The concept of uncanny valley, which was initially introduced by Masahiro Mori in 1970, argues that the increase anthropomorphic features of robots would lead to fright, disgust and fear among humans after a while (Katsyri et al., 2015; Lay et al., 2016; Mori et al., 2012; Wang et al., 2015). According to Mori, the fact that beings (such as robots) that we initially knew as inhuman have anthropomorphic appearances and movements, allowing us to establish affinity and empathy and interact with them. However, when the resemblance is indistinguishable, these positive emotions could become negative and lead to uncanniness in people (MacDorman & Ishiguro, 2006; MacDorman, 2019; Mori, 1970).

ETHICAL CONCERNS ASSOCIATED WITH THE EMPLOYMENT OF SOCIAL ROBOTS IN EDUCATION

Although the number of studies on the use of social robots in education has significantly increased in in recent years, the studies on the related ethical issues are limited. Two recent meta-analyses studies argued that the number of studies on ethical concerns was limited (Papadopoulos et al., 2020; Woo et al., 2021). Tolksdorf et al. (2021) emphasized the need for further research on ethical issues in a paper that discussed ethical issues associated with child-robot interaction in kindergartens. Albeit limited, studies on the ethical issues associated with the employment of social robots in education provided valuable data on anthropomorphism and the ontological boundary problem.

The studies where ethical issues associated with the employment of social robots in education emphasized the vulnerability of children (Sharkey, 2016; Smakman et al., 2021; Tolksdorf et al., 2021). Sharkey (2016) categorized these ethical concerns as follows: privacy, attachment, deception and loss of human contact, and control and accountability. Tolksdorf et al. (2021) argued that children whose perceptions, communication requirements and emotions are different from the adults, are a vulnerable group; thus, further care should be taken to avoid undesirable results when working with these age groups. For example, children do not consider issues such as privacy, security, attachment to social robots, which adults consider as ethical problems (Smakman et al., 2021).

Tolksdorf et al. (2021) discussed the ethical issues associated with social robot-child interaction in four domains: the institutional setting of a kindergarten, children as a vulnerable group, the role of caregivers, and pedagogical concepts. The authors noted that current research is mostly based on a micro-approach that focused on learning outcomes, system availability, multimodality (multimedia synchronization), and vulnerable groups, and macro-approaches such as institutional goals, institutional trust, key stakeholders (such as parents and educators), expectations from the activities should be included in research and robot design.

Smakman et al. (2021) conducted a qualitative study with 118 participants that included five stakeholder groups (teachers, parents, children, policy makers and employees of social robot companies), and reported that the stakeholder groups considered social robots as useful educational tools but expressed various ethical concerns. In the research, 14 ethical stress points were discussed, and 3 further topics were added after the study: robot bias, physical safety of children, security of the data collected by robots, deception (the ability of robots to convince children inaccuracies), attachment to robots, friendship that could develop between the robot and the child, contact of robots with the users, accountability, responsibility, confidentiality and privacy. Stakeholder groups except the children expressed various ethical concerns on these issues and stated that robots could reduce human emotions and sociability in children. Certain policy makers were concerned about the possible attachment of children to the robots. Parents and teachers were concerned about potential robotic behavior among children. In the study, participants expressed concerns about the security of the data collected from children and stated that children could prefer to share their secrets with robots instead of their parents. The authors emphasized that stakeholders were concerned about the decrease in human contact and socialization due to attachment to robots and argued that social robot manufacturers should take this concern into account.

Serholt et al. (2017) investigated the ethical concerns of participants about social robots in the classrooms in focus group discussions conducted with 77 teachers in three European countries (UK, Sweden and Portugal). The authors asked questions associated with four ethical themes: "privacy, the role of robots in replacing humans", "relational effects of robots on children", and "responsibility". Participants mentioned the harms that child-social robot interaction could such as social isolation, excessive attachment, changes in self-perception, and dehumanization. They argued that robots do not have the ability to understand and reflect emotions, they cannot communicate with students at the same emotional level, which could harm children's emotional intelligence and dehumanize them. In the study, teachers also mentioned the ontological boundary problem, emphasizing that children could perceive robots as psychological friends, and when they finally recognize that they were not, they could feel cheated and disappointed. One participant raised the possibility harming an entire generation. The authors claimed that robots could behave as if they were "alive", which could change children's perceptions about life and lead to "category ambiguity". Concerns about confidentiality and privacy were also raised. It was stressed that social robots could learn children's emotional traits in detail, unlike other data collection technologies. The participants were concerned that the student data could be employed by governments for surveillance and control or purchased by commercial organizations. One participant stated that the students would feel uncomfortable with the robots if they knew that the data and their emotional profiles were stored. The authors indicated that children who think they are under emotional surveillance would need to regulate not only what they should do, but also how they should feel.

