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Human-Robot Interaction in Autism: FACE, an Android-based Social Therapy

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Abstract*— In human-machine social interaction, the intersection between biology and engineering needs a context which allows for the development of adapting dynamics. The android FACE is able to interact with the external environment, interpreting and conveying emotions through non verbal communication. FACE captures expressive and psychophysical correlates from its interlocutor and actuates behaviours following two communicative modalities of semeiology. FACE interacts with kinesics, non verbal communication conveyed by body part movements, or facial expressions, and so on, taking into account the proxemic space. FACE's goal is define and test a therapeutic protocol for autism in order to enhance social and emotive abilities in people with autism. Data regarding our latest clinical study are reported. The clinical study was aimed at verifying FACE's capabilities in enhancing imitative skills and shared attention in subjects with autism. In particular, we monitored their attention towards FACE and then we checked if the android remains a restricted and repetitive interest or an object to share with the therapist. The study involved an experimental group, composed of 4 children with autism. The participants were diagnosed using ADI-R and ADOS-G, two specific diagnostic instruments. The experimental set up consisted of a specially equipped room provided with two remotely orientable cameras in which the subject, under the supervision of a therapist, can interact with FACE. During twenty minutes sessions, we observed both spontaneous behavior of the participants and their reactions to therapists presses in correlation with the time course of the physiological and behavioural data. The participants showed a spontaneous ability of imitation of the head and facial movements of the android. Moreover we observed that the children with autism focused their attention towards FACE's eye movements following verbal suggestions from the therapist.

I. Introduction

Autistic Spectrum Disorders (ASD) refer to a wide continuum of associated cognitive and neuro-behavioral disorders, including, but not limited to, three core-defining features: impairments in socialization, impairments in verbal and non-verbal communication, and restricted and repetitive patterns of behaviors. Although autism was first described over 50 years ago, our improved comprehension of this complex disorder has emerged over the past two decades. Despite recent intense focus on autism, our understanding continues to be an art and science in fast evolution. There is marked variability in the severity of symptomatology across patients, and level of intellectual function can range from profound mental retardation through the superior range on conventional IQ tests. In ASD we can find: impairment in the use of multiple nonverbal behavior, such as eye-to-eye gaze, facial expression, body posture, and gestures to regulate social interaction. The communication impairments seen in the autistic spectrum are far more complex than presumed by simple speech delay and share some similarities with the deficits seen in children with developmental language disorders or specific language impairments. Young autistic children, even if verbal, almost universally have comprehension deficits, in particular deficits in understanding higher order complex questions. Deficits in pragmatics, the use of language to communicate effectively, are almost universally present too. Another core characteristic of ASD is the presence of stereotyped behaviors and circumscribed/unusual interests, that encompass qualitative deficits in several behaviors. It is moreover well documented that individuals with autism have impairments in processing of social and emotional information, as evident in tasks assessing face and emotion recognition, imitation of body movements, interpretation and use of gestures and theory of mind [1], [2], [3], [4]. Typically developing infants show preferential attention to social rather than inanimate stimuli; in contrast, individuals with autism seem to lack these early social predispositions [5], [6]. This hypothesis was recently substantiated in a neurofunctional study [7] of face perception in autism, in which adequate task performance was accompanied by abnormal ventral temporal cortical activities, which in turn suggested that participants had treated faces as objects. Klin et al. [8] created an experimental paradigm to measure social functioning in natural situations, in which they used eye-tracking technology to measure visual fixations of cognitively able individuals with autism. When viewing naturalistic social situations, people with autism demonstrate abnormal patterns of social visual pursuit consistent with reduced salience of eyes and increased salience of mouth, bodies and objects. In addition, individuals with autism use atypical strategies when performing such tasks, relying on individual pieces of the face rather than on the overall configuration. Alongside these perceptual anomalies, individuals with autism have deficits in conceiving other peoples mental states [9], or "mindblindness". The cognitive theory of mindblindness [10] suggests that individuals with autism have difficulty in conceiving of people as mental agents, and this, as well as the other observations described, has led to the development of several therapeutic approaches based social interaction and emotional

