Technology-based aids for people affected by Autism Spectrum Disorder (ASD)

Cristina Gava, Peron Davide

Neurosensorial Engineering final project

A.A. 2017/2018

Abstract

Individuals affected by Autism Spectrum Disorder(ASD), especially the not-verbal ones, are often unable to communicate in an appropriate way, they show strong difficulties in social interactions and in manifesting their affective states or their necessities. The conventional techniques, used to improve the performances of these people in the everyday tasks, are observation-based and can require a lot of effort in terms of time and money, with limited results. Technology-assisted therapies can result more powerful and fast.

Our aim is to analyze the current technology-based solutions that can help the therapist and the family of an autistic subject to interact with him. These solutions exploit the joint use of human intelligence and artificial intelligence to improve the powerfulness of therapies and to allow a better integration of these individuals in the society.

Index Terms

Autism Spectrum Disorder, Avatar-robots, Wearable Technology, Health Monitoring

CONTENTS

I. Introduction

Autism Spectrum Disorder (ASD) is a term used to cover a very big set of disorders. There are a lot of studies and experiments in this field, but still a lot questions about it are unresolved: for example, the symptoms are well known, while the causes are still mostly unknown. Nowadays *screening tests* are used to classify a person as affected by ASD, but these tests have an high percentage of error (false positive or negative) and they can be administered to a patient who is at least 3 years old. For this reason, several techniques have been studied in order to establish if a children has this disorder in the first 2 years of life.

With respect to these aims, this work is divided into two main sections: In section II we present some innovative tools and procedures to help diagnosing the syndrome in the first one or two years of a child; in section III we describe three **(Cri says: vedere se poi il numero va bene)** devices and methods useful for learning and improving cognitive skills.

II. Diagnostic techniques

A. Hand-eye coordination

A different aspect to take into consideration when facing subjects with ASD, is the motor disorder related to the syndrome. In [1] a new approach to face the issue is presented, where the proposed protocol may be used for ad hoc subject training, helping children with ASD to enhance motor abilities related to hand-eye coordination.

Moreover, although normally it is not considered as a diagnostic criteria, motor impairment associated with ASD may have a significant impact on daily life tasks and, since up to 80% of children with autism show motor anomalies highly correlated with the severity of social deficiency, hand-eye coordination could be considered as a new early diagnostic strategy for ASD syndrome [1]. In fact, it has been suggested that sensory integration with bad timing brings to poor motor performance in children with ASD: the task of integrating multisensory input influences the forming of coherent perception, action coordination and planning. Nowadays, the normal procedure to assess this motor coordination deficiency is the clinical observation and self-report questionnaires, so a new non-invasive objective method to map the development of ASD such hand-eye motor performance, could be a powerful diagnostic tool.

1) Material and methods In [1] the experimental set-up involved sixteen children aged between 8 and 10 years old and was composed by a haptic robotic manipulandum (Phantom

Omni, Sensable-Geomagic) with a 3D printed pen-like handle, a control pc with a suited control algorithm running and a table-mounted screen Eye tracker T60 (Tobii) of 1280×1024 pixels. The manipulandum's sampling frequency was of 1 kHz, while the Eye Tracker's sampling frequency was of 60 Hz.

Prior to the beginning of the trial, a brief amount of time was given to the children in order to familiarize with the system.

The actual trial consisted in two main tasks: the first task was about following a diagonal straight path moving an end-effector from a start square to an end square without exiting the path boundaries; in the second task a target moved on the screen following a curvilinear predefined path representing a digitalized version of the visuo-motor precision sub-task of the NEPSY-II protocol.

During the first task, a primary amount of attempts was done without applying external force disturbance to the pen-like handle; the attempts that followed, instead, were perturbed by an external force, while the final ones were not perturbed again. Results from this task show that:

- the task was fulfilled pretty well in the first unperturbed part;
- during the first perturbed attempts the performance of the subjects were significantly low and attest a slow adaptation to the change;
- after some perturbed attempts the subjects eventually manage to compensate the force almost properly, with a progressive reduction in the product $pathL\dot{T}$ (where $pathL$ is the length of the path while T is the time taken to travel through it);
- when the attempts go back to be not-perturbated there is an initial overcompensation, which eventually is re-calibrated with even better performance than the ones obtained initially.