SOCIAL ROBOTS AND ANTHROPOMORPHISM

Anthropomorphism was derived from the words "*anthropos*" (human) and "*morphos*" (form) in Greek (Dokur, 2019). Anthropomorphism is the tendency to attribute human forms to inanimate objects, animals and other beings (Duffy, 2003; Zlotowski et al., 2015). Several philosophers such as Darwin, Freud, Feuerbach, and Hume argued that humans tend to anthropomorphize non-human beings (Epley, 2007). Airenti (2018) claimed that anthropomorphism is a common human attitude that starts in infancy and maintained throughout life. Anthropomorphism and animism, which Piaget considered as a manifestation of irrational thinking in his discussion of cognitive development, are correlated. According to Guthrie (1993, p. 62), who introduced anthropomorphism, animism and anthropomorphism are rational rather than irrational responses to the uncertainty of the world. They originate in the human search for order and meaning. It could be suggested that animism and anthropomorphism are also functional. According to Guthrie, it is better for someone to compare a rock to a bear than to compare a bear to a rock (Guthrie, 1993, p. 6). In certain conditions such as uncertainty, fear, and despair, humans describe natural events such as storms and earthquakes with an anthropomorphic approach. It is natural for humans to try to explain the universe with anthropomorphic models, since the highest level of organization known to humans is human ideas and actions (Airenti, 2018). According to Foerster (Cited by Hegel et al., 2008), anthropomorphizing allows us to express what we do not understand in comprehensible terms, and individuals understand themselves the best. Thus, humans try to understand God by attributing human properties (Guthrie, 1993, p. 6). According to Airenti (2018), although the concepts of animism and anthropomorphism are closely related, there are also differences between them. Piaget's animism is a step in human ideas and explained by human egocentrism. When humans reach the causal thinking stage, they get rid of this erroneous approach. Furthermore, animism is used to attribute deliberate action or "life" to objects and natural events. Anthropomorphism is the attribution of human psychological states or affective traits to non-humans. Piaget considered animism as a temporary and primitive stage in the preoperational period. However, anthropomorphism could persist throughout the lifetime and is unlikely to be associated with primitiveness or underdevelopment of reasoning (Airenti, 2018).

WHY ANTHROPOMORPHIC SOCIAL ROBOTS ARE PRODUCED?

Certain experts consider this a necessity. Duffy (2003) argued that robots should be anthropomorphic in shape, behavior or both to establish meaningful social interactions with humans. However, it was also argued that zoomorphic or non-anthropomorphic robots could also enter social interaction with humans (Brezeal, 2016). Social robotics industry designs anthropomorphic robots based on the assumption that humans would prefer to interact with machines as they interact with other humans (Fong, 2003; Lee et al., 2021). The purpose of the anthropomorphic design of social robots that are designed to interact with individuals due to their intended use (education, care, entertainment, therapy, communication, counseling, etc.), is to facilitate interaction (Duffy, 2003) and social acceptance of the robots (Breazal, 2016). Certain studies evidenced that individuals found robots with anthropomorphic behaviors more acceptable (Fink, 2012). The basic idea has been to design robots that encourage users to attribute human emotions and mental functions to robots, allowing users to actively participate in the social performance and presence of the robots (Damiano & Dumouchel, 2018). It was reported that variables such as availability, adaptability, enjoyment, sociability and friendship were important in social robot design to ensure user acceptance (de Graaf & Allouch, 2013). Social robot architecture is a broad field that includes a variety of disciplines on incorporating multiple anthropomorphic traits into social robot design such as auditory (Dou et al., 2021) and tactile senses (Willemse et al., 2017), social distancing (Kim & Mutlu, 2014), emotions (Arkin et al., 2003), and personality (Arora, 2021).