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expression. Recent studies have shown that individuals, particularly those with high functioning autism, can learn to cope with common social situations if they are made to enact possible scenarios they may encounter. By recalling appropriate modes of behavior and expressions in specific situations, they are able to react appropriately. There are now a number of highly structured therapeutic approaches based on emotion recognition and social skill training using photographs, drawings, videos or DVD-ROMs (for example Mind Reading, produced by Human Emotions, UK). Currently, these treatment approaches suggested the use of robotic systems in order to encourage children with autism to take initiative and to interact with the robotic tools.

The use of the robotic technology aimed to help autistic subjects in the everyday life began in 1976 with the work of Sylvia Weir and Ricky Emanuel [11]. They used a mobile turtle-like robot, LOGO, able to interact with a patient within a highly structured environment. More recently François Michaud [12], [13] and his research team at the University of Sherbrooke, investigated the use of mobile robot as a treatment tool. They tested several robots, different in shape, color and behavior, in order to study the characteristic that mainly may capture the attention of people with autism. They obtained important insights for the comprehension of the human-robot interaction in autism sustaining the robot hypothesis as useful. People with autism focus their attention on single details, but the interaction with a robot may allow an autistic subject to concentrate herself/himself on the limited number of communication modalities of the robot. In addition, while the stress of the learning with a teacher can be excessive, the interaction with a robot, which often the young patients associate with media and/or cinema characters, can reduce the pressure allowing the child to learn better from the environment.

A more structured approach to the use of autonomous robots is AURORA (AUtonomous RObotic platform as a Remedial tool for children with Autism) [14], [15]. AURORA represents the first systematic study on robot therapy in autism. People with autism are invited to interact in coordinated and synchronized social actions with the robots and the environment. In AURORA, behavior-based architectures for the use of different robotic platforms such as mobile and humanoid robots (Robota developed by Aude Billard [16]) were developed.

Recently the development of emotional cognitive architectures allowed the interaction to be based on empathy, e.g. the KISMET [17] project developed by Cynthia Breazeal at the Robotic Life Group of MIT Media Lab, INFANOID or KEEPON [18], [19] developed by Hideki Kozima at the National Institute of Information and Communications Technology (NICT) of Japan. INFANOID is an upper-torso child-like robot, capable of pointing, grasping, and of expressing a variety of gestures, while KEEPON is a simple yellow snowman equipped with both eye-contact and joint attention functions.

FACE (Facial Automaton for Conveying Emotions) [20], [21] follows a biomimetic approach. In FACE the biological behaviour is mimicked by means of dedicated smart soft materials and structures, and the control strategy, algorithms and artificial neural networks are inspired by nature. It is an innovative android-based treatment which focuses on core aspects of the autistic disorder, namely social attention and the recognition of emotional expressions. FACE is a social believable artifact able to interact with the external environment, interpreting and conveying emotions through non verbal communication. Expressive and psychophysical correlates are captured from an interlocutor to actuate behaviours with kinesics, a non verbal communication conveyed by body part movements and facial expressions. In the framework of a social therapy FACE can act as an interface between a patient and a trained therapist in a specially equipped room. FACE allows the real-time acquisition of both physiological and behavioural information by means of an unobtrusive sensorized wearable interface from a patient during the treatment. This approach is close to an environment that people with autism could consider to be social, helping them to accept the human interlocutor and to learn through imitation. On the basis of a dedicated therapeutic protocol FACE is able to engage in a social interaction by modifying its behaviour in response to the patient's behaviour. Following an imitation-based learning strategy, we hope to verify if such a system can help children with autism to learn, interpret and use emotional information. Moreover, our aim is to determine if such learned skills may be extended to a social context.

