D1.3 State-of-the-art of the Michelangelo related technologies and of the therapeutic methods

Michelangelo Project - "Patient-centric model for remote management, treatment and rehabilitation of autistic children"

Version 2

Document Information

Contract Number	288241
Project Website	http://www.michelangelo-project.eu
Contractual Deadline	30th September 2014
Dissemination Level	Public
Nature	Report
Status	Vers.2
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Keywords	Therapeutic programs; joint attention; imitation; ICT

Change Log

Version	Description of Change
0.1	UPMC contribution
0.2	Adding ULSTER contributions
1	November 2012
2	Revised version reflecting the recommendations of the EC experts

CONTENTS

List of abbreviations

ABA	Applied Behavior Analysis
ASP	Autism Spectrum Disorders
EDD	eye-direction detector
EIBI	Early Intensive Behavior Intervention
ESDM	Early Start Denver Model
IBI	Intensive Behavioral Interventions
ICT	Information and Communication Technology
ID	intentionality detector
IDC	International Classification of the Diseases
PDD	Pervasive Developmental Disorders
PECS	Picture Exchange Communication System
PRT	Pivotal Response Training
TEACCH	Treatment and Education of Autistic and Related Communication Handicapped children

Executive Summary

This paper presents state-of-the-art treatment programs and technological methods that may be implemented for young children with autism spectrum disorders (ASDs). In the first section, the paper briefly presents the different therapeutic methods by making a distinction between global and focused approaches. We also present the international professional recommendations for each method mentioned. In the second section, we review research on informative and communication technologies (ICT) employed for the support of children with ASD in the field of imitation and joint attention, with a focus on social signal processing and social robotics. One of the main objectives of this deliverable is to identify the different therapeutic methods and ICT approaches used in children with ASD in order to facilitate the choices of possible scenarios to be implemented in the MICHELANGELO project.

SECTION 1: OVERVIEW OF TREATMENT APPROACHES IN ASD

1. Introduction

In the context of pervasive developmental disorders (PDDs), the International Classification of Diseases (ICD-10) is the reference for classification. PDDs are classified according to the ICD-10 as disorders of psychological development: "The PDD is a group of disorders characterized by qualitative impairments in reciprocal social interaction and communication patterns, as well as a repertoire of interests and activities restricted, stereotyped and repetitive. These qualitative abnormalities are a pervasive feature of the functioning of the subject, in all situations." In the scientific literature, they are also referred to as autism spectrum disorders (ASDs).

One of the major objectives of MICHELANGELO is to develop and evaluate Information and Communication technologies (ICT) for personalized treatments by deploying technologies for observation and the stimulation of more adapted behaviors in children with ASD. Before going into the details of reviewing ICT for treatment in ASD, we must focus first on today's state-of-the-art assessments and therapeutic approaches for ASD.

Diagnosing ASD in a given child requires that an initial assessment of the functioning of the child be made within 3 months after the first consultation. Following this assessment, a personalized program intervention will initially be implemented. Translating the assessment results into goals and objectives of the interventions is an essential step in defining the program. This process requires that educational and therapeutic interventions for children must be coordinated. Although in practice, the border is not as clear between different interventions, we have divided the educational interventions and non-drug therapies into two broad categories for clarity:

1. Structured interventions or global approaches that are coordinated within a comprehensive approach: These interventions, called "programs" or "support" in the literature, are said to be "comprehensive", as they aim to meet the multidimensional needs of the person with PDD, and they suggest goals for several areas of functioning, activities and social participation. The profiles of children with ASD are extremely heterogeneous, so these comprehensive programs are divided in the form of customized projects to meet the unique needs of each child within the multidimensional approach;
2. “Focused" or "specific" interventions that target a specific symptom, activity or developmental dimension (e.g., language) and not on the overall functioning of the person. These specific interventions are designed to achieve a specific improvement in one area of functioning of the individual with PDD or in his or her activities, including imitation, joint attention, social interactions, behavioral problems, stereotypes, aggressiveness, anxiety, etc. These specific interventions can be integrated into comprehensive programs to enhance their effects in a specific functional area. There are a large number of intervention programs that are either global or focused. We will briefly present the most popular program; the list is not exhaustive.

2. Global approaches

Global interventions establish a working agenda for the child with long-term goals. These programs include the interventions that target all of the deficient domains in autism, such as communication, socialization, behavior and motor skills.

2.1 Intervention programs based on behavioral techniques

2.1.1 Applied Behavior Analysis (ABA)

The principle of Applied Behavior Analysis is based on the rule that a person's behavior is the result of background events and that the consequences alter the frequency of occurrence of a given behavior. A.B.A. aims to analyze the behavior to understand how the environment influences it and to develop strategies for change based on reinforcements. The objectives are to improve social behavior significantly and to limit problem behaviors (Magerotte, 2001).

2.1.2 Early Intensive Behavior Intervention or Intensive Behavioral Intervention

An early intensive behavior intervention (EIBI) or intensive behavioral intervention (IBI.) derives from ABA. Of the EIBI. programs, among the best known is the Lovaas program, which uses techniques of intensive behavioral intervention on a temporal plane (at least 40 hours per week) to treat children aged 2 to 3 years old over a period of 2 to 3 years. The strategies currently used are discrete trials, as well as incidental teaching, working in dyads with peers, and integration into small groups and school (Lovaas, Smith, 2003; Lovaas, 2003).

Lovaas was the first researcher to use the principles of applied behavioral analysis (ABA) to treat children with PDD. Critics of this approach have addressed the following concerns: a) difficulties in the generalization of learned behaviors; b) mechanical responses (like robots); c) lack of spontaneity; d) excessive dependence on the caregiver; and e) slow progress. These criticisms have led to the development of pivotal response training (PRT), a more naturalistic behavioral treatment, which has had good documented effectiveness. The principles of PRT are: choosing 'pivotal' skills as the target of treatment; following the child's choice of activities and games; strengthening not only the correct answer, as expected by the therapist, but also incomplete attempts to answer; alternating between acquisition and maintenance and using intrinsic reinforcers.

2.2 Intervention program based on developmental approach

2.2.1 TEACCH: Treatment and Education of Autistic and related Communication with handicapped Children

This method uses many technical interventions to meet the individual needs of people with autism. Individual needs are assessed through a comprehensive assessment of several developmental dimensions, also taking into account emerging capacities. The environment is organized to help children and adults to understand and remember what to do (e.g., visual agendas, making expectations clear and explicit, visual materials, structured architecture). The focus is on positive strategies to support behavioral and teaching strategies, using verbal rather than visual information. Parental involvement is sought. The main objective is to enable people with autism to function as independently as possible in the community (Perry, Condillac, 2003).

