Human-robot interaction in autism

S. Casalini, G. Dalle Mura, M. L. Sica, A. Fornai˜, M. Ferro, G. Pioggia, R. Igliozzi, A. Ahluwalia, F. Muratori*, D. De Rossi (Interdepartmental Research Center "E. Piaggio" , Faculty of Engineering - University of Pisa; *Scientific Institute "Stella Maris", Department of Developmental Neuroscience - University of Pisa; ˜ Ph.D. Student in Cognitive Science – University of Siena)*

FACE AND AUTISM

Autism is a developmental disorder characterized by qualitative impairments in social interaction and communication and a restricted range of activities and interests. It is in fact well documented that individuals with autism have impairments in processing social and emotional information [1]. This is particularly evident in tasks assessing face and emotion recognition, imitation of body movements, interpretation and use of gestures and theory of mind. Typically developing infants show preferential attention to social rather than inanimate stimuli; in contrast, individuals with autism seem to lack this early social predisposition. This hypothesis was recently substantiated in a neurofunctional study of facial 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.* [2] 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 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 people's mental states. According to the cognitive theory of mindblindness, this impairment is related to the difficulty that people with autism have in conceiving of people as mental agents. Mindblindness is, thus, the inability to perceive another person's mental state. 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 (e.g. Mind Reading, produced by Human Emotions, U.K.). Their aim is to enable individuals with autism to interpret meanings and intentions of people and to anticipate their emotional reactions to typical situations they may encounter during the course of their daily lives. These methods show that basic emotion understanding can be taught; however, since the learning process derived from these therapeutic approaches repeatedly uses a limited repertoire of predefined scenarios, it is biased toward the memorization of a scene, and its interpretation within a therapeutic setting, and so does not allow generalization or abstraction of the experience. In fact, the capacity of generalizing that learn within a therapeutic setting is one of the principal problems of currently used treatments for autism. We present here Facial Automaton for Conveying Emotions (FACE) [3], a facial automaton with an anthropomorphic passive body, developed at the Interdepartmental Research Centre "E. Piaggio" of the University of Pisa, capable of expressing and recognizing basic emotions and describe an innovative robot-based treatment method which focuses on core aspects of the autistic disorder, namely social attention and the recognition of

emotional expressions. FACE acts as an interface between the patient and a trained therapist. A dedicated experimental setup enables both the creation of predefined social situations, as well as the possibility of the therapist rapidly setting up individualized scenarios during a session. Moreover, the flexible and interactive modular architecture of the control system allows each session to be recorded, repeated, or modified. FACE could have greater visual impact for patients than other methods used for social training and could greatly reinforce them. It can also enable more complex and varied situations to be constructed during therapy. Moreover, as argued by Nadel, social imitation of a robotic experimenter can pave the way to the acceptance of social environment and human presence [4].

FACE: AIM WITHIN AN ENVIRONMENT

Human beings have an extraordinary capacity for social interaction. Not only can humans communicate their moods, emotions, and reactions, but they can also interpret and predict those of an interlocutor. The fundamental elements in biomimetic robotics are the materials and how they move, and the sensory inputs and how these are controlled. As a result, the use of biologically-inspired paradigms are taking on an increasingly important role. However, to create a real mechanical android, it is not enough to evolve and assemble these technological blocks. Believability and the capacity of non-verbal communication of a life-like artefact that acts as a human-machine interface in a social environment are fundamental characteristics [5].

The underlying principle of FACE's automatic facial expression recognition is based on Darwin 's idea of adaptability and on the importance of experience in neurological processes. In this study an automatic system based on a Hierarchical Neural Network has been developed. Landmarks are selected in order to seek and identify four facial zones (right eye, left eye, nose, mouth). FACE is placed in an environment in which the only stimuli come from the non-verbal communication of a human placed in front of it. Its aim is to be a credible human-machine interface that can establish non-verbal communication through learning and imitating the emotional behaviour of the interlocutor. As pointed out by Jaqueline Nadel, the process of imitation is innate to humans, and place a crucial role in distinguishing between actions arising from within or actions induced by others. Moreover, imitation establishes a reciprocal nonverbal communication process in which the roles of imitator and model are continuously exchanged. We believe that a truly biomimetic approach to implement human-like facial dynamics and behaviour is through a process of imitation-based learning [6,7].

FACE'S CONTROLLER

The aim of the FACE project is to develop a biomimetic machine which is believable not only concerning the materials used and the movements but also through its behaviour. By behaviour we mean an emerging form of interaction with the environment FACE is engaged with. The problem we are currently setting ourselves is that of realizing a neural structure capable of creating its own representation of the surrounding environment in order to make it possible for innovative behaviours to emerge. These could derive from 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 will be 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* [8], 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. Moreover, the current neural models do not include the role of glia cells and in particular those of the astrocytes. As has been recently demonstrated, the glia modulates the neural communication achieving a two-dimensional continuum in which calcium ion waves influence synaptic communication [9]. The glia cells 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 [10].

FACE AND ETHICS

From a bioethical point of view, the relation between FACE (as a doctor) and the autistic child (as a patient) is far from being a strictly paternalistic one. FACE employs a “specular” kind of therapy, the so called F.A.C.E.T., whose purpose is to create an “intellective-emotional bridge” between child and robot.