II. Social interaction and communication

Since the first days of our life we are social beings. Children meet people's gaze, turn towards a voice, catch mom or dad's fingers and smile, but children affected by ASD show difficulties in taking part in such daily social interaction and communication with others. Children affected by ASD have impairment in the use of multiple nonverbal behaviors, such as eye-to-eye gaze, facial expression, body posture, and gestures. Young autistic children, even if verbal, almost universally have comprehension and language communication deficits, i.e. the use of language to effectively communicate. The presence of stereotyped behaviors and circumscribed interests can be also underlined. Meltzoff argued that an underdevelopment of the social communication can be explained in terms of imitation impairment [22]. Children usually imitate the behaviour of an interlocutor; children with autism do not, causing serious consequences. Early imitation is one of the most important instruments for the social learning, and innate to humans [23]. An essential prerequisite for imitation is a connection between the sensory systems and the motor systems such that percepts can be mapped onto appropriate actions. This mapping is a difficult computational process as visual perception takes place in a different coordinate frame to motor control. This process is also more complex than pure object recognition since it requires integration of multiple objects (i.e., several limbs), their spatial relations, their relative and absolute movements, and even the intention of these movements.

The possible connection to imitation, however, came with the discovery of the mirror neurons [23], a new class of visuomotor neurons recently discovered in the monkey's premotor cortex (F5 area). These neurons respond both when a particular action is performed by the recorded monkey and when the same action, performed by another individual, is observed [24]. From imaging and transcranial magnetic stimulation studies, there are also several pieces of evidence to show that a similar mirror system exists in humans [25], [26], [27]. Surprisingly, this system seems to involve the Brocas area [28], a brain region normally associated with speech production. The possible homology of F5 in monkeys and the Brocas area in humans led some authors [28] to speculate that the ability to imitate actions and to understand them could have subserved the development of communication skills. This idea is consistent with Meltzoff and Moores' [29] works and interpretations. Gallese and Goldman [30] rather suggest that mirror neurons participate in mind reading, a process accomplished by using ones own mental apparatus to predict the psychological state of others through mental simulations.

Rizzolatti pointed out the process of imitation places a crucial role in distinguishing between actions arising from within or actions induced by others [23]. Imitation paves the way to the comprehension of the intentions of others establishing a reciprocal non verbal communication process in which the roles of imitator and model are continuously exchanged [31], [32]. Moreover, in the early years, imitation plays a fundamental role for the emergence of the proprioception, of the perception of the external world and of the ability to act out our own actions. Enhancing the imitation skills of children through specifically designed treatments based on imitation may yield to an improvement in social development. Recently it has been proposed that the characteristic impairments of ASD, including deficits in imitation, theory of mind and social communication, can be caused by a dysfunction of the mirror neuron system [33].

However, what strategy can be used to control and enhance the emergence of human-android imitation? As a first step, our idea was the realization of a neural structure capable of creating its own representations of the surrounding environment. It is an associative memory through which it may be possible to navigate within a behavioural space. These characteristics are typical of some areas of the central nervous system like the hippocampus, upon which the architecture for the neurocontroller of FACE is based. The current hippocampus models make use of a preformed topology of artificial neurons with varying levels of complexity, like Integrate And Fire or Leabra [34], interconnected between themselves, whose learning process depends on parameters linked to the epochs of presentation of the training set. This method creates a dichotomy between learning and acting, with different times and procedures which impede a continuous learning process. This led us to abandon the idea of realising a neurocontroller based solely on a group of neurons in various states of connection. Furthermore, preformism impedes the topological and geometrical structure from developing in an adaptive manner. As a first approach, we used the model developed by Izhikevich [35] and a learning model based on the Theory of Neuronal Group Selection (TNGS) of G. Edelman [36].

The learning process in FACE is based on imitating predefined stereotypical behaviours which can be represented in terms of FAPs (Fixed Action Patterns) followed by a continuous interaction with its environment. FAPs can be classified as belonging to action schemes, partly fixed on the basis of physical constraints and sensory-motor reflexes, partly subjected to specialization on the basis of experience. FACE is therefore able to continually learn, to adapt and evolve within a simplified behavioural space as a function of the environment and to maintain spontaneous activity open to any innovative and intelligible behaviours arising which may then be interpreted.

