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***Abstract*—This paper presents a study to explore the feasibility and efficacy of using the socially assistive robot, i.e. QTrobot, during a group-based Cognitive Behavioural Therapy protocol aimed at teaching emotional skills in children with autism. During treatment, both behavioural and physiological data were collected. The innovative aspect is the use of QTrobot with upper-body gestures and animated faces combined with physiological monitoring during emotional tasks. Preliminary results were presented and discussed. The study evidences the potential feasibility and efficacy of QTrobot combined with physiological sensors to track socio-emotional changes in children with ASD.**

Keywords — social robotic, QTrobot, autism

I. Introduction

Children with autism spectrum disorder (ASD) present heterogeneous clinical manifestations. These include deficits in facial expressions recognition and in social and emotional reciprocity [1]. To teach socio-emotional skills and treat impairments in this area, a promising approach is the Socially Assistive Robotics (SAR) [2-4]. The SAR is a field of robotics where social robots are used to assist patients during therapies to facilitate the learning of social behavior skills [5]. Social robots have proven to be valid social mediators to improve emotional and social behaviours in children with ASD, promoting social interactions and improving their attention and imitation [6-8]. Hence, in literature there are evidence for the potential benefits of the use of SAR in the treatment of social, emotional and communicative impairments shown by children with ASD. However, this evidence has been gleaned from previous studies limited in terms of the size of their subject groups with limited statistical power, short duration of time and methodological limitations. Thus, much more advanced knowledge in this area is still needed before attaining solid and robust models for the use of SAR in ASD. In this paper, we present a study in progress that is part of a larger research project, called "Social Empathetic Robot for Autism" and aimed to address the limitations of the previous research on SAR for ASD by

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conducting a novel large scale clinical study. The main aim of the present study is to examine the feasibility and efficacy of employing a socially assistive robot, the QTrobot, during a group-based Cognitive Behavioural Therapy (CBT) protocol focused on the comprehension of emotions, their properly attribution to the contexts and the learning of a basic emotional vocabulary. This CBT protocol has been used in previous studies obtaining positive and significant results [9]. The QTrobot is an expressive humanoid robot with 12 degrees of freedom and a screen for presenting upper-body gestures and animated faces, used in previous studies on social robotics for ASD [10]. More importantly, we also want to assess whether the QTrobot's screen for presenting upper-body gestures and animated faces is motivating enough to enhance the attention of children with ASD and consequently their emotional ability, or it is a distractor stimulus. To achieve these objectives, we are collecting behavioural and physiological data, given that children with ASD can be also affected by physiological abnormalities. In the present study is proposed a method based on wearable wireless technologies for the acquisition and analysis of physiological parameters during social robot-assisted treatment in a group of children affected by ASD.

II. Methods

A. Participants

For this study we enrolled 11 children with the following inclusion criteria: (1) aged between 5 and 8 years; (2) a diagnosis of ASD according to Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) by a licensed child neuropsychiatrist; (3) a severity score between mild (level 1) and moderate (level 2) in both Social Communication (SC) and Restricted Repetitive Behaviors (RRB) areas; (4) a total Developmental Quotient (Verbal and Performance) above 70; (5) absence of aggressive behaviors or severe oppositional tendency; (6) no auditory, visual, or physical impairments; (7) not being on psychiatric therapy; and (8) not undergoing any other emotional and/or social skills treatment during the study. All the parents signed an informed consent for children participation to the study.

B. Experimental Setup

The robot-mediated protocol was administered inside a specifically designed room called HomeLab. It is a naturalistic environment simulating a home, with all the equipment for a group-based intervention. Setting included (a) a socially assistive robot able to act as co-therapist through the use of specific prompts and visual and motor reinforcements with partial autonomous control, and (b) a Zephyr heart rate variability chest belt for each participant to acquire physiological parameters. The robot used to mediate the intervention is the QTrobot (Fig. 1), a plastic humanoid robot with the size of a child (63cm tall and 5kg), commercially available (LuxAI S.A.). The QTrobot is able to perform upper-body gestures thanks to 12 degrees of freedom, eight of which are motor-controlled, while the remaining four are manually configured. The first eight are arranged two in each shoulder, one in each arm and two for the head movements (pitch and yaw). The others are one in each wrist and one in each hand. Moreover, the robot is equipped with a microphone array and a RealSense 3D camera is mounted on its forehead.

Fig. 1. QT robot

QT is provided with an Intel NUC processor and Ubuntu 16.04 Lts, and it may be programmed in Python or C++ languages through a native ROS interface. QTro-bot can be partially controlled by therapist using a visual programming interface, developed as an Android application for tablets and smartphones. This application is easily usable by informatic technological non-experts. Correct and wrong responses of children, during the execution of therapy task, were automatically recorded by QTrobot through an online platform. This platform has been specifically developed to collect data in a quantitative and graphic way. The wearable chest belt provides an unobtrusive tool to monitor children heart rate variability in a semi-naturalistic setting over-coming the limitations due to the constrains of the traditional approaches [11, 12]. Data were recorded during the execution of the therapy task using the compact device Zephyr HxM Bluetooth Technology designed for continuous monitoring of tachogram (Interval between consecutive R peaks in an ECG waveform), plugged into wearable strap positioned on the thorax. The strap is lightweight, comfortable and fully washable. A native swift application (API) has been specifically developed to interface the Zephyr belt with iPad for real time monitoring. Besides heart rate variability, the system records the video of the session. All the data are stored both on the mobile device and on a remote drive for later processing.