By using a communication system focused on facial expressions, FACE is able to meet the child's affective needs, building an *ad personam* relationship aimed at every child. This link between robot and child doesn't rest on a set of rules establishing either a robot-centric or an anthropocentric moral. The bridge developed through a set of interactive child-robot steps is of an intellective-emotional type and its purpose consists in building the relationship itself: as soon as FACE can interact with the autistic child, F.A.C.E.T.'s goal is reached.

The only intervention tool is represented by the strategy FACE adopts to build the bridge. F.A.C.E.T. depends in fact on the context; anyway, therapist play an essential role in every kind of robot-child interaction. This actor is able to help FACE in setting up the intellective-emotional bridge which has to be regarded as the starting point of a future, structured relation between child and robot.

Then, if a reflection on F.A.C.E.T.'s morality is possible, it must start from the context from which the robot-child interaction arises. The question is: how much is therapist involved in the construction of this intellective-emotional bridge?

We try to answer drawing the role at stake; F.A.C.E.T. resorts to a context-dependent construction strategy whose main feature is the absence of pre-determined constructive rules. From a bioethical point of view, the morality of each robot-child interaction is an emergent property coming out from the connections between context, child and robot. In other words, it's all about a sort of “connectionist ethical stand point”. As an emergent property, morality is not subdued to any component in the interaction: its source is the interaction itself. So our point of view on F.A.C.E.T.'s morality is based on the results of a complex interaction. In fact, our research model proceed at the same rate with a principle of precaution as a set of action procedures able to estimate both risk and benefits.

We are therefore interested in the “historicity” of each robot-child interaction, since this approach allows us under treatment to take advantage of a pattern-free, ruleless construction model, being able to subsequently draw the main features of interaction even from a bioethical point of view.

To sum up, the morality of every interaction between FACE and the autistic child does not display any sort of fixed structure. F.A.C.E.T.'s morality results on interaction itself! The several construction steps involved resemble a vortex whose purpose is to let the autistic child gain access to the intellective-emotional world of non-autistic people. F.A.C.E.T.'s therapeutic efficiency relies thus upon its capability to emancipate autistic children from their pathological isolation. And this is what is ethically relevant to our research project.

REFERENCES

[1] G. Pioggia, R. Igliozzi, M. Ferro, A. Ahluwalia, F. Muratori and D. De Rossi. *An Android for Enhancing Social Skills and Emotion Recognition in People With Autism* . IEEE Transactions on Neural System and Rehabilitation engineering. Vol. 13 No. 4. December 2005.

[2] A. Klin, B. A. W. Jones, R. T. Schultz, F. R. Volkmar, and D. Cohen. *Visual fixation patterns during viewing of naturalistic social situations s predictors of social competence in individuals with autism.* Arch. Gen. Psychiatry, vol. 59, pp. 809–816, 2002.

[3] G. Pioggia, A. Ahluwalia, F. Carpi, A. Marchetti, M. Ferro, W. Rocchia, and D. De Rossi, *"FACE: Facial automaton for conveying emotions,"* Appl. Bionics Biomech., vol. 1, no. 2, pp. 91–100, 2004.

[4] J. Nadel, A. Revel, P. Andry, and P. Gaussier, "Toward communication: First imitation in infants, children with autism and robots," *Interaction Stud.* , vol. 1, pp. 45–75, 2004.

[5] G. Pioggia, M. Ferro, J. Kozlowski, A. Marchetti, F. Di Francesco, A. Ahluwalia, D. De Rossi. *Automatic facial expression recognition by means of a neural approach.* Proceedings of the 2nd International Symposium on Measurement, Analysis and Modeling of Human Functions ISHF2004, Genova, Italy, 2004.

[6] G. Pioggia, M. Ferro, J. Kozlowski, A. Marchetti, F. Di Francesco, A. Ahluwalia, and D. De Rossi, *Automatic facial expression recognition by means of a neural approach* . Proc. 2nd Int. Symp. Measurement, Analysis and Modeling of Human Functions , Genoa , Italy , 2004, pp. 121–124.

[7] M. Ferro, G. Pioggia, D. De Rossi. *A Hierarchical Neural Network for Automatic Facial Expression Recognition.* Pattern Recognition, submitted.

[8] G. Pioggia, R. Igliozzi, M. Ferro, A. Ahluwalia, F. Muratori, D. De Rossi. *An Android for Enhancing Social Skills and Emotion Recognition in Autistic Patients* . IEEE Transactions on Neural Systems and Rehabilitation Engineering, submitted.

[9] M. Zonta, G. Carmignoto. "Calcium oscillations encoding neuron-to-astrocyte communication". *Journal of Physiology* , 96, 193-198, 2002.

[10] G. Pioggia, M. Ferro, S. Casalini, C. Caudai, A. Ahluwalia, D. De Rossi. *Sensory Fusion and Emerging Behaviour in an Anthropomorphic Robot as a Man-Machine Interface.*

[11] S. Bartolommei. P*recauzione sospetta. Un commento al documento del CNB sul "principio di precauzione*, Bioetica, 2005 4