Figures 1 and 2 show the results just described.

During the second task there is a significant difference between Typically-Developing (TD) (TD) children and children with ASD and between the first and the second attempt:

- Even though there is not a strong correlation among the children of a same group, it can be noticed that both TD children and ASD children performed better during the second attempt, when they already knew the path to follow a priori;
- In general, TD children had better performance than ASD children;
- For ASD children, the *hand-gaze* distance was higher than for TD children, but quite the same in both the attempts.

Figure 3 shows an example of trial with a TD child.

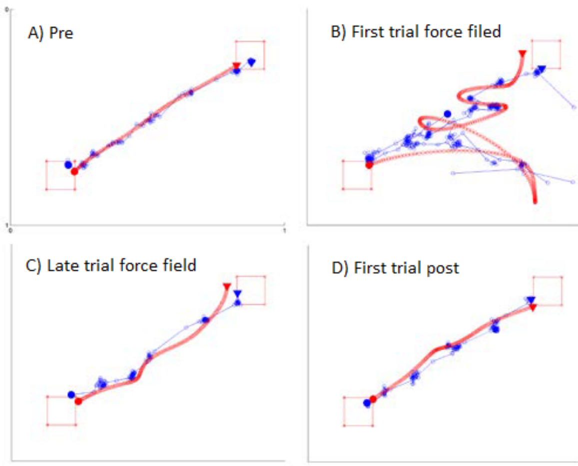

Fig. 1: Task 1 path following

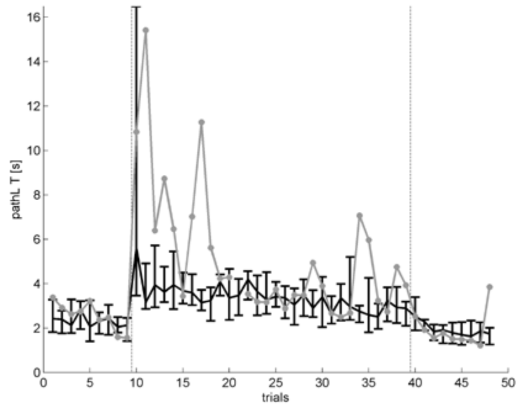

Fig. 2: Task 1 pathLxT vs n of trials

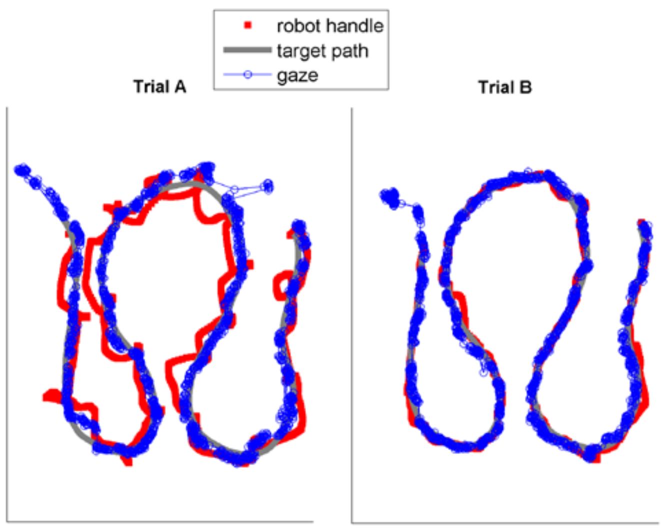

Fig. 3: Trials A and B for a TD child

2) summary observations The experiment results can be summarized with a few crucial conclusions:

- the first task showed how children with ASD took longer to learn the task execution correctly, even though once the process had been assimilated the execution was correct, this meaning that these children showed a delayed ability to learn from sensory prediction errors; moreover the ASD child had more variability in motor execution, this suggesting more difficulty in maintaining performance consistency, and the gaze pattern was sticking less to the hand pattern if compared to the TD children.

