Socially assistive robots for teaching emotional abilities to children with autism spectrum disorder

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ABSTRACT

Socially assistive robots, when used in a way that takes into consideration children's needs and developmental characteristics, can be useful tools to enable children's development. More specifically, due to their characteristics (predictability, simplicity, and repetition) robots can be especially helpful to teach emotional abilities to children with autism spectrum disorder (ASD). Previous research has provided preliminary evidence that robots can help children improve in some domains such as joint attention and imitation. However, no studies have examined how robots can be integrated in intervention protocols targeting the acquisition of emotional abilities in children with ASD. This paper presents a work in progress on an emotional ability training developed for children with ASD using the QT socially assistive robot. This training aims to test whether children with ASD can benefit from a robot-mediated training to improve emotional ability.

Keywords
Autism spectrum disorder, socially assistive robotics, emotional abilities, training.

1. STATE OF THE ART

Socially assistive robots operate in close proximity to humans and can serve as toys, educational tools, and therapeutic aids [1]. Among several features, these robots can express or perceive emotions, can communicate using dialog, can recognize or even learn models from other agents, can establish social relationships, and can have distinctive personalities [2]. These features make socially assistive robots ideal tools to be used to support children's development [3]. More specifically, robots are promising to support children with social interaction difficulties such as children with autism spectrum disorder (ASD).

1.1 Emotional Difficulties in ASD

ASD is a neurodevelopmental disorder characterized by deficits in social communication, social interaction, and by restricted and repetitive patterns of behaviors and interests [4]. In addition to these difficulties, internalizing and externalizing problems in ASD are the most common reasons for referral [5]. Internalizing problems can be described as inner-directed behaviors that generate distress in the individual [6], like withdrawal, anxiety, and depression. While externalizing problems can be described as outer-directed behaviors that generate discomfort and conflict in the surrounding environment [6], like impulsivity, aggressiveness, and control problems. Both internalizing and externalizing problems are strongly linked to social competence problems, peer acceptance, and adaptive development in childhood [7]. Moreover, internalizing problems during childhood can have repercussions into adolescence and adulthood [7].

These internalizing and externalizing problems are common in children with ASD [8] and have been linked to difficulties in emotional reactivity and emotion regulation [9, 10]. Emotional reactivity and emotion regulation constitute two aspects of emotional functioning that although not independent, have distinct features [11]. Emotional reactivity refers to the arousal of experiential, behavioral, and physiological systems in response to an emotional event [12] and emotion regulation refers to the efforts to change or maintain emotional responses [13]. Additionally, emotional awareness has been found to be linked to some emotional disturbances in individuals with ASD [9, 14]. Finally, children's capacity to produce and recognize facial and vocal expressions of emotions is a fundamental pre-requisite for effective emotional ability [15]. Therefore, improving emotional ability in children with ASD can be of paramount relevance for their development.

1.2 Therapies for ASD using socially assistive robots

So far, studies that used robots in therapies for ASD have focused in four main domains: to analyze individuals' responses to robots in comparison to humans; to use robots to elicit behaviors; to use robots to model, teach, and practice skills; and to use robots to give feedback [16]. These studies have shown preliminary evidence that robots can be used to increase engagement [17], attention [18], and social behaviors such as joint attention [19], cooperation [20], and imitation [21, 22] in individuals with ASD.

There has also been some evidence that robots can be used to increase children's emotional expression [21, 23, 24]. Nevertheless, not many studies have examined ways in which robots can be integrated in intervention protocols [16] and to our knowledge, no studies have so far examined the effectiveness of using robots to train emotional abilities in children with ASD. Due to the characteristics of socially assistive robots, they could be ideal tutors for emotional trainings with children with ASD. In some studies, preliminary evidence based in small samples shows that children with ASD prefer interactions with robots over humans [17, 25, 26]. Additionally, robots provide novel sensor stimuli [27] which can stimulate children's interest, attention, and increase therefore children's assimilation of contents. Finally, robots, compared to humans, are more predictable, more systemized, less complex, and less distressing for children with ASD [27], which can potentially reduce treatment related anxiety and fear. Furthermore, some studies have shown that outcomes can be better for robot-based therapies than for human-based therapies [17, 27-29].

