Development of Robot-enhanced Therapy for Children with Autism Spectrum Disorders

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Development of Robot-enhanced Therapy for Children with Autism Spectrum Disorders

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D1.4. Manual of best practice in robot enhanced therapy for autism spectrum disorder

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Table of contents

Executive Summary

The deliverable D1.4. Manual of best practice in RET is developed for teachers, psychologists and parents. Resulting from task T1.4., this manual integrates the outputs from previous work regarding best practice in RET for ASD. Deliverable D1.4. provides descriptions of the techniques developed and tested in work package WP2 (T2.1–T2.3) based on the protocols developed in tasks T1.1 to T1.4 and the ethical considerations in work package WP7. Input to the task is provided through deliverables D1.1, D1.2, D1.3, D2.1, D2.2, D7.1, and D7.2.

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First draft, describing the overall structure of the deliverable and a tentative integration of the available data.

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Second draft.

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Third draft, expanding on ethical issues and therapeutic alliance.

1. Context and background

1.1. ASD

ASD is characterized by social and communication impairments as well as severely restricted interests or activities and rigid or repetitive behaviors (American Psychiatric Association, 2013). The diagnostic criteria for ASD included in the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5; APA, 2013), refer to ASD as a single diagnosis category that includes autistic disorder (autism), Asperger's disorder, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified. The reported prevalence of ASD appears to be increasing, with recent estimates as high as 1 in 68 (Baio, 2014), with higher rates among males than females (Loomes, Hull, & Mandy, 2017).

ASD is diagnosed in children and adults and high levels of comorbid psychiatric disorders and other associated problems (e.g., social anxiety disorder, oppositional defiant disorder, intellectual deficits) have been reported among individuals suffering from ASD (Croen, Zerbo, Qian et al., 2015; Leyfer, Folstein, Bacalman et al., 2006; Mannion & Leader, 2016; Matson & Shoemaker, 2009). ASD has high direct and indirect costs across a wide range of life domains, such as health, education, employment, housing, social care, and productivity, thus being associated with high economic burden (Buescher, Cidav, Knapp, & Mandell, 2014; Ganz, 2007; Leigh & Du, 2015). Lifetime societal costs associated to each individual diagnosed with ASD were estimated at around €2.45 million, of which almost one third (~€0.80 million) are incurred in childhood (Ganz, 2007). In addition, a significant division of these costs are linked to the lost economic productivity of parents of children with ASD (Matthews et al., 2011).

Impairments in imitation, joint-attention and turn-taking skills are commonly met among individuals suffering from ASD (Dawson et al., 2004). These impairments are particularly problematic given that imitation, joint-attention, and turn-taking are important prerequisites for developing social communication skills. For example, previous studies reported that improvements in imitation can facilitate the recognition of peers and caregivers as "social others", the hand-eye coordination, and the later development of communication skills (Ricks & Colton, 2010). Imitation also enables children to learn new information from their social environment

(Cabibihan, Javed, Ang, & Aljunied, 2013). Similarly, joint-attention (i.e., the ability to focus simultaneously on the same object/activity with another social partner) is particularly important for perceiving the social others, an important prerequisite for successful learning (Ricks et al., 2010) and language acquisition (Dawson et al., 2004). In what turn-taking skills are concerned, it appears that they play a fundamental role in regulating conversations (Ricks et al., 2010, Cabibihan et al., 2013) and social interactions. Due to these impairments in social skills, ASD children have difficulties sustaining a conversation or playing a game in which the partners' roles constantly alternate. As a consequence, the three social skills are often targeted by various interventions that have been developed for ASD.

1.2. Available treatments for ASD

Given the increase in the prevalence of ASD and the impairment caused by ASD, a number of treatments emerged in order to mitigate ASD symptoms as well as the morbidity associated with ASD. In order to promote evidence-based interventions for ASD, a number of workgroups and systematic reviews aimed to identify interventions with strong empirical evidence of effectiveness for ASD related outcomes (e.g., National Autism Center (NIC), 2009; Warren et al., 2011; Wong et al., 2015, 2014).

The treatments proven to be effective/ efficacious for ASD have been developed across various theoretical perspectives and fields of studies. Still, the vast majority of the evidence-based treatments for ASD that have been identified through systematic reviews (e.g., NIC, 2009) were developed exclusively or predominantly within the behavioral approach. The evidence-based interventions for ASD are based on a mixture of applied behavior analysis techniques (e.g., prompting, reinforcement), analytic techniques (e.g., functional analysis), and other cognitive-behavioral techniques (see Wong et al., 2015, 2014).

There are a few other interventions that have empirical support for their efficacy for ASD, but do not meet the criteria for being classified as evidence-based treatments. One such treatment is the reciprocal imitation training (RIT), which has several studies reporting positive outcomes, but all studies have been conducted by the same research group (e.g., Ingersoll, 2012, 2010).