2.2.2 Early Start Denver Model (ESDM)

The early start Denver model is an early and intensive intervention approach for young children. This program aims to meet the socio-emotional needs of specific young children and their families, to identify socio-communicative symptoms of autism that arise during the second year of life and to use validated and effective intervention techniques that are based on developmental needs (Smith, Rogers, Dawson, 2006).

The interventions are based on the following: (i) a curriculum that evaluates the child's development across different developmental domains; and (ii) specific procedures for learning and incorporating ABA principles, such as *pivotal response training.* The sessions focus on interactions with children, interpersonal exchanges, a positive affect, shared commitment with materials and activities of daily living and verbal and nonverbal communication cues. This program is implemented in small groups or individually, at a specialized center or at home. It is administered by a multidisciplinary team that is individualized for each child and parental involvement is sought.

2.2.3 Intervention programs based on psychodynamic approaches

In the context of diverse practices within clinical settings, such as day care and hospitals, adapted psychodynamic psychotherapy is most often associated with educational activities, games and mediations, which are provided to support the development of communication and symbolization. The objectives are to promote in children with autism relationships with others and with themselves, by giving them the means to build greater capacity for representation and to assist these children positively in reinvesting their mental activity.

When children reach school age, they can fit into an institution's health and social sector, such as a medical-educational institution or a therapeutic and teaching institution, where the educational aspect becomes central and the frequency of time care is less than in hospital units. For children who have improved, combinations with regular schooling are also feasible (Baghdadli, Noyer, Aussilloux, 2007)

3. Focused interventions

Unlike programs that include a set of coordinated interventions, focused interventions usually have a more limited character regarding time and they are administered in regular sessions. They can be part of the components of the overall program. They are focused on deficient areas in autism, such as communication, socialization, behavior and sensory integration (Baghdadli, Noyer, Aussilloux, 2007).

3.1 Communication and language

A variety of interventions are used and their goal is to influence the child's ability to use communication to monitor, understand and participate in the social world (Goldstein, 2002).

3.1.1 Picture Exchange Communication System (PECS)

The PECS method is primarily used with preschool children with a diagnosis of ASD (Perry, Condillac, 2003). The goal is to teach children how to initiate interaction spontaneously. They are taught to choose an image that represents an activity, a person or a desired object and to present the image to the communication partner to obtain the desired object. To assist in the generalization of learning using these images of communication in all areas of a child's life (food, clothing, daily life), the system uses references and strategies from both behavioral (it changes the behavior of the child who comes into communication with others) and developmental (it changes the environment of the child who is more accessible) perspectives.

3.1.2 Makaton

This tool is not specific to people with autism. It is used to meet the needs of people with severe language disorders. It consists of a basic vocabulary (450 concepts), which is taught using graphic signs and symbols that symbolize spoken language. It requires a large number of participants and family involvement is necessary to allow for its use in daily interaction (Walker, 2006).

3.1.3 Speech therapy

Speech therapy in individuals with autism is based on Rapin and Allen’s proposals regarding the intensive treatment of children with dysphasia (Rapin and Allen, 1983). They proposed to consider language impairments in children with autism as a dimension and to use the validated techniques used in dysphasic children to treat this specific aspect of the symptoms of children with ASD. The proposals require experienced professionals and a precise assessment of the different linguistic dysfunctions (phonology, semantics, syntax, pragmatics) to address therapeutic needs. It can be used in combination with PECS or Makaton, in particular when vocalization is difficult to achieve.

3.2 Social interactions

Pro-social interventions seek to improve the relationship problems observed in ASD and to develop the prerequisites for reciprocal relationships (joint attention, imitation, games).

3.2.1 Games

Different programs focus on various games (play with toys, pretend play and social play). These programs are based on developmental approaches, assuming that games can facilitate the development of skills, social interaction and communication with positive feedback (Baghdadli, Noyer, Aussilloux, 2007).

3.2.2 Floor time

The floor time model is also called the "developmental, individual difference relationship" (DIR) model (Greenspan, Wieder, 1997). It is stimulated by the capabilities of games to promote social interaction and the emotional regulation of children. In this model the child and his or her parents rehearse emotional interactions using the emerging communication skills of the child (initially with gestures instead of words). The floor time is used in young children. It includes interactive sessions, during which the participant (adult, parent or teacher) is guided by the child in a quiet environment for 2 to 5 hours per day (6 to 10 sessions of 20 to 30 minutes per day).

3.2.3 Reciprocal imitation training

Reciprocal imitation training targets the widespread spontaneous imitation skills of young children with autism during game situations. This method is used to teach the imitation of gestures, with or without objects (Field, Sanders, Nadel, 2001)

3.2.4 Social history and social scenarios

Social histories focus on specific social situations that are likely to occur and they teach the behavior to be adopted in each case. Histories are imaged or not and they can be acted or played within sessions, with a therapist or within dedicated, serious games (Rust, Smith, 2006).

3.2.5 Learning of joint attention

Learning of joint attention is not a technique by itself. Joint attention is taught using a technique of behavior modification. Working on joint attention is aimed to improve gambling behavior, communication and the social behaviors of children with autism (Whalen, Schreibman, 2003).

3.3 Motor activity and sensory integration

3.3.1 Sensory integration therapy

Sensory integration is the hierarchical organization of somatic sensations, which serves as the foundation for an individual's perceptions, behaviors and learning (Ayres, 1979; Bullinger, 2004). Many individuals with PDD show impairments in sensory integration and/or emotional regulation. This intervention includes vestibular (swinging game), proprioceptive (body pressure, deep pressure), and tactile stimulation (massage). The procedure is administered in individual sessions based on games. The objective is to provide the child with a controlled sensory experience, which will lead to an appropriate response to sensory stimulation and functioning. Some approaches also include a developmental view of sensory motor milestones (Kloeckner et al., 2009; Jutard et al., 2009).

3.3.2 Snoezelen

This method proposes various sensory experiences to be lived in an atmosphere of trust and relaxation. This method is based on relaxation and sensory perception (music, play of light, vibration, and tactile and olfactory perception) (Baghdadli, Noyer, Aussilloux, 2007). It has also been used in individuals with multiple handicaps.

3.4 Behavior management problems

3.4.1 Programs to support positive behavior

The objective of this program is to try to reduce behavioral problems by changing the circumstances in which they occur, for example, changing environmental conditions, control and strengthening good behavior and ignoring bad behavior, using reinforcements (Turnbull & all.2002).