The realisation of a social interactive machine entails critical requirements for the body, the sensory perception system, the mobility and the ability to perform tasks. The human mind responds and modifies itself with respect to the real world making the body able to perceive, to act and to survive; human intelligence primarily rises from the interpretation of body needs. For this reason we preferred to follow a mind-body monism, i.e. an embodied mind able to perform the elaboration processes taking into account the domain of experiences where the machine is placed; such processes influence and are influenced by its own presence.

Dynamic interaction mechanisms are needed in order to place the android inside its environment: FACE is provided with extrinsic perception in order to interiorize the external world and to be able to suitably react. FACE possesses body structures as a support to the intrinsic perception (proprioception) and motor activity. The rising of a relationship domain close to a human context underlies the need of a high degree of believability in the FACE robot. FACE possesses a time-space capability for both egocentricity and allocentricity, taking into account the actuation of preprogrammed behaviours as well as an imitative learning strategy.

III. FACE

FACE consists of a passive articulated body equipped with a believable facial display system based on biomimetic engineering principles. The latest prototype of the FACE robot is shown in figure 1. FACE's head consists of an artificial skull covered by an artificial skin which is a thin silicone-based mask equipped with sensory and actuating system. It is fabricated by means of life-casting techniques and aesthetically represents a copy of the head of a subject, both in shape and texture. FACE can express and modulate the six basic emotions (happiness, sadness, surprise, anger, disgust, fear) in a repeatable and flexible way via an artificial muscular architecture and servomotors. This process can be controlled thanks to an artificial skin consisting of a 3D latex foam equipped with a biomimetic system of proprioceptive mapping. The sensing layer responds to simultaneous deformations in different directions by means of a piezoresistive network which consists of a carbon rubber mixture screen printed onto a cotton lycra fabric. These sensors are elastic and do not modify the mechanical behaviour of the fabric [20]. This structure allows the expression required to be achieved by means of a trial and error process. The artificial skin covers an artificial skull which is equipped with an actuating system.

Fig. 1. The latest prototype of FACE

Real-time acquisition of both physiological and behavioural information from the subject is obtained by means of an unobtrusive sensorized wearable interface. FACE is able to analyse the emotional reactions of individuals through optical analyses of facial expressions, and to track a human face over time and to automatically store all data. FACE's eyes are realised using animatronic techniques and their expressiveness is achieved through an artificial muscular structure surrounding the orbital region. It sees differently from man, using stereoscopic vision over frequency rather than over space. A three-dimensional contouring apparatus, equipped with a section for data analysis, rebuilds an internal representation of a portion of the world before it. Currently FACE surveys the curvature of the three dimensional scene once per second. We adopted a neural approach to allow FACE to recognize the expression of a subject. A dedicated process detects a number of points (markers), which are used to divide the human face into four main areas (left eye, right eye, nose and mouth). The data of each area are processed by a hierarchical neural-network architecture based on Kohonen self organizing maps and a multi-layer perceptron.

IV. Biomimetic proprioception

A sensing layer underlies the 3D latex foam to form an artificial sensing skin. The sensing layer responds to simultaneous deformations in different directions by means of a piezoresistive network which consists of a Conductive Elastomers (CEs) composites rubber screen printed onto a cotton lycra fabric. CE composites show piezoresistive properties when a deformation is applied and can be easily integrated into fabric or other flexible substrate to be employed as strain sensors. They are elastic and do not modify the mechanical behaviour of the fabric. CEs consist in a mixture containing graphite and silicon rubber. In the production process of sensing fabrics, a solution of CE and trichloroethylene is smeared on a lycra substrate previously covered by an adhesive mask. The mask is designed according to the desired topology of the sensor network and cut by a laser milling machine. After the deposition, the cross-linking process of the mixture is obtained at a temperature of 130°C. Furthermore, by using this technology, both sensors and interconnection wires can be smeared by using the same material in a single printing and manufacturing process.