1.3. Limitations/costs of the available treatments

Although a number of evidence-based intervention programs have been developed, many individuals with ASD do not receive these treatments in community settings (Brookman-Frazee, Taylor, & Garland, 2010). It has been argued that lack of access to such treatments might be a major factor that increases the likelihood of keeping ASD individuals on a difficult life trajectory (e.g., Eaves and Ho, 2008, Marriage et al., 2009).

The low levels of access to evidence-based interventions may be partially explained by the complexity of these treatments which poses difficulties for practitioners. It was found that implementing such interventions may be challenging for practitioners even after receiving expert training (e.g., Kretzmann et al., 2015, Locke et al., 2015). Moreover, intensive behavioral interventions, which are among the most effective available interventions, involve extensive resources in order to be effective and the high associated costs make them inaccessible for many ASD individuals (Masi, DeMayo, Glozier, & Guastella, 2017). Thus, there is a need for developing evidence-based interventions that reduce the burden on therapists and have the potential to increase the availability of high quality interventions for ASD.

1.4. The use of RET

The use of robots for ASD therapies is based on a series of findings indicating that ASD children prefer to interact with a robot over a human (due to their simplified and predictive structure; Cohen, 2009), and are more interested in treatment when it involves electronic or robotic components (Robins et al., 2006). ASD children appear to encounter difficulties when it comes to understanding the social cues, but tend to display strengths in understanding object-related cues (Klin et al., 2009, 2000). Of importance, even when it comes to social cues, ASD children appear to be more responsive to social feedback provided via technology rather than to human feedback (Ozonoff, 1995). Previous investigations suggest that the use of robots as interaction partners can provide a simplified, safe, and predictable learning environment (Dautenhahn & Billard, 2002; Robins et al., 2005;Tapus et al., 2012).

The human-robot interaction is expected to lay a foundation for developing a set of implicit rules about communication that will be transferred later on to human-human interactions. It is assumed that ASD children may be more motivated and engaged in RET and associated learning activities and this would facilitate an early acquisition of new skills, thus requiring less time and human resources. Robots embody human-like social cues within a simple object-like format that may be more accessible for ASD children. In addition, robots have the capacity to repeat the same tasks with very high accuracy (tackling issues related to trainer fatigue or frustration) until the learning process is successful and can gradually increase the complexity of interaction. Thus, RET may generate less frustration for children with ASD who have difficulties interpreting and responding to social interactions (Sartorato, Przybylowski, & Sarko, 2017).

The more recent semi-autonomous robots, such as Aldebaran's Nao, have an additional advantage as they have the potential to reduce the burden on human therapists on the long term, while providing ASD children with consistent therapeutic experience. The semi-autonomous robots are able to operate without explicit human control for relatively short periods of time and periodically revert to the human therapist for supervision. Thus, lower levels of attention resources are required from the therapist in RET.

1.5. Overview of the Manuals' main sections

This manual aims to provide an integration of technology into therapeutic processes and psychological assessment of ASD children. In the current section we provided the background for developing robot enhanced therapy (RET) for children with ASD. In section 2 we describe a complementary approach which includes machine-perception-guided technologies to augment the existing observational diagnoses and judgments made by clinicians. In section 3 we briefly synthesize the etiological factors contributing to ASD, as well as the main theories on which the evidence-based interventions for ASD are based. In section 4 we propose a possible integration of a social robot into therapeutic processes that is based on the existing literature and the work developed and validated in the DREAM project. In Section 5 we describe the therapy environment in which RET is to take place. In sections 6 and 7 we briefly cover issues related to therapeutic alliance and ethics in RET, respectively.

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2. Tools for the assessment of child-robot interaction and diagnostic

There are a number of clinical guidelines providing systematic recommendations for use of diagnostic tools and assessment procedures for ASD (see Hayes, Ford, Rafeeque, & Russell, 2018) that can be easily accessed by clinicians and other stakeholders. Thus, this section does not aim to present an exhaustive review of the available tools for the assessment and diagnosis of ASD. Instead, we attempt to provide a rationale and a brief description for a complementary approach which includes machine-perception-guided technologies to augment the existing observational diagnoses and judgments made by clinicians.

2.1. Rationale

A series of assessment tools have been developed for the evaluation of autistic symptoms and diagnosis based on DSM criteria. Of these, the Diagnosis Interview Revised (ADI-R; Rutter & Le Couteur, 2003), the Autism Diagnostic Observation Schedule Generic (ADOS-G; Lord et al., 2000), the Childhood Autism Rating Scale (CARS; Schopler, Reichler, DeVellis, & Daly, 1980), the Diagnostic Interview for Social and Communication Disorders (DISCO; Wing, Leekam, Libby, Gould, & Larcombe, 2002), and the Gilliam Autism Rating Scale (GARS; Gilliam, 1995) are among the most relevant and widely used. Although these well-established instruments for the screening and diagnosis of childhood autism made important contributions to the field, they are not without limitations. For example, some of these instruments might have a somewhat reduced sensitivity, especially among younger children (e.g., Corsello et al., 2007; Eaves et al., 2006b; Lord, Rutter, Dilavore, & Risi, 2002).