Therapists could also potentially benefit from trainings using socially assistive robots with children with ASD. Administering trainings to children with developmental disorders can often be repetitive and lengthy, and can become frustrating and stressful to the therapist. A training which is administered by a robot can therefore reduce the therapist's burden of memorizing the content in a standardized way and of administrating the same training to several children while following strict protocols.

2. EMOTIONAL ABILITY TRAINING

In this paper we present our work in progress on an emotional ability training developed for children with ASD using the QT socially assistive robot (see Figure 1). We aim to test whether children with ASD can benefit from a robot-mediated training to improve emotional ability. In this training, the QT robot acts as a tutor and administers the training.

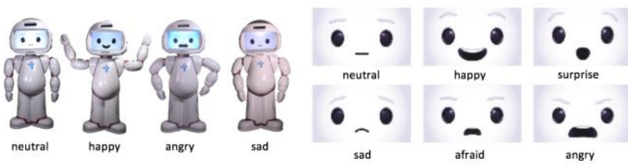

Figure 1: QT Robot expressing different emotions.

2.1 Objectives

The direct objective of the training is to improve emotional ability in five domains of emotional ability in children with ASD: facial and vocal production of emotions, facial and vocal recognition of emotions, emotional reactivity, emotional awareness, and emotion regulation. The indirect objective is to, by increasing emotional ability, reduce internalizing and externalizing problems in children with ASD.

2.2 Robot's Characteristics

In our experiment we use prototypes of QT, a commercial social robot from LuxAI[1]. QT is a humanoid robot with an expressive social appearance. It has a screen as its face, allowing the presentation of facial emotions using animated characters, and has 14 degrees of freedom to present upper-body gestures (see Figure 1). Eight degrees of freedom are motor-controlled, two in each shoulder, one in each arm plus pitch and yaw movements of the head. The other four, one in each wrist and one in each hand, are manually configured. QT has a close-range 3D camera mounted on its forehead and is provided with a microphone array. QT is powered with an Intel NUC processor and Ubuntu 16.04 Lts, supporting native compilation of programs in Ubuntu, and is provided with a native ROS interface. Communication with QT is established by wifi.

QT is programmed using a visual programming interface we have developed as an Android application for tablets and smart phones, details of which are presented in another paper, "ProCRob Architecture for Personalized Social Robotics", submitted in parallel to the "Robots for Learning" workshop of HRI 2017. Empowered by Blockly [40], our Android app provides a set of blocks which non-computer experts such as teachers and therapists can use to build complex social robot applications and control QT. Blockly-based programs are then translated into the RobAPL source code [41] for execution, a language we previously developed to support the programming of autonomous robots.

2.3 Participants

The training is target at N=40 boys and girls who have been diagnosed with ASD and who are aged 5 to 12 years old. Children can either attend regular or special education schools but must have average or above average intelligence (full-scale IQ > 70) and be able to understand simple instructions and provide simple answers to questions. Additionally, children should know numbers (1 through 20) and the alphabet. Children are being recruited primarily in Luxembourg but also in France, Belgium, and Germany.

2.4 Measures

2.4.1 Screening Measures

For screening purposes the following instruments are used: a demographics questionnaire, the Wechsler Nonverbal Scale of Ability [30] for functional cognitive assessment and IQ, and the parent-reported Social Responsiveness Scale [31] for ASD screening.

2.4.2 Outcome Measures

Emotional ability is assessed through the parent-report questionnaires Emotion Regulation Checklist [32], Emotion Regulation Rating Scale [33], Self-Control Rating Scale [34], and Alexithymia Questionnaire for Children [35]. Children also perform emotion production, emotion recognition, reactivity and regulation, frustration-eliciting, and Cyberball tasks [36, 37].

Internalizing and externalizing problems are assessed with the parent-reported questionnaires Children Behavior Checklist 6-18 [38], Strengths and Difficulties Questionnaire [39], and a questionnaire developed for the purposes of the present study to assess children's most difficult behaviors from parents' perspective.

2.5 Research Design

The effects of the training are assessed through individual pre-post training comparisons and through comparisons between treatment group and waitlist control group in the different outcome measures at several time points (see Figure 2).