From the technical viewpoint, a piezoresistive sensing fabric is a system whose local resistivity is a function of the local strain. In a discrete way, it can be thought of as a two dimensional resistive network where single resistors have a non-linear characteristic that depends on the local strain. The integral impedance pattern is a function of the overall shape of the sensorized fabric and allows mapping between the electrical space and the shape space. For the characterisation of the sensors in terms of their quasi-static and dynamic electromechanical transduction properties sensors were serially connected. In this case, a current is superimposed in the circuit and high impedance differential voltages are acquired from each sensor. Two multiplexers allow a sensor to be selected and the relative signal is acquired by a differential amplifier. A microprocessor drives the whole system, performs the analogous/digital conversion and exchanges data via USB interface. The device is provided with an automatic calibration subsystem which allows gain and offset to be tailored to each sensor.

V. The neural network for the classification of the behavior of the interlocutor

A powerful neural network approach to codify the behavior of the interlocutor and to interactively adapt FACE to the patients reactions was adopted. The complexity of a biological neuron may be reduced by using several mathematical models. Each of these reproduces some of the functionalities of real neurons, such as the excitability in response to a specific input signal. E. Izhikevich [35] recently developed a simple model for an artificial neuron which is able to reproduce almost all the functionalities of biological neurons. The model takes 13 FLOPs to simulate one millisecond of neuron activity and it is based on a top-down approach, using two differential equations with four parameters. The computation efficiency and the introduction of axonal delays show the possibility of creating a neural network able to perform real-time classification and prediction tasks. In this work the Spike-Timing-Dependant Plasticity (STDP) rule [37], which permits the implementation of a real time learning rule based on signals which continuously flow, has been adopted according to the TNGS on selection as the basis for the learning process [36].

The TNGS suggests a novel way for understanding and simulating neural networks. The time variable is taken into account in the learning task, so that neural groups may raise from a selection process. The correspondence between synaptic weights and axonal delays exists as a result of the neuron behavior. One neuron can belong to many groups, and the number of groups is usually higher than the number of the neurons in the map. This guarantees a memory capability which is higher than the capability reached by classical artificial neural networks. The classical approach in artificial neural networks simulation takes into account the modulation of the action potential rhythm as the only parameter for the information flowing to and from each neuron. Such a strategy seems to be in contrast with novel experimental results, since neurons are able to generate action potentials which are based on the input spike timings, with a precision of one millisecond. The spike-timing synchrony is a natural effect that permits a neuron to be activated in correspondence of synchronous input spikes, while the neuronal activation of the post-synaptic neuron is negligible if pre-synaptic spikes arrive asynchronously to the target neuron. Axonal delays usually lie in the range [0.1 - 44] milliseconds, depending on the type and location of the neuron inside the network. Such a property becomes an important feature for the selection of the neural groups. The selection of neural groups is the result of the variation of synaptic connection according to STDP rule. If a spike coming from an excitatory pre-synaptic neuron causes the fire of the post-synaptic neuron, the synaptic connection if reinforced since it given the possibility to generate another spike in order to propagate the signal. Otherwise the synaptic connection is weakened. The values of the STDP parameters are chosen in order to permit a weakening that is grater than the reinforcement. Such a strategy permits the progressive removal of the unnecessary connections and the persistence of the connections between correlated neurons.

The network design is inspired by the anatomical structure found in the mammalian cortex. With respect to the total number (N) of neurons, a percentage equal to 80% consists of excitatory neurons, while the remaining 20% are inhibitory neurons. Cortical pyramidal neurons showing a regular spiking behaviour have been adopted for the excitatory subsection, which correspond to appropriate values for the Izhikevich neuron model. Inhibitory neurons have been simulated adopting the model of the cortical interneurons which exhibits fast spiking properties. Each neuron is connected to M different neurons in order to obtain a connection probability (M/N) equal to 0.1, but inhibitory neurons are connected only to excitatory neurons. Moreover, the synaptic weights of the connections arising from the inhibitory neurons remain unchanged during the learning process, while those regarding the connections from the excitatory neurons change according to the STDP rule. Axonal delays are fixed in the range between 1 millisecond and 20 milliseconds. The time resolution has been set to 1 millisecond. The training phase has been carried out for more than 8 hours.