Another drawback of most of the commonly used ASD assessment tools is that they require time-consuming training that is generally expensive and difficult to secure (Charman & Gotham, 2013). The data collection procedure generally requires clinicians to observe, code, and interpret the behaviors simultaneously. The multitasking might result in errors at any of the three levels. There might also be some small variations between clinicians concerning the manner in which different specific tasks are applied, based on their expertise, which could also lead to different clinical judgments.

The use of clinicians-based instruments also limits the amount of collected data. It would be very difficult for the clinician to assess multiple relevant outcomes simultaneously during sessions, while also delivering the intervention. Thus, an important source of information generally remains unexplored. The data gathered during sessions could provide important insights concerning the evolution of ASD symptoms throughout intervention.

Using different types of technological tools can contribute to an increase in the amount of collected data, by simplifying the process and helping professionals to quickly scan through data in order to take better informed decisions (Kientz, Hayes, Westeyn, Starner, & Abowd, 2007). Moreover, the resulting annotations might be of higher quality and more consistent than manual annotations. This approach does not aim to provide a substitute for the human expert, but to explore a tool intended to increase the accuracy and objectivity of the data collected. Within this approach, the human expert would be able to concentrate on subtle manifestations of the disorder and get involved in more natural interactions with the child, offering added value to the diagnosis.

2.2. Automation of diagnostic processes for ASD

The automated assessment tool is based on a binary coding system. Here we will briefly describe how the binary coding is implemented for three key abilities (imitation, joint-attention, and turn-taking) and engagement in the task. We do not aim to provide technical details concerning the involved algorithms (interested readers can refer to Deliverable 4.1 for a technical approach; https://dream2020.eu/wp-content/uploads/2014/11/DREAM_Deliverable_D4.1.pdf).

Imitation related behaviors were coded with “1” when children executed the requested movement correctly and with “0” when children did not execute the requested movement. Joint-attention performance was coded with “1” if the children looked at the picture indicated by the interaction partner and with “0” when children did not look at the indicated picture. Similarly, in the case of turn-taking, a score of “1” was assigned when children waited for their turn (did not move their hands above the touchscreen of the tablet when it was the partner’s turn) and a score of “0” was assigned when children did not wait for their turn (they moved their hands above the tablet).

Task engagement was assessed exclusively during intervention sessions. The outcome has three relevant dimensions: eye contact, positive emotions, and physical presence (i.e., being present in front of the interaction partner during tasks). The primitives that are detected in order to assess these dimensions (mutual gaze - for eye contact; facial expressions - for positive emotions; and body position - for physical presence) are defined in D1.3. Next, we will exemplify the procedure that has been implemented for eye contact, one dimension of task engagement. In order to compare the system generated assessments with clinicians' annotations, the codes from the two sources were overlapped. Subsequently, the system generated quotations have been categorized as follows (categories defined in D5.1):

- Correct annotation - includes correctly identified start and end times within 0.5s for an existing eye contact (i.e., the child looking or glancing at the robot or at the therapist);
- Merge - indicates a single eye contact marked as two or more consecutive annotations;
- Adjust - comprises annotations or an existing eye contacts, but where the start and/or end times are not correctly identified;
- False positive - comprises incorrect annotations, not overlapping with an existing eye contact;
- False negative - are existing eye contacts not identified by the classifier;
- Ambiguous - comprises borderline-cases, where the clinicians were not able to determine whether there was an eye contact or not due to variation in the robot's positioning.

2.3. Preliminary empirical data

We aimed to gather empirical data concerning the utility of the assessment tool developed in DREAM. The available results suggest that the use of the automated assessment tool for turn-taking indicates performances that are similar to those indicated by clinicians (i.e., based on manual annotations). However, the automated tool is less reliable for the assessment of imitation and joint attention. Overall, the results are somewhat promising but the algorithms need further improvements and more empirical data are needed in order to allow the translation of the automated assessment tools in clinical settings.

3. Conceptualization of ASD

A number of genetic risk factors and environmental events have been linked to ASD, but the specific etiological factors involved in ASD are yet to be determined (Volkmar, Paul, Rogers, & Pelphrey, 2014). Although earlier studies indicated a high heritability (up to 80-80%) of ASD (Bailey, Le Couteur, Gottesman et al., 1995), more recent studies highlight the role of environmental factors (Deng, Zou, Deng et al., 2015). Genetic studies linked ASD with amygdala, nucleus accumbens, various chromosomal abnormalities, metabolic errors, and genes (e.g., UBE3A locus, serotonin transporter genes, GABA system genes; see Park, Lee, Moon, et al., 2016). Similarly, a number of environmental factors, such as advanced parental age, birth complications, the burden of organic pollutants, were found to be associated with increased risk for ASD (Masi, DeMayo, Glozier, & Guastella, 2017; Modabbernia, Velthorst, & Reichenberg, 2017).