However, the extent of the adaptation of the anthropomorphic elements in social robotics is an important ongoing debate. Designing robots that would be perceived as capable could lead to unrealistic expectations among users. Duffy (2003) argued that establishment of a balance between the expectations of individuals and the capabilities of the machines was an important criterion. Thus, the anthropomorphic design of robots is a matter of delicate boundaries. In terms of form, Duffy (2003) proposed an "anthropomorphism triangle", which argued that the heads of social robots could be designed with three approaches: "human", "iconic" and "abstract". The human angle of the triangle included fully anthropomorphic designs, while the abstract angle included designs with minimal resemblance to humans. The iconic angle featured cartoonish head designs. The iconic angle is anthropomorphic but does not look perfectly human due to the exaggerated design. According to Duffy (2003), the optimum anthropomorphism should be near the center of the triangle. A study conducted with 578 8-14 years old children confirmed Duffy's findings (Tung, 2016). The study findings demonstrated that children preferred moderately anthropomorphic robots when compared to highly anthropomorphic ones. A recent study suggested that the degree of anthropomorphism could vary based on the context and argued that social robots should exhibit more anthropomorphic features when compared to industrial robots (Roesler et al., 2022).

WHY PEOPLE HAVE ANTHROPOGENIC TENDENCIES?

It was reported that the tendency of humans to anthropomorphize non-human beings dates back to ancient times. The criticism of Xenophanes the ancient Greek philosopher about the anthropomorphic deity approach adopted by Homer and Hesiod evidence that the tendency goes back to ancient times (Şimşek, 2015). Furthermore, anthropomorphic figures carved from mammoth teeth between 35 and 40 thousand years ago were found and it was claimed that individuals tried to form objects with anthropomorphic motives (Jones, 2021). David Hume (1995, p. 41) claimed that anthropomorphism was universal: “People have a universal tendency to reflect themselves on all beings, attribute to every object the qualities they see, know and hear from within. We see human faces on the moon and armies in the clouds…” According to Hume, if experiments and ideas do not correct this tendency, we will continue to attribute intent to all that makes individuals sad or happy. Thus, Hume considers anthropomorphism a primitive inclination.

However, how can the persistence of this trend be explained? Are anthropomorphic attributes simply a misconception or a powerful pattern built into human nature? Studies demonstrated that humans frequently anthropomorphize animals (Eddy et al., 1993), nature (Williams et al., 2021), products and brands (van Esch et al., 2019). Certain studies reported that simply moving geometric shapes were also anthropomorphized. Heider and Simmel (1944) reported that individuals attribute desires, intent, and beliefs to shapes such as circles, rectangles, and triangles. The origins of the anthropomorphic tendencies of humans have been discussed by philosophers, anthropologists, archaeologists, biologists and psychologists. Certain studies indicated that anthropomorphism is not a simple pareidolia, but has evolutionary and biological origins (Serpell, 2002). Certain studies conducted with neuroimaging techniques revealed that anthropomorphic responses such as empathy towards robots had neurological origins (Gazzola et al., 2007; Suzuki et al., 2015; Waytz et al., 2010). In particular, there suggested that mental anthropomorphism was an innate, rooted, strong, and involuntary biopsychosocial tendency as old as humanity (Varella, 2018). The universality of anthropomorphism is explained by the fact that anthropomorphic thinking promotes adaptation and survival. Also, certain pragmatic approaches emphasized the benefits of anthropomorphic approaches to non-human beings. Certain studies demonstrated that anthropomorphism promoted pro-environmental attitudes and behavior (Williams, 2021) or animal welfare (Butterfield et al., 2012), although other findings conflicted these views.

PSYCHOLOGICAL ANTHROPOMORPHISM

Limited psychological experiments have been conducted to understand the human susceptibility and methods to anthropomorphize robots (Duffy, 2003). The three-factor anthropomorphism theory developed by Epley et al. (2007) was the first approach that comprehensively investigated the interaction between humans and nonhumans in psychology. Epley et al. expanded the concept of anthropomorphism beyond the appearance or realism of the robots and investigated the phenomenon of psychological anthropomorphism (Kamide et al., 2013). Kamide et al. (2013) later developed various tests to measure psychological anthropomorphism and published empirical evidence for psychological anthropomorphism.