- the second task showed how children with ASD obtained performance slightly worse than the TD children, but anyway they were able deploy the information regarding the previously assimilated path to improve the performance. This suggests that glsasd children are able to take advantage of the availability of the whole motor plan and supports the hypothesis that simple motor planning is intact but there is a diminished use of feedback.

From these results, since the timing (which is strictly associated with adaptation and prediction) is one of the crucial aspects managed by the cerebellum (known to be the cerebral section reporting the most consistent brain differences in autism), it can be supported the hypothesis that bad timing in sensory integration causes degraded motor performance and delayed learning in children with ASD.

Such dysfunctions could affect not only motor processes but also cognitive ones, and this form of motor tracking could also be useful to better understand the mechanism at the basis of the well-documented visuo-motor impairments in ASD ([2], [3], [4]) and throw more light on the functional integrity of brain networks during development in people with ASD.

B. Abnormalities in Connectivity of EEG activity

In 1943 a first case of an autistic person developing epilepsy was described. Since then, multiple cases have been registered and so researchers started to look for associations between abnormal Electro Encephalography (EEG) findings and individuals with ASD. This field is still mostly to be uncovered, since classification and evaluation of EEG signals are limited for now, but recent studies suggest a feasible use of this diagnostic technique in the field of glsasd [5].

If we unify the knowledge on the EEG functioning principles, to the signal processing theory, we obtain a powerful diagnostic tool: representations based on Fourier Transform have been commonly applied and this brought to light that the EEG spectrum contains five main frequency bands with characteristic waveforms and so the main way to highlight differences between normal subjects and autistic subjects can be to analyze the coherence of EEG signals form different brain regions in order to find coupling among the signals in frequency domain.

1) Example of procedure In [5] the authors describe a trial done on 10 children with ASD and a control group of 9 age-matched control subjects that have not suffered from neurological disorder. From the 21 scalp loci of the international $10-20$ system the EEG signals were recorded, the subjects were in a relaxed state with the eyes open and more than 10 minutes of data were collected for each child.

Cases \ Membership	Autism	Normal
Autism	90.0	10.0
Normal	11.1	88.9

Table I: Table of confusion for the correct group discrimination using STFT-BW

The signal processing passage consisted in low-pass filtering at 100 Hz, subsequent sampling at 256 Hz and digitization through 12-bit ADC. Finally. EEG signals were divided into 3 artifact-free epochs, subsequently filtered trough a Hamming window FIR band-pass filter.

With the signal set in this way the Fourier Transform has been applied, using a Gaussian time window in order to observe sections in which the signal is seen as stationary.

The last passage was the estimation of coherence variables: MSC is the estimated coherence range (it goes form 0 to 1) and is obtained from auto and cross-power spectra of the channels.

To evaluate the statistical difference between the control group's signals and the ones from the ASD children group, the authors used one-way analysis of variance tests, while to measure the discriminating ability of the test they used Receiver Operating Characteristic (ROC) plots. Moreover, to classify between ASD subjects and control subjects, nearest neighbor classifier has been used.

2) results Results show that the discriminating ability of nearest neighbor classifier over STFT-BW is satisfactory (0.967 for the F3 electrode) and table I shows a 89.5% probability of correct classification through STFT-BW. Moreover, figure 4 shows the obtained results for the three frequency bands alpha beta and gamma: coherence values that show meaningful differences with $p < 0.05$ are represented through dot lines, while differences with $p < 0.01$ are represented through solid lines: the resulting observation is that there are more abnormalities in connectivity for the left temporal lobe than the other ones, observation that sticks with the assumption of a correlation between ASD syndrome and abnormal behavior of temporal lobes [6] [7].