There are two predominant types of theoretical approaches that generally guide the interventions for ASD: behavioral approaches and developmental/ transactional approaches (see Smith & Iadarola, 2015). The behavioral approaches to ASD (e.g., applied behavior analysis; ABA) generally attempt to apply learning principles, working from the assumption that ASD children do not successfully acquire new skills from the natural environment. Thus, ASD is viewed as a learning difficulty (Smith, 2011). In order to tackle this difficulty, the environment needs to be changed in order to provide simplified instructions (i.e., simple cues that can be more easily differentiated) and readily available reinforcements in the early stages of treatment. These approaches tend to emphasize that ASD children respond to the same learning principles as typically developed children if provided with the correct learning environment. Operant behaviors (i.e., social skills) are broken into discrete components and are taught in a one-to-one interaction (e.g., discrete trial teaching; DTT). Subsequently, the treatment aims to generalize the new skills to more complex real-life settings (Lovaas, 2003). One can notice that behavioral approaches do not maintain the presence of a central deficit in ASD that would lead to overall improvements if tackled. In turn, it is assumed that several separate behavioral deficits are present in ASD and need to be targeted separately.

The developmental/transactional approaches to ASD (Ingersoll, Dvortcsak, Whalen, & Sikora, 2005) focus predominantly on the impaired ability to engage in mutual activities with another person, which is viewed as a core feature of ASD that subsequently leads to a series of problems that are specific to ASD individuals. Hence, these approaches aim to promote social communication and interaction among individuals with ASD. In order to attain these goals, the therapist/ caregiver needs to respond to the child's initiations in a highly responsive manner (i.e., by imitating the child's behaviors, expanding on and joining into the activities of the child).

4. RET intervention

In this section we propose a possible integration of a social robot into therapeutic processes that is based on the existing literature and the work developed and validated in the DREAM project. The tasks presented here have been developed for the training of the imitation, joint-attention and turn-taking abilities. However, the structured behavioral approach (DTT) in which these tasks have been developed, as well as the overall structure of the tasks, could be adjusted for training other abilities.

According to Smith (2001), DTT can be particularly useful for the acquisition of new behaviors and for teaching discriminative behavioral responses. Working from the assumptions of this approach, the training tasks should take place in a highly structured learning environment. Thus, it is desirable to organize all training tasks around a working table (see section 5.2. bellow for details). The interaction partner (i.e., the Softbank Robotics' Nao robot) is required to direct the child towards the task during training. Each targeted behavior/action is preceded by the robot's discriminative stimulus or instruction (e.g., "Do as I do!") and followed by a contingent reinforcement (e.g., "Try again!", "Well done!"). The behaviors are presented over multiple successive trials and the robot provides explicit prompting when the child doesn't succeed to accomplish the targeted behavior after several trails. Each action is repeated three times.

In order to increase task involvement, it is recommended to personalize the intervention protocol for the needs of each child. Thus, the intervention should be informed by the results of the initial assessment to ensure that the training of each ability starts from the baseline level (i.e., the level determined in the first two evaluation sessions; see Section 2). As the child's performance improves, the training moves to the next level (i.e., a sub-task of an increased level of difficulty is approached). The goal of the intervention is to reach the highest level possible for each child, on each of the three social abilities. In the following section we will briefly describe the levels of difficulties, as well as the structure of the tasks used to train imitation, joint attention, and turn-taking abilities.

4.1. Imitation

Repeated sessions of interactive imitation games are employed to teach motor behaviors in order to train imitation abilities. The child is sitting at a table during the imitation tasks while the robot is placed on the table in front of the child (see Section 5.2. of the manual). The child is verbally instructed by the robot to imitate the actions made by the robot. The target imitation movements should be organized by the level of difficulty (e.g., beginner level, intermediate level, and advanced level). The imitation ability is trained though the following sub-tasks:

- level 1 of difficulty: imitation with objects (e.g., moving a car, pretending to drink from a cup);
- level 2 of difficulty: imitation of gestures (meaningful movements; e.g., waving one hand and say “bye-bye”);
- level 3 of difficulty: imitation of movements without a meaning.

It should be noted that the specific set of movements may not be as relevant as it is the process of initiating imitation and learning the imitation rules. Thus, the selection of these movements is limited mainly by the capabilities of the robot that is being employed as a social partner. It may be useful to assess the progress of the child using different types of movements and situations in order to evaluate learning generalization. The test of imitation generalization can be facilitated by using different categories of gestures (corresponding part of the body, crossing the median line, symmetrical and asymmetrical) in different situations (initiating vs. following, neutral actions vs. oriented towards object) and covering a wide spectrum of conditions.

Table 1. The structure of the imitation task.

<u>Instruction</u>
Provided by the robot *“Do as I do!”*
<u>Response</u>
Provided by the child

Moving arms/objects in similar ways as the robot.
Consequence
Provided by the robot Depending on the child's answer: *If the child executes the requested movement correctly, he/she receives positive feedback: "Well done!"* *If the child doesn't execute the requested movement, he/she receives encouraging feedback: "Try again!"*

4.2. Joint-attention

First, the child should receive a rationale for the task before starting the training phase (e.g., "Now, we will play another game. In this game I will show you the objects I've seen in an office"; see Table 2). Next, two pictures are displayed simultaneously on a big touch-screen incorporated in the table: one on the left side and the other one on the right side. In this task the child has to look at the picture indicated by the robot. The robot implements different ways of indicating one of the two displayed images, the number of modalities used to indicate the picture determining the task's level of difficulty.