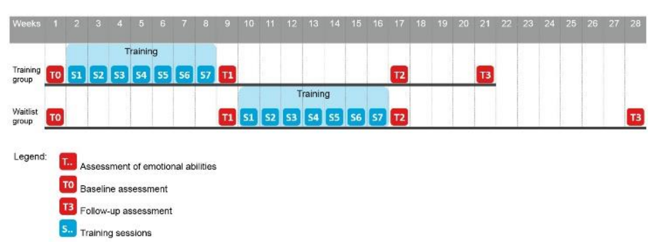

Figure 2: Study procedure

The study starts with a screening session in which children's inclusion criteria are verified. In this same session, children's reactions to the robot will be compared to a therapist in a

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[1] www.luxai.eu --- Pouyan Ziafati and Aida Nazarikhorram are founders of LuxAI S.A., a social robotic spinoff from the University of Luxembourg. In order to avoid any conflict of interest, they do not participate in parts of this research related to scripting, conducting, testing and reporting robot applications and experiments for children with autism.

counterbalanced design: duration of look towards robot/therapist, displayed emotional valence, comprehension of instructions, and compliance to instructions.

After the screening session all children are assessed on different outcome measures (T0). Then, half of the children (*n*=20) are assigned to the treatment group and start the training automatically. The other half of the children (*n*=20), which have similar diagnostic and socio-demographic characteristics as well as similar reactions to the robot, are assigned to the waitlist control group and wait for the same duration of the training (seven weeks) to start the training. At this point (T1), all children are assessed a second time on the same outcome measures. Then the waitlist control group starts the training. When the waitlist control group finishes the training, all children are assessed one more time on the outcome measures (T2). Ten weeks after the end of the training a follow-up assessment takes place for each group (T3).

The training has a fixed amount of sessions and duration that are similar to all participants of the study. The training is considered successful when a statistically significant improvement in the outcome measures is observed between pre- and post-training assessments and between training and waitlist control group. A follow-up assessment will also take place 10 weeks after the end of the training to verify lasting effects of the training. Effects of the training will be assessed against the effects of children's reactions towards the QT robot before the training.

2.6 Setting

The training is administered in a calm laboratory of the University of Luxembourg. The child sits at a desk and QT is placed at the opposite end of that desk. The parent accompanying the child is able to observe the session by sitting on a chair placed at a discreet location, outside the room, and away from child's direct field of vision. A researcher is present at all moments in the room. However, in order to increase the child-robot interaction, the researcher sits in a remote corner of the room and looks busy taking notes, while avoiding eye-contact with the child. QT's embedded camera records the child and child's interactions towards the robot. An additional camera is placed behind QT and facing the child in order to record overall aspects of the session such as moments when the child might get up.

2.7 Sessions

The training is administered in seven weekly sessions lasting 30 to 40 minutes each. Small breaks are suggested by QT at regular intervals. All instructions and interactions with the child are provided solely by QT. However, interactions are controlled by a therapist using the QT's tablet application. Additionally, for some exercises, printed images are placed in front of the child by the researcher. The training is administered to the child in Luxembourgish, French, or German, depending on the child's mother tongue.

Each session starts with a short introduction where objectives and concepts are explained to the child in an age appropriate language. Then QT proposes several interactive and playful games where different aspects of emotional ability are trained with the help of supporting material and concrete examples. The games and dialogues have been developed to fit the age and developmental levels of the children. Each session finishes with a summary of what was taught during the session and instructions for home practice are given. Sessions are divided into modules covering the five targeted emotional abilities: facial and vocal production of emotions, facial and vocal recognition of emotions, emotional reactivity, emotional awareness, and emotion regulation.

3. CONCLUSIONS

In the present training program an innovative experimental design is used in which a socially assistive robot is integrated into an intervention protocol aiming at improving emotional ability in children with ASD. The training is designed to fit the developmental level of school-aged children with ASD. Emotions are explained in simple terms and difficulty increases progressively throughout the sessions. Emotional concepts and social situations are explained with examples that the child can relate to. Additionally, the sessions are built around games, which make the learning of the contents playful and pleasant to the child. QT has also been designed to fit the age and developmental levels of the children. It expresses emotions in a simple and clear way (see Figure 1), with the help of body expressions, and intonation of speech that is attractive to children.

The training is currently at pilot stage and 5 training sessions with a child with ASD have been conducted. Even though the effects of the training will be tested against children's reactions to the robot as compared to a therapist, the present study design does not allow us to assert whether possible improvements in emotional ability will be due to the training, to the robot, or to a combination of both. In order to assert this, future studies will need to use the same training program in children with ASD using other training administration mediums (e.g. face to face with a therapist, through a computer, or tablet).

The present study complies with ethical and informed consent requirements.

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