3.4.2 Packing or wet sheet packs

Wet sheet packs, or packing therapy, are an adjunct treatment administered by occupational therapists. Packing therapy involves enveloping a patient in damp sheets for 1-hour sessions while he or she is fully and spontaneously invited to express him /herself and his/her bodily experiences. The packing technique, used in children with developmental disorders, was proposed as a possible intervention for children and adolescents evincing severe forms of self-injurious behaviors or catatonia, after having exhausted other possible therapies. The goals are to facilitate sensory integration in these patients and for the child to experience the relaxing effect of packing (Goeb et al., 2009).

3.5 Individual psychoanalytic therapies

There are many psychoanalytic approaches “applied” to the treatment of children, adolescents or adults with autism, but they are not precisely described as protocols (Amy, 2004). For psychoanalysts, autistic processes, whatever the causes, are related to archaic anguish. This anguish leads the patient to react with defensive mechanisms that isolate them gradually. The different proposed devices (play, drawing) are intended to allow for the expression of these archaic elements within the relationship with the therapist, who can comment, support and give meaning to the child of what he/she understands from his/her experience. The therapist also ensures a presence capable of receiving the anguish and processing it. It is intended to raise the internal state of the child and his/her emotions and to help him to enter the world of communication.

4. Summary

Table 1. Interventions for people with autism and international professional recommendations.

Method	Contents	Objectives	Population	Recommendation
		FOCUSED ON COMMUNICATION		
P.E.C.S.	Alternative method of communication by exchange of pictograms	Spontaneously initiate interaction	Children with ASD	**Recommended** by Health Institute Carlos III, in 2006; Scottish Intercollegiate Guidelines Network, in 2007; French HAS and ANESM in 2012
Makaton	Alternative method of communication by gestures	Initiate communication	Children with language disabilities	
		FOCUSED ON SOCIAL INTERACTION		
Games	In different forms: Free game, Thurs structured material, With object or not	Developmental approach assuming that the game develops skills, social interaction and communication.	Children	**Recommended** by Health Institute Carlos III, in 2006
Floor time	The child directs the play sessions for 2 to 5 hours per day	Improve the capacity of social exchange and regulation	Young children with ASD	**Not recommended** by New York State Department of Health, in 1999; French H.A.S and ANESM, in 2012
Reciprocal imitation training	Teach the imitation of a gesture involving an object or imitation of a simple gesture	Recognition by the child to be imitated and commitment of the child to reciprocal games	Children with ASD	
Social history and social scenarios	Scenarios description and reflection on social order to find appropriate behavior	Teach appropriate behavior in new situations	People with high-level ASD and Asperger's	**Recommended** by Health Institute Carlos III, in 2006; French HAS and ANESM, in 2012
Learning of joint attention	Show or follow the pointing or the gaze of the experimenter, coordination between gaze and pointing	Improve gambling behavior, communication and social behavior	Children with ASD	

	FOCUSED ON SENSORY AND MOTOR INTEGRATION		
Sensory integration therapy Provide vestibular, proprioceptive and tactile stimulation to the child during play sessions	Provide the child with a controlled sensory experience, which leads to an appropriate response to sensory stimulation and function	Children with ASD	**Not recommended** by New York State Department of Health, in 1999
Snoezelen Presentation of various sensory experiences lived in an atmosphere of confidence and relaxation	Learn to relax	Not specific	
	FOCUSED ON BEHAVIORAL PROBLEM MANAGEMENT		
Programs to supports positive behavior Changes in natural conditions	Reinforce good behavior; learn new behavior; planning implications	People with ASD	**Recommended** by Health Institute Carlos III, in 2006; Ministry of Health and Education, New Zealand, in 2008; French HAS and ANESM, in 2012
	FOCUSED ON EMOTIONAL EXPERIENCE OF THE CHILD AND DEVELOPMENT		
Psychoanalytic therapies The different devices proposed are intended to allow for the expression of these archaic elements in a relationship with a therapist who can comment for, talk to, and interpreting for the child what he/she understands from his/her experiences, assuring a presence capable of receiving the anguish and processing it	The analysis and interpretation of transfer and cross-transfer intended to raise the internal state of the child and his/her emotions and to help him/her enter the world of communication	Children, adolescents or adults with ASD	**Not recommended** by the Health Institute Carlos III, in 2006; the Ministry of Health and Education, New Zealand, in 2008
	GLOBAL INTERVENTION PROGRAMS BASED ON BEHAVIORAL APPROACHES		
A.B.A. and E.I.B.I. The principle is that a person's behavior is the result of backgrounds events and that is the consequences altering the frequency of occurrence. He is to analyze the behavior to understand how the environment influences and to develop strategies for change.	To improve social behavior significantly and limit behavior problems	People with ASD	**Recommended** by New York Department of Health, in 1999; Health Institute Carlos III, in 2006; Scottish Intercollegiate Guidelines Network, in 2007; Ministry of Health and Education, New Zealand, in 2008; French HAS and ANESM, in 2012; Scientific merit and treatment effect according to Eikeseth classification, in 2009

GLOBAL INTERVENTION PROGRAMS BASED ON DEVELOPMENTAL APPROACHES			
TEACCH and ESDM The developmental interventions are based on the use of the natural interests and motivations of the child.	Restore the development of communication with and in relation to the other and function as independently as possible in the community	People with ASD	**Recommended** by Health Institute Carlos III, in 2006; Scottish Intercollegiate Guidelines Network, in 2007; Ministry of Health and Education, New Zealand, in 2008; French HAS and ANESM, in 2012; Scientific merit and treatment effect according to Eikeseth classification in 2009
GLOBAL INTERVENTION PROGRAMS BASED ON INSTITUTIONAL SUPPORT			
Institutional support with psychodynamic references Most often associated with educational activities, games, and susceptibility, providing mediation and support to the development of communication and symbolization.	To promote in children with autism relationships with others and themselves by giving them the means to build capacity for representation and to help them reinvest their mental activity positively	Not specific	

HAS=High Authority for Health; ANESM=National Agency for Assessment and the Quality of Medical and Social Institutions and Services; ASD=autism spectrum disorder

5. Therapeutic methods in the MICHELANGELO project

The MICHELANGELO project is intended to provide children with ASD with individualized and personalized support within a natural environment. We have chosen to use the method of the Early Start Denver Model (ESDM) of Geraldine Dawson and Sally Rogers, which is the treatment that has received the most support in recent years in several evidence-based studies (for details see deliverable 4.1.). In particular, it appears to be very promising in young children (<4 years old), and it will be our main focus in the MICHELANGELO project because the project focuses on this time period, with maximum brain plasticity.