On the 1st level of complexity, the robot has to perform three actions in order to prompt joint-attention: a verbal action (saying "Look!"), a gestural action (pointing towards one of the pictures), and a gaze-related action (making eye-contact with the child and then switching his gaze by also moving his head in the direction of the picture). On the 2nd level, the robot omits the verbal action and prompts joint-attention only by simultaneously looking at one picture and pointing to that picture. Finally, on the 3rd level the robot omits both verbal and gestural actions and employs only a gaze-related action.

In theory, the complexity of joint-attention task could also be varied by changing the position of the objects (pictures) with respect to the position of the child (in addition to reducing the number of attention cues. Still, although this strategy may increase the ecological validity of the task, the efficacy/ effectiveness of this strategy was not yet empirically assessed in RET due to technical challenges.

Table 2. The structure of joint-attention task

Instruction
Provided by the robot "Please, pay attention to what I am looking at!"
Response
Provided by the child Looking at the picture indicated by the robot.
Consequence
Provided by the robot Depending on the child's answer: If the child looks at the picture indicated by the robot/human, he/she receives positive feedback: "Well done!" If the child doesn't look at the picture indicated by the robot/human, he/she receives encouraging feedback: "Try again!"

4.3. Turn-taking

The training for the turn-taking ability involves different activities during which the child and the robot have to play by taking turns. The sub-tasks presented here are designed to be implemented on a big touch-screen tablet (Sandtray) and include: sharing information, assigning items to categories and continuing repeating patterns activities. As it can be seen in Table 3, in all subtasks the robot provides an instruction/ question before the targeted behaviors and administers a consequence depending on the child's response/ behavior.

- sharing information: Five pictures are displayed simultaneously on the screen of the tablet. In this task the child has to choose a picture from a series of five pictures displayed on a touchscreen (when it is his turn) and wait when the robot chooses a picture (when is the interaction robot`s turn).
- categories:
  - level 1: Three pictures are displayed simultaneously on the screen of the tablet (two of them represent categories and the third one is the item that has to be categorized). In this task the child is required to categorize the items (when it is his turn) and wait when the robot categorizes (when is robot`s turn). The categories presented at this level of difficulty should be chosen so that they are familiar to the children of their age (e.g., between the ages of 3 to 7 years: fruits vs. vegetables) and the items that have to be categorized should appear one by one;
  - level 2: Ten pictures are displayed simultaneously on the screen of the tablet (two of them represent categories and the other eight are the items that have to be categorized). Similarly to the first level, the child is also required to categorize the items (when it is his turn) and then wait for the robot to categorize (when is the interaction partner`s turn). However, the categories chosen for this level are more complex (ground vehicles vs. water vehicles) and the child is asked to choose just one picture at a time from a larger number of pictures that are simultaneously displayed.
- patterns
  - level 1: Six pictures are displayed simultaneously on the screen of the tablet (two of them in the middle of the screen and the rest of them arranged in a string). The task of the child is to continue the pattern illustrated by the string (when it is his/her turn) and wait for the robot to add a picture to the string (when is robot`s turn). At this level of difficulty the task should be organized so that the repetitive pattern consists of two or three repetitive items and the only relevant criterion for

categorization is the geometrical shape (e.g., rectangle, rectangle, triangle, rectangle, rectangle, ...);

- level 2: Ten pictures are displayed simultaneously on the screen of the tablet (four of them in the middle of the screen and the rest of them arranged in a string). As in the case of the first level of difficulty, the child has to continue the pattern illustrated by the string (when it is his turn) and wait for the robot to add a picture to the string (when is robot`s turn). However, the complexity of the task increases so that four items repeat and there are two relevant criteria based on which the categorization has to be made: the geometrical shape and its color (e.g., green squire, star, orange squire, circle, green squire, star, ...; see Table 3).

Table 3. The structure of turn-taking task

Sharing information
Instruction
Provided by the robot *a. "It's your turn first! What's your favorite [...]?"* *b. "Now it's my turn!"*
Response
Provided by the child a. The child chooses a picture that represents what he/she likes the most. b. The child waits his/her turn (doesn't move his/her hands above the touchscreen of the Sandtray when is the partner's turn)
Consequence
Provided by the robot

Depending on the child's answer:

a. If the child chooses a picture from those shown on the touch-screen, he/she receives positive feedback: "You showed me very nicely what you like!"

If the child doesn't choose a picture from those shown on the touch-screen, he/she receives no feedback.

b. If the child waits his/her turn (doesn't move his/her hands above Sandtray), he/she receives positive feedback: "You have waited very nicely!"

If the child doesn't wait his/her turn (he/she moves his/her hands above the Sandtray), he/she receives an encouraging feedback: "You have to wait! It's my turn."

Categories

Instruction

Provided by the robot

a. "Let's sort [...]! It's your turn first."

b. "Now it's my turn."