As the application starts, all the connections have the same synaptic weight. The network needs many seconds to get stabilised through depression and strengthening of the synaptic weights. During this first phase, the network shows the presence of a high amplitude rhythm, with frequency in the range between 2 Hz and 4 Hz (delta waves).

After a few hours of network activity the spiking rhythm becomes uncorrelated and frequency in the range between 30 Hz and 70 Hz appear (gamma waves). The appearance of such rhythms is called PING (Pyramidal-Interneuron Network Gamma) and it seems to be related to the spikes of the pyramidal cells which excite the inhibitory interneurons. Such interaction allows a mutual inhibition which temporarily switches-off the network activity. As the network becomes stable, the oscillation rhythm is assessed in the frequency range between 2 Hz and 7 Hz and the training phase is ended. It can be noticed the presence of a large number of neural groups, each of them able to perform a reproducible spike sequence with a precision of one millisecond. The test phase consists in recording neural groups activity in response to predefined FAPs. A labeling procedure allows association of a specific FAP to a neural group. Each FAP is able to select one group inside the network, showing that the network is able to perform classification tasks. Such classification is realised by a memory capability which is far greater than the number of entities involved in the network.

In our opinion, the current neural models do not include the role of glia cells and in particular those of the astrocytes which play a fundamental role in modulating synaptic communication. As has been recently demonstrated, the glia modulates neural signalling through a two-dimensional continuum in which calcium ion waves influence synaptic transmission. The glia are the centre of spontaneous activity induced by the continuous rhythm of the oscillations of ions at specific frequencies which influence the coordination and control of neural cells. The complex and dense branching which extends from each astrocyte defines a three-dimensional space, thereby defining an anatomical domain of influence. It is our intention to consider the group of the domains of influence as a single continuous domain, as first suggested by Beurle [38]. The FACE neurocontroller is made up of groups of neuro-entities placed inside a continuous volume of connected astrocyte cells within an epigenetic topology.

VI. Experimental set-up

The experimental set-up is shown in figure 2. It consists of a specially equipped room, provided with two remotely orientable video cameras, in which the child, under the supervision of a therapist, can interact with FACE through an interactive software by means of a liquid crystal screen and a keyboard or mouse. Both FACE and the interactive module are connected to a computer. The subject wears an unobtrusive system for recording physiological data. The database also contains data from the audio visual recording system present in the room. Other therapists or Hidden Observers compile evaluation sheets during sessions, and the data scanned from these will also be added to the database and used for successive analysis.

PDD	CA	PIQ
S1	10y6m	105
S2	9y6m	87
S3	8y11m	85
S4	20y6m	52

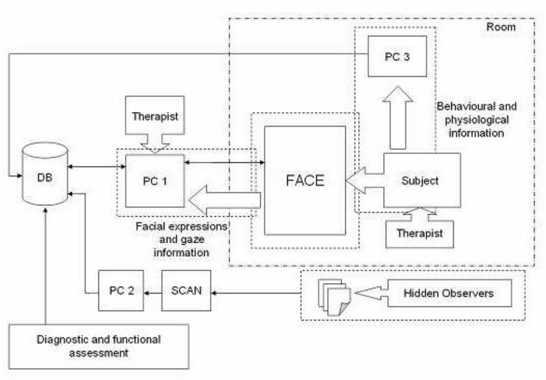

Fig. 2. Experimental set-up

In order to obtain a preliminary evaluation of the behavior of children affected by ASD when exposed to FACE, we set up an experimental session in which the reactions of 4 subjects (3 male and 1 female), between 7 and 20 years old, were monitored and compared. The children with autism had been diagnosed using ADI-R and ADOS-G, two specific diagnostic instruments, as high functioning autism, and are currently under treatment at the Stella Maris Institute (IRCCS) of the University of Pisa, Italy.

