Robot-Enhanced Therapy for Children with Autism

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Autism Spectrum Disorder (ASD) is a developmental disorder affecting communication and behavior (NIH, 2018). ASD is typically characterized by abnormalities in social interactions and communication, most often appearing within the first two years of life. ASD is referred to as a spectrum as it comprise a wide range of difficulties for the individual, ranging from relatively mild problems as ADHD to severe deficits in communication and behavior requiring constant supervision out through life.

People diagnosed with ASD often receive medication that may reduce symptoms, e.g., a reduction of aggression, hyperactivity, or anxiety. While medication can be effective in terms of reduced symptoms, there is no medical treatment for ASD as of today. The only known treatment with persistent effects involves cognitive-behavioral therapy.

We here briefly summarize some of the outcomes of the European research project *DREAM – Development of Robot-Enhanced therapy for children with Autism spectrum disorders*[1] (Esteban et al., 2017). The project has been running since spring 2014 and is planned to finish fall 2018, engaging a consortium of seven partners. DREAM targets a specific form of behavioral therapy for children diagnosed with ASD, called *Robot Enhanced Therapy* (RET).

RET is a variation of the traditional autism therapy, called *Applied Behavior Analysis* (ABA). ABA targets fundamental social skills that can improve the child's ability to interact and reduce repetitive behavior. One challenge is that many children diagnosed with ASD perceive social situations as highly distressing, making the child refrain from social interaction and communication, further reducing the child's chances to learn and improve social skills. In these situations a social robot can provide an environment where the child gets a chance to learn and explore social behavior on a lower level of complexity, less associated with anxiety (Sartorato, Przybylowski, & Sarko, 2017). One key advantage of using robots as social stimuli is that simplicity and predictability of interaction can be maintained, while at the same time providing an engaging embodied social interaction for the child (Huijnen, Lexis, Jansens, & de Witte, 2016).

A wide range of robots have been evaluated in the context of autism therapy, for example Labo-1, Keepon, Pleo, Probo, NAO, KASPAR, FACE. Although several of these robots have shown promising results, most of the clinical findings are exploratory (Diehl, Schmitt, Villano, & Crowell, 2011) and build on a Wizard of Oz (WoZ) setup (Huijnen et al., 2016; Thill, Pop, Belpaeme, Ziemke, & Vanderborght, 2012), where the robot is remotely controlled by a human operator. While WoZ configurations can be an effective evaluation method, making the robot respond as if it can interpret the actions of the child, it is impractical for long-term studies and does not constitute a realistic scenario for clinical use due it its high human workload. The opposite extreme, involving a fully autonomous robot, may be equally problematic. An autonomous robot makes decisions and adapts its actions to the current situation without human intervention. This is still very difficult to achieve from a technical point of view, and may also raise ethical concerns (Richardson et al., 2018).

One of the goal of DREAM is to develop an application for RET using *supervised autonomy* (Senft, Baxter, Kennedy, Lemaignan, & Belpaeme, 2017). In this context, the robot executes a pre-scripted intervention protocol while autonomously adapting to the child's behavior. The intervention is monitored by the therapist, who can intervene in situations where the robot and/or the child are not following the descried intervention protocol.

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Clinical evaluation

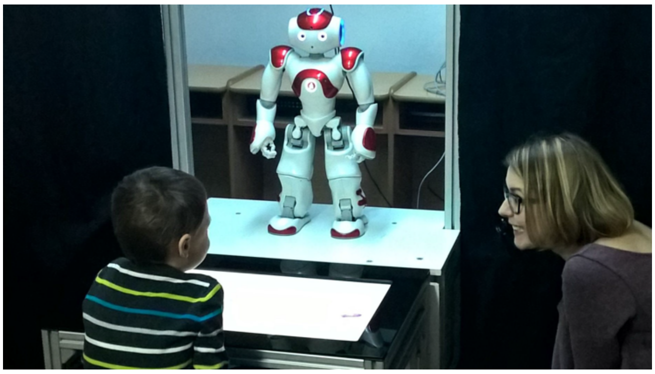
Figure 1: Robot enhanced therapy setting.

From a clinical perspective, DREAM comprise a rigorous evaluation of RET as an alternative to Standard Human Treatment (SHT). Both RET and STH follow a ABA protocol. Specifically, the evaluation target joint attention, imitation and turn-taking skills for children with severe autism. These skills are believed to constitute key components – or building blocks – necessary for improved interaction and communication abilities in general. The clinical evaluation, a randomized controlled trial which is still on-going, is conducted using an experimental setting were children are randomly divided into two groups: one using RET and a control condition using SHT. In both conditions, the child is seated at a customized intervention table and recorded using a camera-based sensing system (Cai et al., 2018) able to record body motion, eye-gaze, face expressions etc. In the RET condition, a SoftBank NAO robot constitutes the interaction partner while a therapist assigned a supervising role is seated at the side of the intervention table (Fig. 1). In the control condition, two therapists are taking part, one as the interaction partner and the other as a supervisor/mediator.

65 children in the age range 3 to 6 years have participated in the evaluation. Up until today, 50 children have completed the protocol of eight interventions over six weeks. Each intervention involves five to seven interaction sessions targeting joint attention, imitation or tern-taking. In addition, each participant goes through a diagnosis protocol, using Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 2000) as a measurement tool to quantify the child's degree of autism. The diagnosis is employed before the first intervention and after the child has completed all interventions. The differences in ADOS score constitute the treatment effect. Only children with an initial ADOS score above 12 and no other neurodevelopmental disorders were included in the study.

Technical contributions

In parallel to the clinical application, DREAM involves research pushing the state of the art in several research areas. We employed component-based software engineering (CBSE) as a way to tackle the need for flexibility for developers while still maintaining a strict interface allowing integration of all system components developed within the project (Vernon, Billing, Hemeren, Thill, & Ziemke, 2015). While the most common motivation for CSBE is component re-use, it is here also employed as in integration platform.

The robot application is implemented using the middleware YARP (Metta, Fitzpatrick, & Natale, 2013), integrating a total of 16 software components. Each component implements its own executable that can be co-located on a single machine or distributed over a cluster of computers. The complete application was initially implemented using placeholder components, constituting a complete executable system running at a very early stage of development. Through the developmental process, placeholder components were replaced by partial or complete implementations, until a complete system was achieved.

In order to guarantee the desirable robot behaviour also when the system could not correctly classify the child's performance, Supervised Progressively Autonomous Robot Competencies (SPARC) was employed (Senft, Baxter, Kennedy, & Belpaeme, 2015; Senft, Lemaignan, Baxter, & Belpaeme, 2016). With this approach, the system will display suggested action a few seconds prior to execution, giving the therapist the chance to intervene and change action if desirable. As such, the system can progress from a WoZ-like setting requiring heavy human workload to supervised autonomy with little human intervention. Another key component is the integrated sensing system, combining recognition of body motion, gestures, head orientation, eye-gaze and voice (Cai et al., 2018; Zhou, Cai, Li, & Liu, 2017).

Discussion

The clinical evaluation is still on-going and its final results are still not available. A preliminary analysis based on partial data does not reveal significant differences between the two evaluated conditions (RET vs SHT). However, both conditions show effects in terms of reduced ASD for all primary outcomes (turn-taking, joint-attention and imitation skills). If these patterns carry over also to the results from the complete evaluation, one interpretation could be that RET may not primarily be feasible for clinical use, but does provide a safe and engaging environment where the child could train social skills also outside the clinical environment. With this perspective, RET may be an excellent alternative in situations where it is difficult to get access to traditional therapy and it may also give children access to more therapy than otherwise would be possible.

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