The ESDM starts with an assessment, which allows for the creation of an individualized educational plan. After training and the regular support of the family, the educational program can also be applied at home, in the natural environment of the child. This program offers the advantage of being regularly reassessed and adjusted based on the child's abilities. The ESDM is a comprehensive educational program. However, under MICHELANGELO, we will focus our training on the capacity for imitation and on the joint attention of children. Joint attention, as well as imitation, is part of the premises of learning communication, which is considered to be a major diagnostic criterion for autism.

5.1 Joint attention

Joint attention is defined as a triadic interaction among self, other and object. It is the ability of a person to focus his/her attention and that of others on a common object. In typical development, joint attention behaviors appear between 6 and 12 months and involve interaction with others. The development of joint attention usually starts by pointing to other objects and checking the direction of the gaze of others to objects. These basic joint attention behaviors are associated with the development of receptive and expressive language. Other behaviors associated with joint attention appearing thereafter are watching with the other tip of the finger, showing an object, pointing, gesturing, taking or giving an object and responding to one's name. To understand language, children must understand the relationship between words and objects and interpret the communicative gestures of others as intentional acts. Deficits in understanding the meanings of gestures, such as pointing and gazing, can be associated with a delay in receptive language and overall language acquisition.

5.2 Imitation

Imitation plays a critical role in the development of every child. It fulfills two essential functions for adaptation: it is used for learning and it serves to communicate without words (Nadel, 2006). Wordless communication is possible when using both sides of imitation: imitating and recognizing that something is imitated. In case of two children each one uses 1 of the 2 sides of imitation; they coordinate two roles: the model and the imitator. Children are temporally synchronized because they are engaging in the same activity at the same time. There are several levels of imitation that constitute a continuum, from simple to complex and from familiar to the new. All of these levels have in common a response to the perception of movements or actions, finalized by the production of a similar behavior.

One of the major objectives of MICHELANGELO will be to develop and evaluate ICT for personalized treatments by deploying technologies for observation and the stimulation of behaviors during imitation and joint attention, according to the ESDM. As we will see in the next section, these two key behaviors during early interaction have received interest in ICT and we believe that specific scenarios can be developed to resolve some of the issues that the MICHELANGELO project will face.

SECTION 2: ICT-BASED METHODS IN ASD: FOCUS ON SOCIAL SIGNAL PROCESSING AND SOCIAL ROBOTICS

1 Introduction

In this section, we will discuss imitation and joint attention in the context of children with ASD and consider how ICT can help to address treatment-related issues. These two abilities are very important during the development of the child. To address these abilities an important concept is that of synchrony, which refers to individuals' temporal coordination during social interactions. The analysis of this phenomenon is complex, requiring the perception and integration of multimodal communicative signals. Synchrony and imitation are linked in the development of children. Originally studied by developmental psychologists, synchrony has now captured the interest of researchers in such fields as social signal processing, robotics, and machine learning. The evaluation of synchrony has received multidisciplinary attention because of its role in early development, language learning, and social signal processing (Delaherche et al. 2012). Our UPMC partner recently published a review of interactional synchrony (Delaherche et al. 2012), in which state-of-the-art evaluation methods are described. In this paper, the UPMC partners review non-computational and computational approaches to annotating, evaluating and modeling interactional synchrony. These state-of-the-art approaches are interesting for the assessment of imitation in the MICHELANGELO project.

Additionally, in the Michelangelo project, technologies for the stimulation of behaviors will be investigated through robotics. The clinical use of social robots is a promising field because children with ASD:

1) exhibit strengths in understanding the physical (object-related) world and relative weaknesses in understanding the social world (Klin 2000, Klin 2009);
2) are more responsive to feedback, even social feedback, when administered via technology, rather than via humans (Ozonoff 1995); and
3) are more intrinsically interested in treatment when it involves electronic or robotic components (Robins 2006).

However, it is difficult to evaluate human-robot interaction, for example, imitation or joint attention (Delaherche et al. 2012).

In this section, we first discuss imitation and joint attention from developmental and clinical points of view, as these two behaviors will be specifically targeted in MICHELANGELO. Then, we describe the state-of-the-art approaches proposed in social signal processing and social robotics directed toward imitation and joint attention. Finally, we discuss the possible contributions of robotics in ASD.

2. Definitions and developmental views of imitation and shared attention

2.1 Imitation

Since the late 19th century, developmental psychologists have been interested in imitation (Thorndike 1898). Today, imitation is a central issue in many other disciplines, such as neurobiology and robotics. Consequently, several definitions of imitation exist, but no definition is universally accepted:

(1) Thorndike (1898) offered a definition based on visual aspects: "to learn to do an action by watching someone do it". The visual aspect is highlighted in this definition. However, if we take the example of bird song, we realize that a full definition of imitation must consider multi-sensory aspects.

(2) Bandura (Wallon 1970) defined imitation as a learning technique without reward (without reinforcement).

(3) Whiten (1992) defined imitation as the process by which the imitator learns some behavioral characteristics of the model.

At the beginning of the 20th century, Baldwin (Baldwin 1902) proposed one of the first theories. Baldwin linked Darwinian evolution and imitation. If we consider imitation to be a mechanism of individual adaptation, it can allow individuals to improve some abilities that are not very efficient at birth to ensure survival.

According to Piaget (1936, 1945), imitation is based on four mechanisms during early development: exploration (the child discovers his/her motor repertoire, i.e., the motor actions that he/she can perform); circular reactions (reflexes that are enriched by the assimilation of external elements and that motivate infants to maintain responses related to external excitation); assimilation (classification of behavior observed in the proximity of a known behavior); and accommodation (ability to detect and correct the difference between perceived behavior and the reproduction of this behavior).

2.2 Joint attention

Joint attention is a key element of social cognition. It teaches us much about social relationships, and it is often considered a critical component of the theory of mind (Premack and Woodruff, 1978). Joint attention is the mechanism of directing one's own gaze depending on the gaze of other. Emery (2000) defined joint attention as a triadic interaction, showing that both agents focus on a single object. An agent 1 detects that the gaze of agent 2 is not directed at him/her and therefore follows the direction of the gaze to look at the "object" of attention. This definition highlights a unidirectional process, unlike shared attention, which appears to be a coupling between mutual attention and joint attention. In shared attention, the attention of both agents concerns the object but also the other agent ("I know that you are looking at the object, and you know that I am looking at the object").

3. Synchrony as a core issue of social signal processing to understand interaction

In recent years, there has been growing interest in human communication dynamics in several domains, such as social signal processing (Vinciarelli, 2009). Automatic characterization of interpersonal synchrony is identified as the primary challenge of social signal processing. In this section, we review methods related to imitation (mimicry) detection. Currently, few models have been proposed to capture mimicry in dyadic interactions. Mimicry is usually considered within the larger framework of assessing interactional synchrony, which is the coordination of movement between individuals regarding both timing and form during interpersonal communication (Bernieri, 1988). Actual state-of-the-art methods to assess synchrony rely on two steps: feature extraction and a measure of similarity.