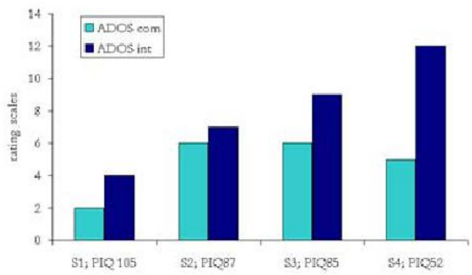

Fig. 3. Autism rating scale for the selected subjects

Experiments were carried out in order to study the interaction with FACE during twenty minutes sessions. We studied:

- both spontaneous behavior of the participants and their reactions to therapist presses in correlation with the time course of the physiological and behavioural data
- the focusing of the attention towards FACE's eye movements
- the spontaneous ability of imitation of gesture and expressions of the android

The evaluation of the treatment was performed by means of the CARS scale (Childood Autism Rating Scales). The CARS was developed in order to aid in the diagnostic process but it is also used to assess changes in autistic symptomatology at two/three years, at one year and at 6 months intervals. More recently it has been used also in shorter longitudinal studies. The CARS scale is subdivided in 15 items, relative to the main behavioural areas; it is assigned a variable score from 1 to 4 to every item; the score 1 indicates a behavior appropriated to the age, while a score 4 indicates an abnormal behavior. The CARS scale can not be one-dimensional: the total score obtained after the CARS test has an undeniable diagnostic and clinical usefulness. By analysing the score of the single items of the test it is however possible to characterize other patient behaviors.

Figures 4, 5, 6 and 7 supply a graphical comparison between the score obtained in items of CARS scale in previous interactions during psychological treatments and the one obtained with FACE. In particular, we observed that the CARS score decreased or remained the same for all items as regards subjects 2 and 3 after the therapy session. Only subject 4 (the oldest, with lowest IQ and highest ADOS rating) showed an increase of 0.5 points for listening, fear and verbal communication. More importantly, all the subjects demonstrated a decrease in the score of emotional response in the CARS scale of between 1 and 0.5 points, and imitation in 3 out of 4 children, so implying a marked improvement in these areas after interacting with FACE. Even though these are the first set of clinical trials, it is clear that the presence of FACE in a therapeutic environment can lead to improvements in the areas of social communication and imitation. Autistic persons often have difficulty in adequately expressing their feelings, so physiological correlates are useful indicators for estimating emotional states. In these preliminary experimental trials we therefore gave the subject a sensorized t-shirt to wear (http://www.smartex.it), which automatically recorded the cardiac frequency during the experiments. The dataset could be increased by adding sensors for skin temperature or ECG electrodes. As shown in figure 8, the cardiac frequency of the patient increases after his attention is focused on the robot, and remain fairly high till he is forced to focus on his emotional relationship with FACE. A more in-depth analysis of the data is currently being undertaken.

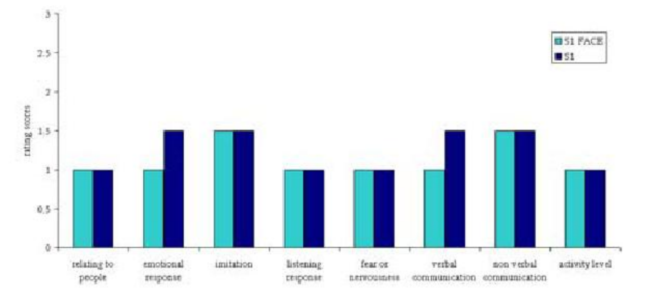

Fig. 4. Subject 1 - S1 FACE: score CARS obtained from the experimental session with FACE. S1: score CARS obtained from the observation of session with psychological tests