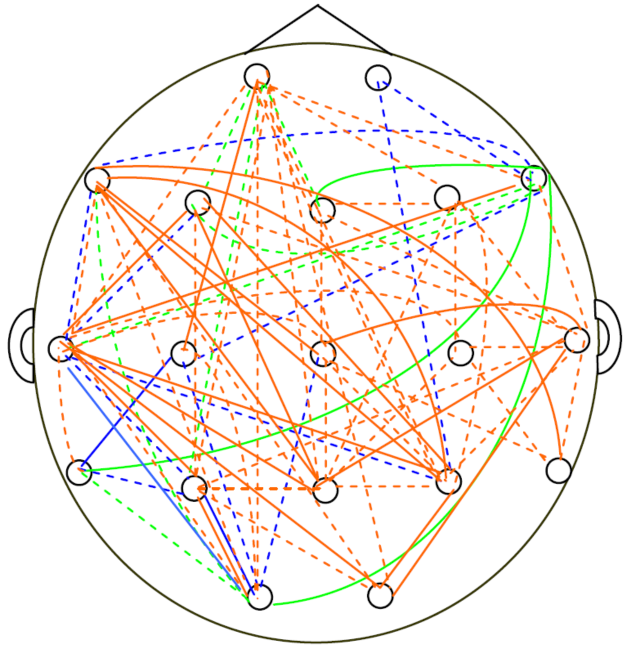

Fig. 4: Results of coherence values and connectivity in channels brain

III. Therapeutical techniques

The classical way to conduct a therapy session is a face-to-face meeting between the subject and the therapist. Usually, it is conducted in four phases: the first one is called *Instruction*, in which the therapist explains what is the skill that the subject is going to learn; the second one is the *Modeling* phase, in which the therapist shows the patient what he has to do; then there is the *Rehearsal* phase, in which the patient tries to imitate the therapist, and finally a *Feedback* phase in which the therapist draws its own conclusions about the test. The problem of this kind of therapy structure is the completely subjective evaluation procedure carried out by the therapist and the non-immediate subject's attention.

To improve the performance of the sessions, the use of Virtual Agents (VA) platforms has been introducted. A VA platform consists of an avatar, that can be a robot or a virtual character, a learning software that receives information from the Avatar, elaborates them and adjusts the response of the Avatar, and an interface for the therapist that interprets the results. In a VA session the therapist, with the aids of the learning software, trains the Avatar to do an action that the child has to imitate. At the same time, the child tries to imitate the Avatar learning new ways to interact with the society. Different system has been proposed, we describe here two different solutions, one more general and one more complex and efficient.

A. General AVATAR idea

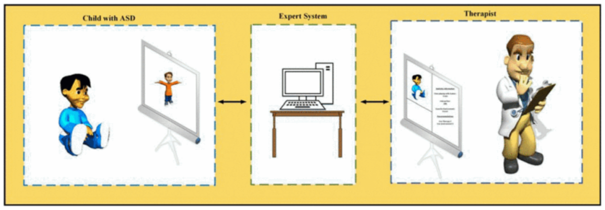

Fig. 5: Scheme of AVATAR system

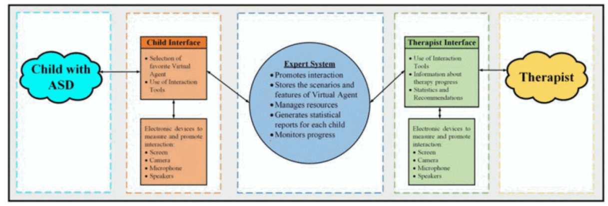

Fig. 6: Structure of AVATAR platform

The idea of an Avatar-based therapy session is shown firstly in [8]. In the paper they propose a system composed by a VA and an *expert system* used by the therapist to instruct the VA. A general scheme of the system is shown in Figure 5.

They chose to use a Virtual Agent instead of a robot since, according with the needs, it provides the possibility to customize the tool, while a robot is limited by its structure and its Degrees of Freedom (DoF).

As can be seen in Figure 6, the platform is organized as follows:

Child Interface It selects the child's favorite Virtual Agent and uses interaction tools as screen, camera, microphone and speakers to interact with the child;

Expert System Contains a learning algorithm that promotes interaction between the child and the Virtual Agent, it stores the scenario and features of the Virtual Agent and it monitors progress of the session in order to generate statistical reports that will be used by the therapist;

Therapist Interface Allow the therapist to access to the reports generated by the Expert System and gives information about the current therapy, in order to allow the therapist to draw conclusions.