According to Epley et al., anthropomorphism explains the imaginary or real nonhuman behavior with anthropomorphic traits, motivations, intentions, and emotions. Anthropomorphism is an inference for the unobservable traits of non-humans rather than observable behavior. The psychological approach to anthropomorphism discussed the reasons why and when humans tend to anthropomorphize non-human beings. Epley et al. identified one cognitive and two motivational psychological factors that affect anthropomorphism. These three factors are affected by four independent variables: dispositional, situational, developmental and cultural. These three factors include the agent, effect motivation, and social motivation. The resulting agent is the primary determinant of anthropomorphism. Thus, self-knowledge or human knowledge of other humans is the basis of their behavior towards nonhumans. Because self-knowledge is abundant, detailed and accessible. Self-knowledge and phenomenological experiences are automatically accessible and well-organized and serve as an automatic foundation for reasoning about others. Thus, since humans have more knowledge about their species, they anthropomorphize to make sense of the nonhuman being until they can establish an adequate mental model.

Effect motivation refers to the increase in anthropomorphic trends when individuals are motivated to understand and explain nonhuman behavior. Individuals desire to have an impact on their environment. However, when uncertain, they act to reduce or estimate uncertainty. According to the authors, the motivation to feel effective leads individuals to understand and analyze uncertainty. An uncertain situation should be predictable to maintain a sense of control. Epley et al. argued that anthropomorphism increases with high effect motivation and decreases with low effect motivation.

Social motivation suggests that individuals without or with weak social bonds with others tend to anthropomorphize more (Epley et al., 2007). Social motivation increases anthropomorphism in two domains. First, social motivation strengthens access to social cues about human traits, increasing the tendency to perceive human traits in nonhumans. Second, it increases the propensity to anthropomorphize non-human agents by increasing one's propensity to seek social connection sources in the environment. For example, an individual who feels lonely, isolated, or deprived of social bonds tend to develop social ties by anthropomorphizing nonhuman agents.

Although anthropomorphism literature demonstrated that this trend is universal, studies reported that not everyone anthropomorphizes robots at the same degree and anthropomorphism is affected by age, gender, personality, prior experiences (exposure to robots) and culture (Eyssel et al., 2012; Festerling and Siraj, 2021; Haggadone et al., 2021; Oranç and Küntay, 2020; Zlotowski, 2015). Younger individuals (Manzi et al., 2020), women (van den Berghe et al., 2020), easterners (Kaplan, 2004), and individuals who feel lonely tend to anthropomorphize more (Shin & Kim, 2020). Shahid et al. (2014) also examined age-related and cultural differences in child-robot interaction and determined that 8-year-old children and Pakistanis established better relations with robots when compared to 12-year-old children and Dutch, respectively. Epley's theory can help explain the sources of these differences (Festerling and Siraj, 2021; Fink, 2012). Certain studies reported findings that supported Epley's theory (Blut et al., 2021; Eyssel and Reich, 2013; Pradhan et al., 2019).

ANTHROPOMORPHISM AND THE ONTOLOGICAL BOUNDARY PROBLEM IN HUMAN-ROBOT INTERACTION

Studies demonstrated that social robots could be included in a new ontological category as psychological entities, as their capacity to establish cognitive and emotional "human-like relationships" increase. This could blur the ontological and psychological borders between humans and machines or could lead to the perception of robots as a new ontological/psychological category (Kahn & Shen, 2017; Prescott & Robillard, 2020; Severson & Carlson, 2010). Prescott and Robillard (2020) argued that the conflict between the ontological and psychological status of the robots is the foundation of the ethical problems associated with human-social robot interaction. While social robots are clearly “machines”, their behavioral skills (e.g., speech, relationship, and emotions) that are only observed in actual classrooms could lead to their exclusion from that classical distinction (Prescott & Robillard, 2020). Studies have not reported clear findings but classified robots as machines, living or humanoid, or hybrid entities.

A relatively early study by Nigam and Klahr (2000) investigated whether 39 students in three age groups (preschool 14, second grade 14, fourth grade 11) attributed vitality to robots. Cognition, emotions, and will were considered as the indicators of vitality. In the study, none of the fourth-grade students attributed vitality to robots. 30% of preschool and second grade students attributed cognition, 20% emotion, and only 10% attributed will to inanimate robots.