The first step in computing synchrony is extracting the relevant features of the dyad's motion. We can distinguish between studies focusing on the movement of a single body part and those capturing the overall movement of the dyad. Numerous studies have focused on head motion, which can convey emotion, acknowledgement or active participation in an interaction. Head motion can be captured using either a motion-tracking device (Ashenfelter, 2009) or a video-based tracking algorithm (Campbell, 2008a; Varni, 2010). Many studies have captured the global movements of the participants with motion energy imaging (Altmann, 2011; Ramseyer, 2011) or derivatives (Delaherche, 2010; Sun, 2011). Then, a measure of similarity is applied between the two time series. Correlation is certainly the most commonly used method to evaluate interactional synchrony. After extracting the movement time series of the partners, a time-lagged cross-correlation is applied between the two time series, using short windows of interaction. Several studies have also used a peak-picking algorithm to estimate the time lag between partners (Ashenfelter, 2009; Boker, 2002a; Altmann 2011). Recurrence analysis is an alternative to correlation (Varni, 2010). It was inspired by the theory of coupled dynamic systems, which provide graphical representations of the dynamics of coupled systems. Recurrence analysis assesses the points in time at which two systems show similar patterns of change or movement, called “recurrence points'”. These models are often poorly selective for mimicry detection. Indeed, the features (e.g., motion energy) describe the amount of movement rather than the form of the gestures performed. Capturing mimicry entails having a finer description of the gestures, which can be achieved with action recognition techniques.

In the context of action recognition techniques, our UPMC partner recently proposed an unsupervised approach to measuring immediate synchronous and asynchronous imitations between two partners (Michelet, 2012). The proposed model is based on two steps: detection of interest points in images and evaluation of the similarity between actions. First, spatio-temporal points are detected for an accurate selection of the important information contained in videos. Then, bag-of-words models are constructed, describing the visual content of the videos. Finally, the similarity between the bag-of-words models is measured with dynamic time warping, which yields an accurate measurement of imitation between partners. Experimental results have shown that the model is able to distinguish between imitation and non-imitation phases of interactions. The current challenges regarding mimicry involve the characterization of both temporal coordination (synchrony) and content coordination (behavior matching) in dyadic interaction (Delaherche, 2012). The synchrony module is dedicated to identifying the time lag and possible rhythm between partners. The imitation module aims to assess the distance between two gestures, based on 1-Class SVM models. These measurements distinguish significantly between conditions in which synchrony or behavior matching occurs and conditions in which these phenomena are absent. In the context of the MICHELANGELO project, these models can be used to evaluate social interactions between children with ASD and adults (therapists, mothers).

4. Social robotics of imitation

4.1. The first robotics experiments on imitation

The first robotics experiments that used imitation were limited to simple tasks and simple robots. For example, Kuniyoshi, since 1994, has focused on learning by observation (Kuniyoshi 1994, Bakker 1996) and has described three phases: (1) observation: watching an action performed by a human, e.g., a human grasps and then moves an object to place it in another position; (2) understanding, which involves the construction and memorization of an internal representation of the observed task; and (3) reproduction of the observed task.

These studies were precursors and highlighted several challenges related to autonomous robotics and imitation, for example, the visual processing in an imitation task and the association between observed actions and actions of the motor repertoire. (Dillmann 2004) presented approaches for learning methods that could enable a robot to learn the typical tasks required in everyday household environments. First, this model concentrates on analysis of the human actions and action sequences that can be identified when watching a human demonstrator. Second, sensor systems are introduced, which augment the robot's perception capabilities while watching a human's demonstration and the robot's execution of tasks, respectively (Dautenhahn 1995), presenting a set of mobile robots that must climb up a hill. For this task, users must imitate the path of a robot teacher to find the top of a hill. In Hayes (1994), a robot follows a teacher in a labyrinth. The robot is able to detect the relevant actions of the teacher and associate them with the perceived situation. The robot (imitator) uses a module that extracts the position and orientation of the teacher, as well as module of proprioception (position and orientation of the imitator). For each movement of the teacher, the imitator must recalculate the movement to maintain the same orientation and the same distance from its teacher.

In Berthouze (1996, 1998), the robot must watch a man who performs an assembly task and then attempt to reproduce the same sequence to perform the task; these studies were similar to the experiences of Billard (1997, 1998), who demonstrated a neural architecture controlling a robot that learned movement sequences performed by a teacher. The robot is a doll that can perform simple actions, such as turning its head and lifting its arm. The robot is equipped with 4 infrared sensors that detect the movements of the teacher. The teacher is also equipped with infrared emitters in each hand and two on the head. A reflex mechanism ensures coordination between the teacher's movements and the robot's movements. For example, the teacher lifts his/her hand in front of the robot, and consequently, the robot imitates and lifts its hand. The robot is also equipped with a keyboard (8 keys) that allows it to communicate with the teacher. The imitative behavior of the robot is performed using a pre-wired architecture that links the infrared sensors and motors. The robot can learn simple sequences (2 to 8 actions by sequence). The professor performs a sequence of movements in front of the robot, and the robot imitates them. At the end of the sequence, the teacher presses a key. Each sequence is repeated until the association is correct between the key and the sequence of movements. This architecture uses recurrent associative memory. The doll was used with children 4-5 years old. The children had to teach the doll to associate a sequence of movements with a sentence. The protocol was simple: the child performed a movement and pressed the key associated with this movement. Each key was associated with a specific task. After the learning phase, the robot performed the sequence according to the sentence that the child said. This study showed that children are fascinated by games with dolls. These first experiments inspired a desire to build robots that can undertake complex behaviors, such as the learning of sequences. Moreover, some experiments with children have shown that children are very interested by the games with the robot. Whether these experiments can be performed with children with ASD and whether the behavior of children with ASD can be analyzed remain unresolved issues, but they will be investigated in the context of MICHELANGELO.