Response

Provided by the child

a. The child categorizes the items.

b. The child waits his/her turn (doesn't move his/her hands above the touchscreen of the Sandtray when is the robot's turn).

Consequence

Provided by the robot

Depending on the child's answer:

a. If the child categorizes correctly, he/she receives positive feedback: "You sorted the picture correctly. Well done!"

If the child categorizes incorrectly, he/she receives encouraging feedback: "You sorted incorrectly. Try again!"

b. If the child waits his turn (doesn't move his hands above the Sandtray), he/she receives positive feedback: "You have waited very nicely!"

If the child doesn't wait his/her turn (he/she moves his hands above the Sandtray), he/she receives an encouraging feedback: "You have to wait! It's my turn."

Patterns

Instruction

Provided by the robot

a. "Let's continue the string!"

b. "Now it's my turn."

Response

Provided by the child

a. The child continues the pattern illustrated by the string.

b. The child waits his/her turn (doesn't move his/her hands above the touchscreen of the Sandtray when is the partner's turn).

Consequence

Provided by the robot

Depending on the child's answer:

a. If the child continues the pattern correctly, he/she receives positive feedback: "You matched the picture correctly. Well done!"

If the child continues the pattern incorrectly, he/she receives encouraging feedback: "You've matched the picture incorrectly. Try again next time!"

b. If the child waits his/her turn (doesn't move his/her hands above the Sandtray), he/she receives positive feedback: "You have waited very nicely!"

If the child doesn't wait his turn (he/she moves his hands above the Sandtray), he/she receives an encouraging feedback: "You have to wait! It's my turn."

The final results in the clinical indicated that RET had an overall a positive impact on ASD children social skills, with significant gains on IM and TT, and to a lesser extent on JA. Moreover, children in the study reported significant improvements on standardized measures such as ADOS and SCQ. When comparing RET to a standard intervention delivered by a human interaction partner, results showed no significant differences, and the effect sizes for the difference between the two groups were in the equivalence margin of a medium effect size. Results were less favorable for turn-taking patterns matching and categorizing tasks. For secondary outcomes however, there was a clear advantage for the RET condition, with effect sizes that crossed the equivalence margin pointing significant and large differences between the two groups. These results support the RET intervention described here as an evidence based intervention that would likely lead to similar results as a standard intervention.

5. Therapy environment

5.1. Robot

There are a number of social robots available on the market and several social robots have been already used in ASD intervention (see Cabibihan, Javed, Ang, M., & Aljunied, 2013). However, few of them have been empirically investigated for determining their efficacy and effectiveness for ASD. Among these, the humanoid Nao proves to be one of the most viable options. Nao was developed by Aldebaran Robotics (Gouaillier et al., 2009), it weighs 5 kg and is 58 cm tall (see *Figure 1*). Nao is a 25 degrees of freedom robot, equipped with an inertial board, two cameras (one downward-looking, one forward-looking) with 60.9° horizontal field of view and 47.6° vertical field of view, eyes with eight full color RGB LEDs for expressive communication, and four head mounted microphones. It also has a sonar rangefinder, 2 IR emitters and receivers, 9 tactile sensors, and 8 pressure sensors

Figure 1. Nao robot

In order to elicit social interaction, Nao provides social cues through anthropomorphic appearance and interactive abilities. These interactive capacities include verbal, para-verbal (e.g., pitch, volume) and non-verbal (e.g., emotions, gestures and mobility) cues. It has various communication devices including LED lights, two loud–speakers, a voice synthesizer with language-specific intonation and pronunciation. Nao is able to detect and recognize pre-learned objects and faces, words and sentences, as well as to localize sounds.

5.2. System Design

A number of additional devices can be used in order to capture as much relevant data as possible during assessment and intervention sessions. In the DREAM project we used a multi-camera system design that included two external cameras, four RGB-D (color-depth) cameras, Kinect sensors, and four high-resolution color video cameras. All these tools are mounted remotely on a dedicated therapy table (see below) with specific coordinates. Three of the RGB-D cameras are directed at the child and are used to determine the physical configuration of the child's body (e.g., the position and orientation of his/her arms).

The fourth RGB-D camera is mounted above the table, facing the robot. It is used to determine the position and orientation of the robot. This is necessary because the robot has to relate the information provided by the other sensors in a real-world frame of reference to its own frame of reference (i.e. the frame of reference that is used to determine its movements).

The four color video cameras are used to monitor the child's facial expressions, to determine the child's head gaze, and to detect, locate, and identify objects that the child may be interacting with on the table. They are also used to complement the RGB-D cameras when tracking the child's movements and monitoring her or his actions. These video cameras are placed either side of the robot, at table level and at a higher level looking down. This provides for greater flexibility when sensing the child's appearance and movements.