In a study conducted by Beran et al. (2011) with 184 5-16 years old children that included 95 females and 86 males, who visited a science museum in Canada, a robot that picks up wooden blocks with its mouth to build a tower was displayed. The robot was programmed to make eye contact with children from time to time when performing that task. Then, the authors measured whether the children attributed vitality to the robot by asking two cognitive, emotional and behavioral questions. The cognitive questions included the following: “If you meet the robot again, can the robot remember you?” and “Does the robot know how you feel?” The emotional questions included the following: “Does the robot like you?” and “Would the robot feel left out if a friend came and you played with her (him)?” The behavioral questions included the following: “Does the robot see the blocks?” and “Does the robot want to play with you?” The findings demonstrated that the children attributed several human traits to the robot. In the cognition dimension, 52.7% of the children stated that the robot would remember them, in the emotional dimension, about 64% of the children stated that the robot liked them, and in the behavioral dimension, 41.8% of the children stated that the robot could see the blocks. The authors argued that children attributed vitality to the robot, albeit emotional attributes were more significant.

In another study conducted by Oranç and Küntay (2020) with 80 3-6 years old children, children were asked to choose between human, robot and cartoon characters to acquire new knowledge in five fields. The study findings revealed that children preferred to ask questions about machines to the robots and did not prefer to ask psychological and biological questions. The authors reported that the children perceived robots mostly as machines and not as a source of biological knowledge due to their belief that robots and machines are the same.

Oranç and Küntay (2020) emphasized that children considered robots at a point on the continuum between these extremes rather than considering them as animate or inanimate. Serholt et al. (2017) investigated the views of 77 teachers in three countries on the robots employed in the classrooms and reported that although children did not perceive robots as completely human, they attributed certain human traits to robots. Pradhan et al. (2019) reported a similar finding in a study conducted with digital assistants (i.e., Alexa, Google Assistant). In a study conducted with 7 seniors, certain participants considered Alexa "neither human nor machine" (Pradhan et al., 2019). Similar results were reported in a recent meta-analysis (Wang & Wang, 2022). Wang and Wang (2022) analyzed the findings reported in 40 papers on the perceptions of 3-12 years old children about digital assistants (smart speakers). The study findings revealed that children attributed anthropomorphic features to smart speakers and considered them neither completely animate nor inanimate.

Based on a series of studies (Kahn et al., 2002; Kahn et al., 2004; Kahn et al., 2006; Kahn et al., 2007; Melson et al., 2009), Kahn et al. developed the “New Ontological Category” hypothesis (Gaudiello et al., 2015; Kahn et al., 2011). This hypothesis is discussed in further detail in the next section.

THE “NEW ONTOLOGICAL CATEGORY” HYPOTHESIS

Kahn et al. (2011) described ontology as the expression of the basic categories of existence and the methods to distinguishing these categories (e.g., animate or inanimate) in a study where they discussed the "new ontological category" hypothesis. Kahn et al. conducted 3 studies on children's mental, social and moral attributes to robots with AIBO (Kahn et al., 2002; Kahn et al., 2006; Melson et al., 2009). The first study was a content analysis of the discussions in three online forums with 182 members, possibly all adults, that owned AIBO robots. While 48% of the participants attributed biological traits to AIBO (e.g., “It seems alive”), 68% attributed mental and social qualities (e.g., “I consider it a friend”). 12% of the participants considered AIBO a moral being (e.g., “I felt sorry and guilty when I caused pain”). While 80 3 to 5 years old children participated in the second study conducted by Kahn et al. (2006), 72 7 to 15 years old children participated in the third study conducted by Melson et al. (2009). The findings of these studies revealed that 38% of preschool children, 23% of 7-9 year old children, and 33% of 10-12 year old children attributed “vitality” to AIBO, while only 5% of 13-15 year old children stated that it was alive. The analysis of the rationale behind these answers revealed that the children did not simply categorize the robots in animate or inanimate categories. Certain responses suggested certain non-biological forms of life. For example, one child said, “It (AIBO) lives as a robot.” However, in both studies, most participants attributed human traits such as thought, emotion, and sociability.