4.2. Gesture imitation

At its lowest level, imitation is performed at the gesture level. The goal is to reproduce an observed gesture. However, fundamental questions must be considered. The first question regards movement recognition: the robot must identify the human arm and characterize the human arm trajectory. In the case of simple gestures, the robot often detects the arm color, the arm movement or color patches applied to the arm joints. Then, the question of the gesture's appearance must be considered: what should the robot imitate? It might be the configuration of the whole arm or the hand position but it might also be also the orientation if the whole gesture should be reproduced. Finally, the question of perspective must also be considered, for example, when the robot must perform the gesture "come" with the hand. In robotics, it is possible to avoid these problems. The solution could be to perform the examples directly with the robotic forelimb, e.g., using a remote control (Campbell 2006), to manipulate the hand (Calinon 2007) or by fitting the robot model with sensors (Maurer 2005; Aleotti 2006) or an exoskeleton (Ijspeert 2002).

4.3. Imitation of complex tasks

Imitation is more complex when it involves interaction with the environment, which is the case in most common tasks. This complexity arises from the sequence of actions necessary to perform tasks and the introduction of objects into the world of the robot. To understand the actions performed, one must identify the gesture and the object, as well as their interactions. Task reproduction is more complex if the robot must consider several objects simultaneously. The difficulty is in determining the relationships among the hands, arms and different objects. However, humans can interact with the robot to help it by specifying the relationships among the objects and showing the robot how to choose from a set of data. It is also possible to endow the robot with primitive movements that resemble simple gestures (e.g., grasping an object and putting it somewhere, opening a door). These primitive movements provide a vocabulary of actions for the robot. In this case, the robot must learn to combine these actions properly to perform tasks that are more complex, for example, setting the table (Pardowitz, Knoop 2007) or serving drinks (Pardowitz, Dillmann 2007). The robot must learn to identify the state in which it is and what action is most appropriate. However, this approach has strong limitations because the robot can only learn to perform tasks that require only this primitive repertoire. The robot can learn how to order its primitive movements to perform tasks, but it cannot involve the other primitive movements that it knows. If these primitive movements become inadequate, the whole system can fail.

4.4. Learning of primitive movements

As a consequence of the limitations described above, it is important for robotic systems to develop learning capabilities (1) to learn primitive movements, such as grasping an object (Campbell 2006) or putting it in a box (Hersch 2008), and (2) to perform gestures by adapting to the environment. For example, the object and the robot can have different positions than they had during the learning phase. Using interpolation among the various examples, the problem can be solved if the examples are sufficiently numerous and are performed under different conditions. It is then possible to perform a movement in different situations (Campbell 2006, Steil 2004), using learning techniques such as Kohonen networking or sophisticated averaging. Another approach is to model a primitive movement as a dynamic system. This dynamic system is learned through the examples provided, and the attractor is the final position to be achieved, for example, the object position that must be grasped (Ijspeert 2002, Hersch 2008). The robot can imitate situations similar to the learning phase, such as the examples provided during the learning phase. However, when the situation changes significantly, for example, if one introduces a new obstacle into the gesture trajectory, the robot does not know how to react if it has not been programmed to solve this problem. Nevertheless, reinforcement learning (Guenter 2007) can resolve the task because it uses a strategy of trial and error.

4.5. Imitation as a way to communicate

Boucenna et al. (2010) investigated how robots learn to recognize facial expressions without having a teaching signal allowing them to associate facial expressions with given abstract labels (e.g., the name of the facial emotional expressions for 'sadness', 'happiness', etc.). They also developed a sensory motor architecture for the recognition of facial expressions. The robot can learn facial expressions if it produces these facial expressions, and the human imitates the robot's facial expression to facilitate the on-line learning. These authors showed, in their first series of robotics experiments, that a simple neural network model could control the robot's head, and it could learn online to recognize facial emotional expressions (the human partner imitated the robot's prototypical facial expressions). Imitation was used as a communication tool instead of a learning tool: the caregiver communicated with the robot through imitation. Moreover, the same architecture could be used to learn posture recognition (Boucenna 2012) and joint attention (Boucenna 2011) (see below).

Others studies have also proposed neural network architectures designed to exhibit learning and communication capabilities via imitation (Andry 2001, Andry 2002, A. de Rengervé 2010). An artificial system does not need to incorporate any other internal model to perform real-time and low-level imitations of human movements, despite the related correspondence problem between humans and robots. A simple sensory motor architecture can perform such tasks. These sensory motor architectures and this type of paradigm are interesting because robots are able to learn online and autonomously, which allows for the creation of real interaction between a human partner (e.g., a child) and a robot. In this case, the human partner communicates with the robot through imitation. In the context of MICHELANGELO, posture recognition, as developed by Boucenna (2012), will be tested as an experimental scenario. The first experiments were performed with human partners, and we want to use the same model in children with ASD.

5. Are robotic systems able to develop joint attention capabilities?

The field of robotics has also been interested in joint attention because it seems essential for social interaction and for building robots that can interact in social environments, as successfully implemented using the Baron-Cohen model (Baron Cohen, 1995) and a humanoid robot (Scassellati, 1998; Scassellati, 2001). According to Baron-Cohen, joint attention is based on two modules: (1) the intentionality detector (ID), which uses sensory modalities and can interpret the actions of other agents, for example, purpose, goal and desire, and (2) the eye-direction detector (EDD), which can detect the presence and gaze direction of other agents than itself. EDD allows the robot to infer that a person looks at an object if his/her gaze is directed toward that object. This model suggests that the mechanism of joint attention is based only on these two detectors. ID allows for the interpretation of gaze direction as a goal state and the interpretation of the gaze of others as intentions. This mechanism allows two agents to focus their attention on an object, agent or event.

More recently, other proposals have been made. The model developed by Yucel et al. (2009) implements an effective model, which integrates image-processing algorithms into a robust estimation of the head pose and an estimation of gaze direction. Other authors, such as Marin-Urias et al. (2009), Marin-Urias et al. (2008) and Sisbot et al. (2007) have focused on the capacity of shared attention in "mental rotation" and "perspective taking". These capabilities allow the humanoid robot HRP2 to acquire representations of the environment from other perspectives and to assimilate the concept of reason from the perspectives of others to obtain a representation of the knowledge of others. In other words, the HRP2 humanoid robot is able to direct its gaze toward an object that a human looks at, even if two objects are in the same field of view (one object obscuring another). The object of attention is visible to humans, whereas the robot has assimilated the other object, which is not visible to human.

Nagai et al. (2003) proposed a developmental model, which would allow a robot to acquire joint attention capability without the assessment of the task. This model showed how a robot can interpret the gaze direction of humans to focus on objects in the environment. This paper provided a constructive model, in which a robot acquired the ability of joint attention without any task evaluation from a human caregiver. Moreover, the robot attempted to reproduce the staged developmental process of infants' joint attention. The model consisted of the robot's embedded mechanisms: visual attention and learning with self-evaluation. The former was used to find and examine a salient object in the robot's view, and the latter was used to evaluate the success of visual attention and then to learn sensorimotor co-ordination. In summarizing the challenges of joint attention, Kaplan and Hafner (2004) attempted first to define this mechanism, as well as the unitary elements that constitute it. In line with Tomasello's views (Tomasello, 1995), Kaplan and Hafner (2004) argued that joint attention implies viewing the behavior of other agents as intentionally driven. In that sense, joint attention is much more than gaze following or simultaneous looking.