Specific technical specifications and information concerning the system configuration is provided in Deliverable 4.1 (https://dream2020.eu/wp-content/uploads/2014/11/DREAM_Deliverable_D4.1.pdf). A schematic representation of the design of the intervention table is provided in *Figure 2*. As it can see in the *Figure 2*, the therapy table also provides the surface on which objects will be placed and manipulated by the robot and the child during the interventions. Note that the table needs to be hinged so that it can be easily removed to provide space for other intervention props (e.g., the sand-box) and to provide sufficient space for the child to move during some of the imitation intervention exercises. A light-weight miniature gantry, comprising two uprights frames and a horizontal connecting frame, is attached to the back of the fixed part of the table. This gantry will house the high-resolution cameras, the Kinect RGB-D cameras, and any necessary lighting.

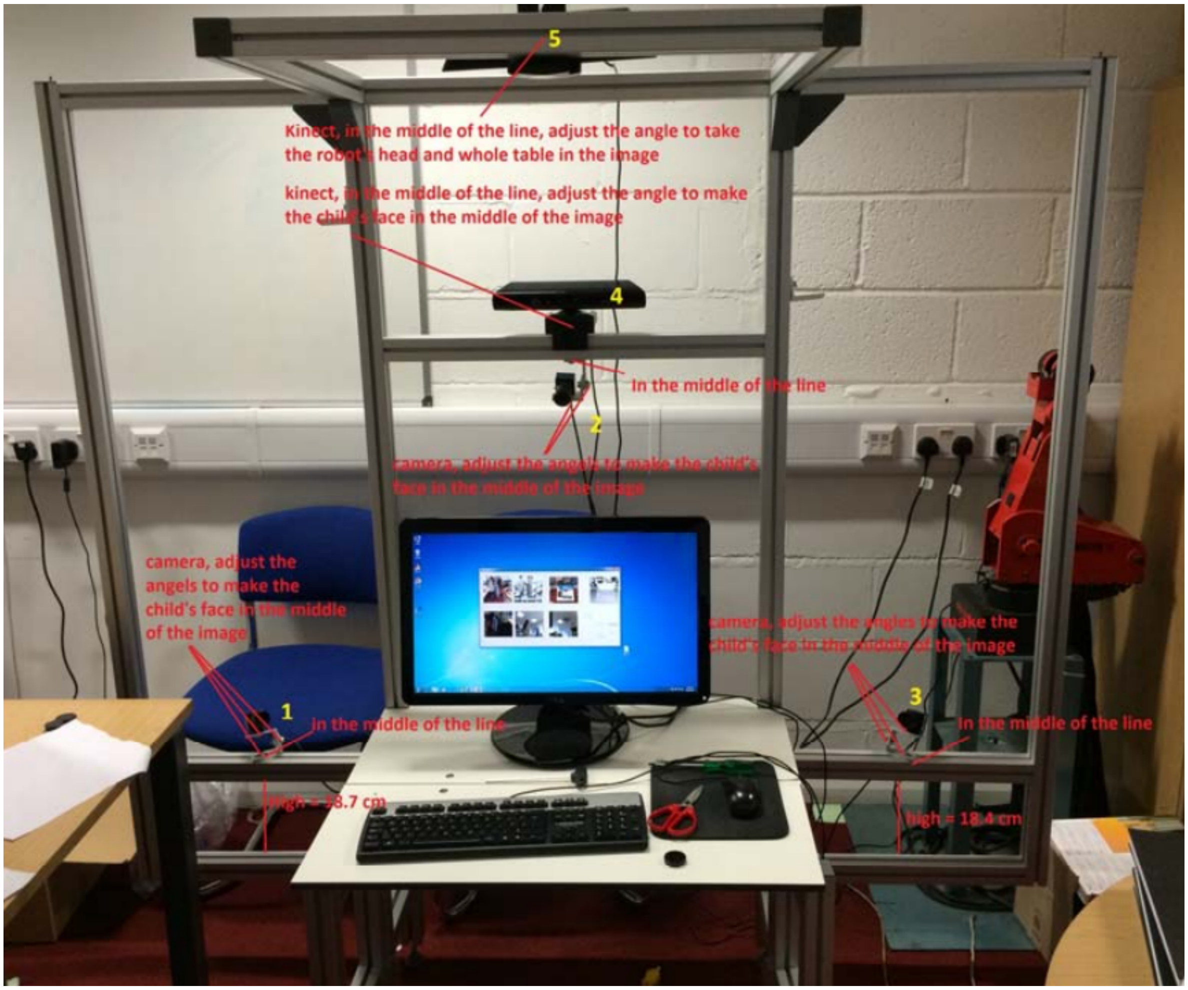

Figure 2. Schematic representation of the therapy table

All the equipment is camouflaged to avoid distracting the child during interventions. The dimensions of the therapy table, required for identifying the required field of view of the cameras and, hence, the focal length of the camera lenses, as well as the final CAD design, are set out in Table 4.

Table 4. Dimensions of therapy table

Dimensions	**Centimeters**
Height of work surface	~ 60
Width of work surface	~ 80
Depth of foldable work surface	~ 30

Depth of fixed work surface	~ 30
Height of mounting frame	~ 140

6. Therapeutic alliance

Most of the general principles concerning therapeutic/ working alliance apply to RET. However, there are some important adjustments deriving from the particularities of RET. Although the intervention is mediated by the robot, the therapist still plays an important role in RET. ASD children also interact with the human therapist both in relation to the robot and in non-robot related contexts.