The choices about the best VA to use during the sessions, or the characteristics that has to be changed in the current VA, are taken monitoring the reaction of the child when he is put in front of them. It is not necessary for the character to be a human, since the highest degree of affinity can be towards an animal or an object.

The key point in this work is that the information received on the screen of the therapist interface shows a real time image of the child and monitored progress statistics. Since the VA that the child observes on his screen is his therapist in disguise, actually it is the therapist who, combined with artificial intelligence, promotes the interaction in combination with the expert system.

B. A more complex system

Another more complex and complete approach was performed in [9], using a robot instead of a VA; this because it has been shown in [10] that patients manifest a more favorable response towards humanoid robots than to other non-humanoid virtual characters.

This approach has sensible advantages but also some intrinsic shortcomings:

- most of the robotic or virtualized therapies are preprogrammed and this makes the session boring and repetitive;
- robots are limited and work in a controlled environment;
- usually robots do not have a quantitative behavioral analysis tool, due to the absence of therapists during their development process.

In this work they try to fulfill these lacks using a set of advanced technology tools, specifically a *NAO Robot* (visible in Figure 7) and a Perception Neuron Set of 32 sensors.

In their proposal, the robot will replace the therapist in the room. The therapist would wear portable motion sensors giving him a partial control of the robot motion, and he would receive a visual and auditory stream from the robot. The therapist would also be able to talk to the child through the robot, by using a robotic voice.

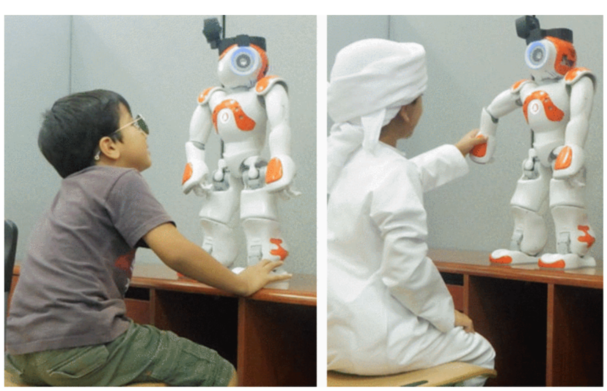

Fig. 7: Scheme of AVATAR system

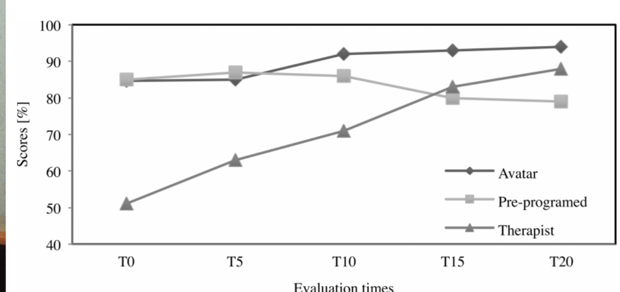

Fig. 8: Structure of AVATAR platform

The strength of this work is that the robot behavior can be adapted based on the degree of engagement of the child in the session. Indeed, as the session starts, a low number of DoF are given to the robot, in order to makes the child imitate a set of very simple movements.

As the patient progresses in the engagement (we'll see later that this means take more points), more DoF are given to the robot, usually enabling disabled actuators, in order to increase the complexity of the movements.

During the whole process a heart-rate measuring band is worn by the partecipant, to monitor the partecipant's level of anxiety and stop or change the session whenever an intervention is required.

To monitor the actual movements performed by the child, a Microsoft Kinect is used.

The movements performed by the robot and imitated by the child are specifically selected to teach the child how to interact with other people and to improve his response to social stimolous.

During the session, points are given to the child as he progresses and performs the right movement at the right time. The total score is given by the sum of three contributes:

Motion Score Is relative to the goodness of the movement made by the patient to imitate the robot;

Attention Score the child takes one point for each second he's looking at the robots face whenever the robot is asking him a question;

Response Score for this score, points are given for the delay time between the moment in which the robot asks a question and moment in which the child start answering the questions. 10 points are given for the first 10 seconds after the robot/therapist stops talking, and one point is subtracted for each second of delay.