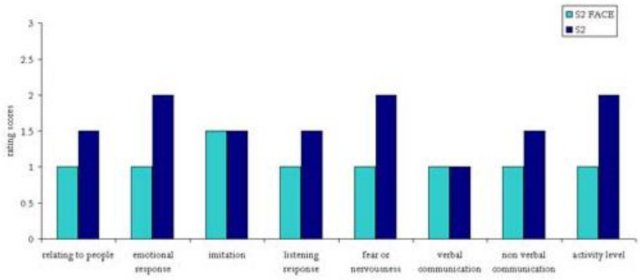

Fig. 5. Subject 2 - S2 FACE: score CARS obtained from the experimental session with FACE. S2: score CARS obtained from the observation of session with psychological tests

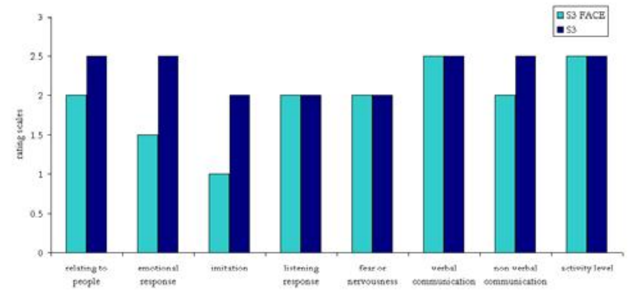

Fig. 6. Subject 3 - S3 FACE: score CARS obtained from the experimental session with FACE. S3: score CARS obtained from the observation of session with psychological tests

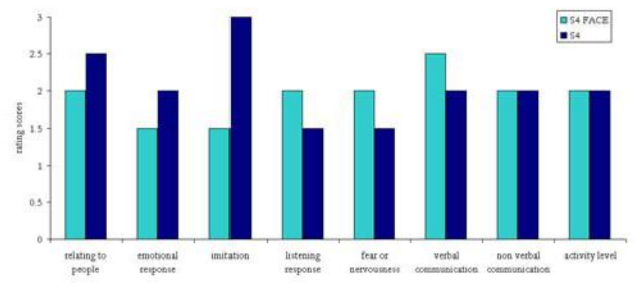

Fig. 7. Subject 4 - S4 FACE: score CARS obtained from the experimental session with FACE. S4: score CARS obtained from the observation of session with psychological tests

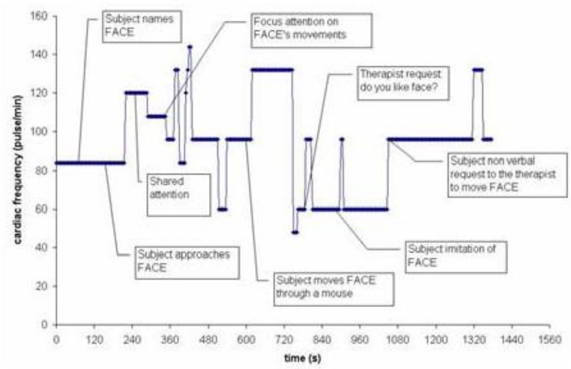

Fig. 8. Typical trace of a subjects heart rate during the treatment

VII. Conclusions

The aim of FACE is to act as a human-machine interface for non verbal communication. The learning process in FACE is based on imitating predefined stereotypical behaviours which can be represented in terms of FAPs followed by a continuous interaction with its environment. At present FACE is being applied to enhance social and emotive abilities in children with autism. The experimental sessions allowed us to collect first data in terms of therapeutic treatment for patients with disorders in the autistic spectrum. However, what is behind FACE? There is the application of the smart soft matter, algorithms and robotics, there is the attempt to understand the complexity of biological behaviour, there are people with autism and there are the immense and yet unknown implications of brain-machine interaction. During a test, little M., following the movements of FACE's eyes, noticed that FACE looked at him again and a little bit surprised, upon the request of the therapist to give a meaning to this situation, said 'I exist too and therefore I'm important'.

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