In the context of the MICHELANGELO project, it would be interesting to evaluate a joint attention task between a child and an adult and between a child and a robot. Doing so would allow us to analyze the child's behavior according to the agent (robot or adult) that interacts with him/her.

6. Robotics and children with autism

Since 2000, there have been an increasing number of clinical studies that have used robots with individuals with ASD. The robot can have two roles in the intervention: practice and reinforcement (Duquette 2008). There have been at least 2 reviews of the literature that have been conducted recently (Scacellati et al. 2012, Diehl et al., 2012). Here, we choose to follow the plan proposed by Diehl and colleagues, as it fits our main focus on imitation and joint attention better. Diehl et al. distinguished 4 different categories of studies. The first category assesses the responses of individuals with ASD, comparison human behavior to robots or robot-like behavior. The second category assesses the use of robots to elicit behaviors to be promoted with regard to ASD impairments. The third group of studies uses robotics systems or robots to model, teach and practice a skill, with the aim of enhancing this skill in the child. The last type of study uses robots to provide feedback on performance during therapeutic sessions or in more natural environments.

6.1. Responses to robots or robot-like characteristics

Although most of the research in this field has been based on short series or case reports, authors have insisted on the appealing effects of robots on individuals with ASD. If we assume that individuals with ASD prefer robots or robot-like characteristics to human characteristics or non-robotic objects, we might wonder why individuals with ASD prefer robots, as well as what is particularly appealing about these characteristics. Pioggia et al. (2005) compared one child with ASD to a child typically developing control over his/her behavioral and physiological responses to a robotic face. The child with ASD did not have an increase in heart rate in response to the robotic face. This response implies that the robotic face did not alarm the child. However, at first, he/she did not show any interest in the robot. In contrast, the control children spontaneously observed the robot with attention and expressed positive reactions to it. However, when the robot's facial movements increased, the children became uncomfortable and exhibited an increased heart rate. In a case series, Pioggia et al. (2008) showed in ASD varying responses to the robotic face in comparison to human interaction. They found that most individuals with ASD showed an increase in social communication, some showed no change, and one showed a decrease when he interacted with the robotic face.

Feil-Seifer et al. (2011) showed that, in a group of eight children with ASD, there was tremendous variability in the valence of affective response toward a mobile robot, depending on whether the robot's behavior was contingent on the participant or whether it was random. In this study, the robot could automatically distinguish between positive and negative reactions of children with ASD to it. Individual affective responses to the robots were indeed highly variable. Some studies (Dautenhahn 2004, Robins 2006) have shown that for some children with ASD, there is a preference for interacting with robots compared to non-robotic toys or human partners. However, Dautenhahn (2004) found individual differences regarding whether children with ASD preferred robots to non-robotic toys. Two of the four participants exhibited more eye gazes toward the robot and more physical contact with the robot than with a toy.

Other studies have investigated movements. Bird et al. (2007) found a speed advantage in adults with ASD when imitating robotic hand movements, compared to human hand movements. In the same vein, Pierno et al. (2008) reported that children with ASD made significantly faster movements to grasp a ball when they observed a robotic arm perform the movement compared to when they viewed a human arm. In contrast, typically developing children showed the opposite effect. Therefore, these 2 studies suggest increased imitation speed with robot models compared to human models (Bird 2007, Pierno 2008).

Additionally, some studies have investigated the responses of children with ASD when exposed to emotional stimuli. Nadel et al. (2006) and Simon et al. (2007) explored the responses of 3- and 5-year-old children to emotional expressions produced by a robot or a human actor. Two types of responses were considered: automatic facial movements produced by the children facing the emotional expressions (emotional resonance) and verbal naming of the emotions expressed (emotion recognition). Both studies concluded that an overall increase in performance occurred with age, as well as easier recognition of human expressions (Nadel et al. 2006, Simon et al. 2007). This result is encouraging in a remediation perspective, in which an expressive robot could help children with autism express their emotions without human face-to-face interaction. Finally, Chaminade et al. (2012) investigated the neural bases of social interactions with a human or with a humanoid robot using fMRI and compared male controls (N=18, mean age=21.5 years) to paients with high functioning autism (N=12, mean age=21 years). Results showed that in terms of activation interacting with a human was more engaging than interacting with an artificial agent. Areas involved in social interactions in the posterior temporal sulcus were activated when controls, but not subjects with high-functioning autism, interacted with a human fellow.

6.2. Robots used to elicit behavior

Some theoretical works have highlighted several potential uses of robots for diagnostic purposes (Scassellati 2007; Tapus 2007). For example, a robot could provide a set of social cues designed to elicit social responses, for which the presence, absence, or quality of response is helpful during diagnostic assessment. In Feil-Seifer (2009), a robot could be programmed to take the role of a bubble gun. The robot produced bubbles to elicit an interaction between the child and the examiner. Additionally, the robot could act as a sensor and provide measurements of targeted behaviors (Scassellati 2007, Tapus 2007). These measurements could be used to diagnose disorders and to assess the severity of these disorders in one or several dimensions. The robots could record behaviors and translate social behaviors into quantitative measurements. Additionally, interaction between robots and children was used to elicit and analyze perseverative speech in one individual with high-functioning ASD (Stribling 2009). Interaction samples have been collected in previous studies in which children interacted with a robot that imitated the children's behavior. Here, robot-child interaction was used to collect samples of perseverative speech to conduct conversational analysis on the interchanges. This study suggested that robot-child interactions might be useful in eliciting characteristic behaviors, such as perseverative speech.

Finally, robots can be used to elicit prosocial behaviors. Robots can provide interesting visual displays or respond to a child's behavior in the context of a therapeutic interaction. Consequently, a robot could encourage a desirable or prosocial behavior (Dautenhahn 2003, Feil-Seifer 2009). For example, a robot's behavior could be used to elicit joint attention: first, a robot could be the object of shared attention (Dautenhahn 2003), or a robot could provoke joint attention by looking at a different object in the same visual scene as the child and "asking" the child with ASD to follow its gaze or head direction. In another study, De Silva et al. (2009) showed that individuals with ASD were able to follow social referencing behaviors performed by a robot. This study showed that social referencing is possible, but the results were not quantitative. Other studies (Robins 2005, François 2009) have tried to elicit prosocial behavior, such as joint attention and imitation. However, the results were not sufficiently robust because of the small number of children with ASD enrolled in these studies. Finally, several studies have aimed to assess whether interaction between a child with ASD and a robot, along with a third interlocutor, can elicit prosocial behaviors (Costa 2010, Kozima 2007, Wainer 2010). Unfortunately, no conclusions could be made due to limitations related to small sample sizes and the significant individual variation in responses to the robot.