After 20 minutes of session therapy, results are collected. This experiment has been done in five healthy male children and with three different type of interaction subject: an avatar programmed as said before, a pre-programmed robot and a therapist in a classical face-to-face session. Score has been collected for each type of interaction and the results are shown in Figure 8.

As we can see the performance of the avatar are initially almost equal to the ones of a pre-programmed robot, but along the session, child gets bored of the last one due to its repetitive movements and requirements, while the score with the avatar increases due to its continuous adaption to the child needs. The scores collected with a real therapist are very lower at the beginning compared with the first two type of interaction and it increases along the session since the therapist adapts the requirements to the child needs.

IV. Conclusions

References

[1] C. Casellato, M. Gandolla, A. Crippa, and A. Pedrocchi, "Robotic set-up to quantify hand-eye behavior in motor execution and learning of children with autism spectrum disorder," in *2017 International Conference on Rehabilitation Robotics (ICORR)*, July 2017, pp. 953–958.

[2] W. Chow, M. H. Lewis, J. W. Bodfish, and C. J. Hass, "Increased Static and Dynamic Postural Control in Children with Autism Spectrum Disorders," *Gait Posture*, vol. 32, no. 1, pp. 6–9, 2010.

[3] S. A. Green, J. D. Rudie, N. L. Colich, J. J. Wood, D. Shirinyan, L. Hernandez, N. Tottenham, M. Dapretto, and S. Y. Bookheimer, "Over-Reactive Brain Responses to Sensory Stimuli in Youth With Autism Spectrum Disorders RH: fMRI Response to Sensory Stimuli in ASD," nov 2013.

[4] N. Papadopoulos, J. Mcginley, B. Tonge, J. Bradshaw, K. Saunders, A. Murphy, and N. Rinehart, "Motor proficiency and emotional/behavioural disturbance in autism and asperger's disorder: Another piece of the neurological puzzle?" 09 2011.

[5] H. Behnam, A. Sheikhani, M. R. Mohammadi, M. Noroozian, and P. Golabi, "Abnormalities in connectivity of quantitative electroencephalogram background activity in autism disorders especially in left hemisphere and right temporal," *Proceedings - UKSim 10th International Conference on Computer Modelling and Simulation, EUROSIM/UKSim2008*, pp. 82–87, 2008.

[6] M. Zilbovicius, N. Boddaert, P. Belin, J. B. Poline, P. Remy, J. F. Mangin, L. Thivard, C. Barthélémy, and Y. Samson, "Temporal lobe dysfunction in childhood autism: a PET study. Positron emission tomography." *The American journal of psychiatry*, vol. 157, no. 12, pp. 1988–1993, 2000.

[7] I. Gendry Meresse, M. Zilbovicius, N. Boddaert, L. Robel, A. Philippe, I. Sfaello, L. Laurier, F. Brunelle, Y. Samson, M.-C. Mouren, and N. Chabane, "Autism severity and temporal lobe functional abnormalities," *Annals of Neurology*, vol. 58, no. 3, pp. 466–469, 2005. [Online]. Available: http://dx.doi.org/10.1002/ana.20597

[8] L. F. Guerrero-Vasquez, J. F. Bravo-Torres, and M. Lopez-Nores, "Avatar, autism: Virtual agents to augment relationships in children," in *2017 IEEE XXIV International Conference on Electronics, Electrical Engineering and Computing (INTERCON)*, Aug 2017, pp. 1–4.

[9] M. Alahbabi, F. Almazroei, M. Almarzoqi, A. Almeheri, M. Alkabi, A. A. Nuaimi, M. Cappuccio, and F. Alnajjar, "Avatar based interaction therapy: A potential therapeutic approach for children with autism," in *2017 IEEE International Conference on Mechatronics and Automation (ICMA)*, Aug 2017, pp. 480–484.

[10] G. Pioggia, R. Igliozzi, M. L. Sica, M. Ferro, F. Muratori, A. Ahluwalia, and D. D. Rossi, "Exploring emotional and imitational android-based interactions in autistic spectrum disorders," in *Journal of CyberTherapy and Rehabilitation*, 2008, pp. 49–62.