Kahn et al. (2012) conducted a fourth study with Robovie, an anthropomorphic robot. Robovie was capable of verbal communication and emotional responses. The study conducted with 90 participants in three age groups (9, 12 and 15) investigated whether children would attribute moral, mental and social traits to Robovie. Participants interacted with Robovie in 15-minute sessions through a game. The study findings demonstrated that the majority of the children perceived Robovie as a cognitive (intelligent and emotional) social being (a friend that could comfort and keep a secret). The study also demonstrated that children attributed moral traits to Robovie. For example, participants believed that Robovie should not be psychologically harmed. About one-third (33%) of the children stated that Robovie should vote in the elections, and 42% stated that if it worked, it was entitled to a wage. One of the interesting results of the study was the difficulty that children experienced in classifying Robovie ontologically. 38% of the children considered that it should be classified in a category between animate and inanimate. For example, a child stated that Robovie was half-alive half-dead. The responses of other children were similar. The authors argued that was "the arrival of a new ontological species". Kahn et al. (2006) likened the robot's status between animacy and non-animacy to the color "orange;" neither yellow nor red, something in-between. In conclusion, the authors argued that these findings supported the "New Ontological Category" hypothesis.

Other studies revealed that children did not perceive robots as inanimate, although they never included them in the human category (Bernstein & Crowley, 2008; Jipson & Gelman, 2007; Saylor et al., 2010). Although children knew that robots were not alive or eat or drink, they attributed psychological characteristics such as emotions or thoughts to robots (Jipson, 2016). According to Haggadone et al. (2021), increasing evidence demonstrated that humans perceived robots as a different species. In a recent study, Guzman (2020) reported that there were five ontological boundaries between humans and computers: origin of existence, autonomy, emotion, intelligence and communication. The findings of the study that these boundaries become more blurred as traits such as emotions are added to new technologies indicated that the boundaries between human and machine have become permeable.

DISCUSSION AND CONCLUSION

In the present article, previous studies on the employment of social robots in education are reviewed, anthropomorphism and psychological anthropomorphism, and the ontological boundary problem in human-social robot interaction are discussed. Although positive views on the employment of social robots in education are emphasized, certain experts warned that human-social robot interaction could lead to negative consequences in mental health. It could be suggested that the objections to human social robot interaction and the employment of social robots in education were based on two premises: a) Humans have a psychological predisposition to anthropomorphize other beings, as proposed by the theory developed by Epley et al. (2007). b) The field of social robotics employs this predisposition to develop deceptive robots (Leong & Sellinger, 2019) c) This deceptive interaction between human and social robot leads to negative consequences for humans (Sharkey, 2016).

The employment of social robots in education is more critical due to three factors. First, education entails contact with children (especially in the preschool, primary and secondary education), who are the vulnerable social segment. Second, this contact is long-term and education has a key impact at a time when the emotions, thoughts and behavior of the children develop. Third, as stated by Woo (2021), “trust” is important in educational environment. Deception and trust are closely associated (Rogers and Howard, 2021; Smakman et al., 2021). The employment of social robots in education, an environment where trust is essential, requires a comprehensive analysis of the consequences of the employment of social robots that could harm mental health.

Social robotics develops social robots that lead to illusions among humans. Various studies documented that the robots could deceive people (Dragan et al., 2015). Kaminski et al. (2017) argued that a social robot could monitor the user continuously with sensors and could record user behavior from all angles, while even not looking at the user directly. “Robot deception” is an important ethical issue in human-social robot interactions. The discussion has been centered on the premise whether it is ethical to design robots as beings that imitate feelings, intentions, and objectives by deceiving the human predisposition to anthropomorphism. Certain experts voiced their concerns about human-social robot interaction and argued that social robot design was inherently "deceptive," and therefore unethical (Saetra, 2021; Sharkey, 2016; Sparrow, 2002; Turkle, 2010). As discussed in the previous sections, the deceptive appearance of social robots could lead to an ontological category ambiguity. It could be suggested that the problem that originates in the increasing ambiguity of ontological categories, is two-dimensional, leading to inaccurate self-perception and perception about the social environment. The first dimension is the perception of the social relation object such as a type of machine as a human or living being, while the second is the self-perception as a social entity that interacts with the robot.