6.3. Robots used to model, teach or practice a skill

Here, the theoretical point of view is to create an environment in which a robot can model specific behaviors for a child (Dautenhahn 2003) or the child can practice specific skills with the robot (Scassellati speaks out ‘‘social crutch’’, Scassellati 2007). The aim is to teach a skill that the child can imitate or learn and eventually transfer to interactions with humans. In this case, the robot is used to simplify and facilitate social interaction. The objective of Duquette (Duquette et al. 2008) was to explore whether a mobile robot toy could facilitate reciprocal social interaction, in case in which the robot was more predictable, attractive and simple. The exploratory experimental set-up presented two pairs of children with autism: a pair interacting with the robot and another pair interacting with the experimenter. The results showed that imitations of body movements and actions were more numerous in the children interacting with the human, compared to the children interacting with the robot. In contrast, the two children interacting with the robot had better shared attention (eye contact, physical proximity) and were able to mimic facial expressions better than the children interacting with a human partner were able to mimic. Fujimoto et al. (2011) used techniques for mimicking and evaluating human motions in real time using a therapeutic humanoid robot, to improve the imitation skill of children with autism. Practical experiments have been performed to test the interaction of children with autism with robots and to evaluate the possibility of improving these children’s imitation skills by training them, using robots, to perform specific tasks.

6.4 Robots used to provide feedback and encouragement

Robots can also be used to provide feedback and encouragement during a skill learning intervention because individuals with ASD might prefer the use of a robot rather to a human to teach skills. Robots can have human-like characteristics, for example, mimicking human sounds or more complex behaviors. The social capabilities of robots could improve the behavior of individuals with ASD *vis-à-vis* the social world. The robot could also take on the role of a social mediator in social exchanges between children with ASD and partners because robots can provide feedback and encouragement (Dautenhahn 2003). In this approach, the robot would encourage a child with ASD to interact with an interlocutor. The robot would provide instruction for the child to interact with a human therapist and encourage the child to proceed with the interaction. However, this approach is only a theoretical perspective, as no studies have yet been conducted.

However, some attempts have been made. Duquette et al. (2008) used a reward as the result of a robot behavior, for example, if a child was successful in imitating a behavior. The robot provided positive reinforcement by raising its arms and saying, “Happy”. In the same vein, it would also be interesting if the robot could respond to internal stimuli from the child. For example, the stimuli generally used in biofeedback (e.g., pulse, respiratory frequency) could be used as indicators of the affective state or arousal level of the child to increase the individualized nature of the treatment (Picard 2010). This capability could be useful for providing children with feedback regarding their own emotional states or to trigger an automatic redirection response when a child becomes disinterested (Liu 2008).

7. ICT and ASD in the MICHELANGELO project

Some authors (e.g., Ricks & Colton, 2010) have highlighted the anecdotal results of introducing robots into experiments with individuals with ASD. In particular, they have wondered why the question of what the best way is to integrate robots into therapy sessions has not been asked. For this reason, they have remained very critical toward the results obtained in the field of robotics and ASD. However, as an emerging field, there are several open questions that must be addressed for better research quality. What are the best roles for robots in therapy? How could we best integrate robots into interventions? Additionally, among individuals with ASD, who is best suited for this approach? These questions are some of the challenges the MICHELANGELO project will face. Taking into account the recent advances in early developmental approaches, we believe that focusing on two skills, such as imitation and joint attention, will have an important clinical impact as (1) they belong to the agenda of the intervention program that has received the best evidence in young children with ASD (Dawson and Rogers, 2002) and (2) both skills have already shown promising results in the field of social signal processing. We also suggest addressing the issues of interpersonal synchrony and multimodal integration during interaction as they appear to be key issues in applying ICT in children with ASD. We believe that the state of the art in social robotics should allow researchers, guided by multidisciplinary approaches, to develop new experimental settings that are able to integrate interactions between children with ASD and robots, with the aim of analyzing children’s behaviors. We believe that the robotic scenario is an excellent way to elicit behaviors by interacting with the child and, in return, analyzing the child’s behavior and adapting to it. In such as case, introducing robots into therapy would be of greater clinical interest. In the MICHELANGELO project, we want to design a situation of mimicry between children with ASD and robots. The experimental paradigm would be an imitation game between the child and the robot, during which we can analyze the behavior of the child. In this experiment, we would ask children to imitate the robot’s postures for 1 min, and then the roles would be reversed, and the robot would imitate the child’s postures. As a result of such an experience, it would be interesting to analyze children’s reactions and to develop metrics that can be used to quantify child-caregiver interaction in the home.

SECTION 3: CONCLUSION

The MICHELANGELO project is intended to provide children with ASD with individualized and personalized support within a natural environment. We have chosen to use the method of the early start Denver model (ESDM) of Geraldine Dawson and Sally Rogers and to focus on young children (<6 years old), as the younger the child is, the higher brain plasticity is, and the better the treatment outcome should be.

The ESDM is an assessment that allows for the creation of an individualized education plan. After training and regular support of the family, the educational program can also be applied also at home, in the natural environment of the child. This program offers the advantage of being regularly reassessed and adjusted to the child's abilities. The ESDM is a comprehensive educational program, but under MICHELANGELO, we will focus our training on the capacity of the child to improve his/her imitation and joint attention skills. Joint attention, as well as imitation, is among the premises for learning communication, which is considered to be one major diagnostic criterion for autism.

Moreover, an emerging field of research has been introducing robots into therapy. In this case, there are several open questions that must be addressed for better research quality. What are the best roles for robots in therapy? How can we best integrate robots into interventions? In addition, who among individuals with ASD is best suited for this approach? These questions are among the challenges of the MICHELANGELO project. Again, we will focus on two skills (imitation and joint attention) because: (1) they belong to the agenda of the intervention program that has provided the best evidence in young children with ASD; and (2) both skills have already received promising approaches in the field of social signal processing. We also choose to address the issues of interpersonal synchrony and multimodal integration during interaction, as they appear to be key issues in applying ICT in children with ASD. Indeed, interpersonal synchrony has recently been the focus of specific research in neuroscience, showing that cerebral and physiological markers exist (Dumas et al. 2011; Omri et al. 2012).

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