C. Robot-mediated intervention and protocol

The robot-mediated intervention was administered in small groups of children by a qualified clinical psychologist (Fig. 2). During the intervention, children wore the Zephyr chest belt. Test of Emotional Comprehension (TEC) and the Emotional Lexicon Test (ELT) were employed to assess pre and post intervention. The TEC is a widely used tool in research for the assessment of ASD children of various ages and with different disabilities [13]. According to TEC theoretical and empirical model (tested with Multidimensional Analysis), the 9 components examined to assess children emotional understanding are grouped as follows:

- External components (recognition, external causes and belief);
- Mentalist components (desire, reminder and hiding);

- Reflexive components (regulation, mixed and morality).

Fig. 2. Robot-mediated intervention

The protocol consists of 12 sessions administered one every week: 1 for the pre assessment, 10 for the therapy and 1 for the post assessment. Each session lasts 50 min and is divided into three phases:

- The first phase aims to teach the context-emotion association. For this purpose, four social situations are randomly introduced asking children to identify the correct related emotions.
- The second phase is focused on teaching the difference and the link between thoughts and emotions.
- The third phase is designed to provide some basic strategies to learn and use a repertoire of useful thoughts related to five basic emotions: happiness, sadness, angry, frightened and disgusted.

Each task is presented by QTrobot, which is controlled by psychologist using the application from the table. This application allows the psychologist to choose the task introduced by QTrobot. According to children's responses, the psychologist conveys "prompts" or "reinforcements" through the robot. For each phase there are "prompts" that the QTrobot randomly provides. For example, if the child provides a wrong response, QT can say "Be careful, I advise you to ask for help. When I feel so smiley and ajar my eyes"; or it can say "I'll show you the expression I had", so QT shows the facial emotional expression on its screen." If the child provides a wrong response when he receives the prompt, QT says "I felt happy". When the child provides a correct response both with or without prompt, QT says "Compliments, exact answer" showing happiness facial expression and moving its arms.

III. Preliminary Results

We present descriptive data related to correct responses of the children and their physiological parameters for each feedback provided by QT. With reference to physiological data, in order to remove typical artifacts and interferences, signals pre-process was performed in Matlab through a stepwise filtering. An example of extracted RR signal is reported in Fig. 3.

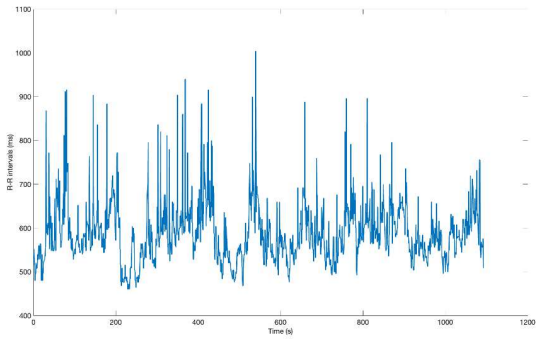

Fig. 3. Example of RR signal of child during tasks execution

In this preliminary study, each child underwent eight different tasks in which he had to understand the mood connected to a specific contest. The QT robot explains the contest to the child and after him answer, it expresses gratification in case of correct answer or gives suggestions in case of mistake. Each feedback is provided through both language and facial expressions. From collected RR signal we observe a variation of the heart rate variability after each robot positive feedback (Fig. 4). This trend suggests the possibility to observe through this system a socio-emotional engagement of the children in the robot-interactive tasks proposed.

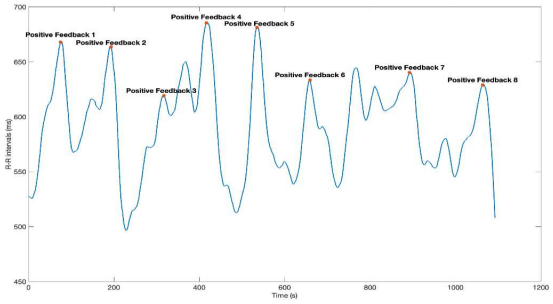

Fig. 4 RR signal after pre-process with highlight on the heart rate variations after Robot Positive Feedbacks

All the enrolled participants completed the intervention protocol. As reported in Table I, there is a trend towards better performance after QTrobot-mediated treatment in the emotional compression (TEC) $P = 0.14$, whereas emotional language improved significantly (ELT) $P < 0.03$.

TABLE I. RESULTS OF TEC AND ELT TESTS, PRE-POST TREATMENT WITH QTROBOT

	ASD group (N. 11)			
	Pre-Treatment	***Post-Treatment***	***t-test***	***p-values***
TEC	4.6 (2.06)	6.1 (1.69)	-1.66	0.14
ELT	6.1 (2.04)	7 (0.05)	-2.65	**0.03**

Furthermore, from this preliminary study we observe the high grade of acceptability of the employed systems. Precisely, when the feedback of the robot is the presentation of facial emotional expression related to the social situation targeted during the task, the heart rate variability is higher that when

the feedback is only communicative, and the correct responses also increase. This indicates that the screen of the QTrobot captures the attention of children, it is motiving in improving their emotional ability and it is not a distractor stimulus.

IV. Conclusion

In this work we describe the preliminary results concerning the validation of the QTrobot as a new device for behavioral treatments in ASD. These results suggest potential feasibility and efficacy of using of the QTrobot in an emotional intervention for children with ASD. Further investigation using a larger population and additional control groups are needed to assess the actual connection between children involvement in the therapy and the variation of their physiological parameters. Moreover, in the next future, we will carry out deeper signal processing and feature extraction of collected physiological parameters to investigate the most correlated patterns underpinning socio-emotional interactions between children with ASD and robots.

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