The most important concern induced by the first dimension is the possibility that the children could start substituting robots for humans in social relations. It was reported that robots do not only have a physical effect in the common social environment, but also have a social and psychological effects (de Graaf, 2016). Sharkey (2016) considered the deceptive relationship initiated by social robots by provoking anthropomorphic tendencies in humans and argued that the development of the robots that seem to understand and care about humans was a hoax in the article "Should We Welcome Robot Teachers?" Sharkey (2016) discussed that the three main ethical concerns about the employment of robots in education purposes were “attachment, deception and loss of human contact”. According to Sharkey, it is difficult to distinguish these concepts. The deceptive social appearance of robots leads to the attachment of individuals to robots, which in turn leads to loss of human contact. Balle (2021) indicated that the bond with social robots could be long-term. According to Balle, attachment to robots could continue after the "novelty effect" wears off. McCurry (2018) reported that a funeral was held for irreparable robot dogs in Japan and people mourned for them. Carter et al. (2020) analyzed the social media posts after the discontinuation of the production of robots such as Jibo and Kuri and stated individuals mourned their "dead" robots and the language used in the wake of these robots was similar to the language used for humans. On the other hand, children could befriend social robots and share their secrets with them, which could lead to a violation of their privacy (Sharkey, 2016). Sharkey warned that the harms caused by the robots that create the illusion of sensitivity and understanding may not be immediate (Sharkey, 2016). According to Sharkey and Sharkey (2011), children and the elderly are the most vulnerable social segment and more likely to be affected by anthropomorphism. Both segments exhibit a strong need for social contact, and social robots could falsely create the impression that they could meet that need. Because these groups may not understand the technology behind the appearance of social robots. Thus, Sharkey (2011) reported that it was not correct to design social robots to encourage anthropomorphic attributes in classrooms (Sharkey, 2016).

One of the strong objections to human-social robot interaction was declared by Turkle (Turkle et al., 2006; Turkle, 2010; Turkle, 2018). Turkle argued that social robotics addressed human weaknesses rather than human needs. According to Turkle, smart digital devices and social robots create the illusion of relationship, reduce actual social relationships among people and basic human abilities such as empathy. Turkle argued that smart technologies and social robots are a simulation, independent of technological advances. A simulated emotion is never a real emotion (Turkle, 2010). Humans crave genuine attention, relationship, and love. Turkle (2018) claimed that smart technologies became a solution for individuals who cannot tolerate loneliness and desire a risk-free relationship, and asked whether we want robots to say things that they cannot really understand such as "I love you" (2006). According to Turkle, smart technologies and robots should not be allowed to intervene with human relations (Turkle, 2010).

The second concern was the changes that could be induced by human-social robot interaction in self-perception. Wan and Chen (2021) argued that an individual has three types of personalities: individual, relational and collective. They reported that considering non-human objects as humans could affect self-identity at all three levels. As reported by Sharkey et al. (2017), robots not only reflect who we are, but also influence who we become. Certain studies suggested that individuals who interact with smart technologies and social robots could perceive themselves as digital or robotic entities. Festerling and Siraj (2021) investigated how children anthropomorphized digital voice assistants and argued that Epley's theory was inductive based on human self-perception; however, the experiences with smart technologies could affect this foundation. In other words, the ontological foundation of self-perception in children who grew up with smart technologies (digital assistants, social robots, avatars, etc.) may be affected by their social reality. Beran et al. (2011) emphasized that the distinction between biological and technological nature has become more uncertain as robots with strong anthropomorphic features are produced, and reported that as robots became more popular and child-robot interaction increased, the standards for animate and inanimate minds could be altered and reorganized. Haggadone et al. (2021) emphasized the significance of contact with and exposure to robots. In a study conducted by Jong et al. (2021) with 570 8-9 years old children, 82% of the children intended to adopt domestic robots and one of the reasons for which could be the early exposure of the children to technologies. Indeed, children get to know smart technologies a a very early age, and as the age of exposure to smart technologies gradually decreases, the domestic use of these technologies becomes more prevalent. According to the data reported in a survey conducted in the USA, 17% of 0-8 years old children had a smart digital assistant at home in 2017, which increased to 41% in 2020 (Rideout et al., 2020). Bryson (2010) reported that children could prefer smart technologies to people, and these technologies could change children. Kubinyi et al. (2010) published a clearer warning. They argued that children who start interacting with robots at an early age would socialize by adopting non-human behavior patterns; and thus, a new human species called "Homo-Technicus" may emerge. Certain studies demonstrated that children do not consider robots only a source of information or a partner, and they adopt the recommendations of the robots more those of the adults (Wollmer et al., 2018).