The terms of the therapeutic alliance in RET are somewhat dependent on the reactions of the child towards the robot. As previously reported in the literature, some children tend to use the robot as an object of shared attention with the therapist (Robins et al., 2005, 2004) and gradually share their in-session robot related experiences with the therapist. During RET, the therapist generally maintains his gaze toward the robot, thus encouraging the child to do the same. The human therapist is physically present and stands with the child near the robot throughout the entire session. Although the intervention is provided mainly by the robot and the human therapist does not generally initiate interactions with the child during robot administered tasks, he/she always responds when addressed by the child and subsequently directs the attention of the child towards the robot in a gentle manner (through gaze and verbal encouragements).

Some studies suggest that social robots are able to build successful therapeutic alliance with people (e.g., high levels of trust, credibility and emotional bond; Kidd, 2008; Kidd & Breazeal, 2008). Hence, the therapeutic alliance can also refer to human-robot interactions in the context of RET. As we have mentioned before, Nao is able to display an array of emotions as well as to recognize some emotional cues. In theory, these features may be used to facilitate a positive therapeutic alliance with ASD children. Still, this hypothesis needs to be more specifically tested in empirical studies in order to determine the extent to which different levels of robot emotional display positively impact on the therapeutic alliance developed with ASD children. The existing literature is promising, given that people tend to respond positively to robots regardless of their age (see Rabbitt, Kazdin, & Scassellati, 2015) and longer periods of time spent in the company of the robot elicit even more positive behaviors towards the robot (Koay, Syrdal, Walters, & Dautenhahn, 2007). These results suggest that the positive interactions with robots cannot be explained merely by a potential novelty effect and robots may be able foster positive responses thorough a longer intervention protocol.

Similar to traditional therapy, in RET both the human therapist and the robot should gradually attune to de client in order to facilitate the development of the working alliance. This may be particularly important in the case of children with ASD for which novel situations tend to trigger some levels of discomfort or anxiety. For these children, the interaction with a new tool, such as a robot and an unknown adult (i.e., human therapist), may be more difficult at first and some adjustments may be required to ensure the interaction is kept at a level that is comfortable for the child (e.g., at first, the child could be involved in pleasant/familiar activities taking place in the same room with the robot and the robot could be introduced only later on, as the child express higher interests concerning the robot). It should be ensured that the ASD children have unconstrained interactions with the robot, especially in the first sessions, in order to build a safe foundation for further interactions that are required for the implementation of RET.

7. Ethics for child-robot interaction

In the DREAM project, the ethical issues concerning the use of robots for delivering RET for ASD have been approached with multiple stakeholders having various levels of knowledge and experience with RET (see Deliverable D7.2; https://www.dream2020.eu/wp-content/uploads/2017/09/original-FINAL-D7.2-The-Ethics-of-Child-Robot-Interaction-1-March-2017.pdf). Thus, the ethics employed in DREAM took into account the perspectives of the consortium team, as well as parents of children with autism, adults with Asperger's, government and trust healthcare providers, healthcare specialists, politicians, educationalists and members of the general public. Below, we approach some ethical concerns highlighted in DREAM, as well as in previous studies.

A first ethical concern is that the robot is programmed to assess the children response and is involved in therapeutic decisions throughout intervention that may have an ethical impact. Although this is a relevant issue, in the semi-autonomous versions of RET the robot is not expected to take therapeutic decisions by itself. The robot is built to propose a course of action, but the decisions having an ethical impact will ultimately be made by the human therapist, as in the case of traditional therapy. The therapist is present in the room at all times and can choose to overrule or change the behavior of the robot.

Related to this issue, a recent survey of our research group found that parents of children with ASD tend to favor the semi-autonomous/supervised RET in which the robot does not replace the therapist (Coeckelbergh, Pop, Simut et al., 2016). Nevertheless, stakeholders tend to accept the idea of using robots in the delivery of interventions for ASD children.

Some parents were preoccupied that involving the robot into the activities of a very young child may impact on their learning. In the current version of RET, children spend relatively short time periods and it is unlikely that this may lead to problems in this area. However, if RET interventions are to become more sophisticated and the children are to spend significantly more time with the robot, this may become an ethical issue that requires closer examination in empirical studies.

Although users tend to respond positively to robots, there is also relevant variation in their reactions (Wang, Rau, Evers, Robinson, & Hinds, 2010). In the studies conducted in the DREAM project, this variation was also observed. While some children responded very positively from the very first interactions, others were more distant at first, and a minority of ASD children displayed some negative reactions (e.g., anxiety). However, given that similar patterns of responses were observed when the therapy was delivered exclusively by a human therapist, the reactions may be partially explained by the novelty effect (i.e., some children may be more apprehensive in new contexts/ interactions). Similarly to what it was reported in the literature (Koay, Syrdal, Walters, & Dautenhahn, 2007), we also observed that children who repeatedly interact with the robot tend to became more comfortable and displayed more positive robot-directed behaviors.

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