Another major concern about human-social robot interaction was associated with security and privacy. Several studies emphasized the issues of confidentiality and privacy (Newton and Newton, 2019; Serholt et al., 2017; Sharkey, 2016; Smakman et al., 2021; Tolksdorf et al., 2020). Social robots could collect and store detailed data about the individuals they interact with. Kaminski et al. (2017) also stressed the participants could not even be aware of this they. In a study conducted by Serholt et al. (2017), a teacher stated that children would feel uncomfortable if they knew that the robots stored data about them. A study by Shamsuddin and Jotterand (2021) included significant warnings. The authors reported that digital technologies include "persuasion technologies". Persuasion technology was described as an data processing system, device, or application that was deliberately designed to change personal attitudes or behavior in a predetermined direction (Fogg, 1999). Shamsuddin and Jotterand (2021) considered social robots as examples of persuasive design. Pepper's manufacturer, for example, openly stated that their design goal was to "attract the consumer." Companies that produce social robots could collect significant user data for product development. For example, Pepper's manufacturer stated that they monitored all behavior and applications installed on the robot (Shamsuddin and Jotterand, 2021). The authors complained that the designs and privacy statements associated with the social robots they reviewed were not transparent. Since the lack of transparency in artificial intelligence algorithms is a serious ethical concern, Iphofen and Kritikos (2021) argued that companies keep their product algorithms a secret due to intellectual property rights. However, several publications on the ethics of artificial intelligence considered transparency and privacy as ethical principles. Jobin et al. (2019) reported in a study where they reviewed 84 papers on artificial intelligence ethics that 73 papers mentioned the principle of transparency and 47 papers the principle of privacy.

Certain experts emphasized that anthropomorphic principles should not be abused in the design of social robots. Kaminski et al. (2017) indicated that robots should be designed based on the principle of "honest anthropomorphism". Leong and Selinger (2019) described dishonest anthropomorphism as the abuse of human predisposition to anthropomorphism. According to the authors, dishonest anthropomorphism was not about simply misleading the user but it aims to exploit innate cognitive and perceptual weaknesses of humans. Leong and Selinger (2019) argued that as robots become more ingrained in our daily lives, dishonest anthropomorphism would pose more serious threats. Because robot designers will recognize the value of deliberately exploiting anthropomorphic tendencies and could cause consequences to the detriment of individuals, deliberately or not. The authors emphasized the importance of ethical principles in robot design and presented a taxonomy of dishonest anthropomorphism, noting that humans were vulnerable to dishonest anthropomorphism. The taxonomy identified the anthropomorphic human tendencies that could be abused by designers, related robotics and artificial intelligence designs, and the potential problems of such designs. Leong and Selinger (2019) indicated that the dishonest anthropomorphism taxonomy could guide robotic designs.

As emphasized in various sections of the present article, certain benefits of social robot use in education were demonstrated. For example, the feedback of social robots could be beneficial for the students in learning stages that require repetition and practice. However, educators should consider the potential harm of this technology to human psychological health and inter-human interaction. It would be beneficial for educators to conduct further studies on the long-term drawbacks of social robots. Social robots and other smart technologies are increasingly introduced in our lives. However, educational institutions should remain prudent about the employment of these technologies, and emphasize the harms associated with these technologies. Schooling, especially preschool and primary school periods, entails critical language, cognitive, social and emotional development stages. Educational institutions require well-defined ethical and legal protocols based on differences observed in various developmental stages. In particular, students should simply be instructed that the social robots are machines and are not conscious or have emotions. The technology-based cultural climate increasingly distances children from human interaction. In educational institutions, children could experience this type of interaction the most. Thus, schools should be sensitive about human interaction. Especially the support of parents, policy makers and senior decision makers is of importance. Finally, educators and mental health professionals should play more active roles in the development of algorithms and designs that would protect the well-being of students.

Artificial intelligence technologies and robotics advance rapidly. As observed in almost every industry, educational institutions will also be affected further by technological advances in the near future. As discussed in the current article, human beings are prone to anthropomorphizing non-human beings. Cognitive psychology has emphasized that expectations, beliefs, and psychological conditions could lead to faulty interpretations and distortion of reality (Beck, 2005, pp. 27, 55; Türkçapar, 2012, pp. 40-41). Human predisposition to anthropomorphize other beings and human potential to misinterpret reality could blurr categorical distinctions between humans and machines. Certain experts have long warned about the problems associated with this development. Since these warnings are important for the organization of the relationship between humans and technology that would contribute to well-being of humans.

Raising awareness about the employment of social robots in education, its advantages and disadvantages for the students could be considered as a contribution to the literature. Further studies that would be conducted on the employment of social robots in education would lead to a better understanding about the associated risks and opportunities.

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