Towards an Integrated Approach to Diagnosis, Assessment and Treatment in Autism Spectrum Disorders via a Gamified TEL System

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Abstract Autism Spectrum Disorders (ASDs) are characterized by atypical patterns of behaviors and impairments in social communication and interactions. Information and Communication Technologies (ICT) have been recognized to have great potential in supporting ASD treatment: ICT-based tools are enjoyed since interaction with computers supports imagination of behaviors necessary for role-play in predictable environments. Differently from most proposals in the literature focused on treatment from the patient side, we are here interested in discussing how moving from paper-and-pencil measures to ICT tools may help psychologists and therapists in their diagnosis activities as well as in conceiving novel technology-enhanced interventions. In particular, we will present some features of a system under development aimed at pursuing an integrated approach including diagnosis and gamified learning.

Keywords Autism Spectrum Disorder · TEL · Gamification

1 Introduction

Autism Spectrum Disorders (ASDs) are characterized by restricted, repetitive and stereotyped behavior and core deficits in social communication and interaction [1].

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Social impairments severely interfere with the process of building relationships, functioning occupationally, and integrating and participating into community [2]. The importance of accurately identifying individuals with ASDs, and therapeutically intervening on them, has never been greater: in the last decade the prevalence of autism has risen dramatically, with a systematic review estimating global prevalence of pervasive developmental disorders at 62 per 10,000 and autistic disorder at 17 per 10,000 [3] (with figures even higher in more developed countries [4]).

If no definitive reason for such an increase has been determined yet, it is certain that more children are identified as having ASD than even before, that these children need help, and that school systems and medical care systems require increasing resources to ensure that people diagnosed with ASD achieve optimal outcomes and improve their quality of life. Accessibility of treatment is to be considered a key factor: traditional behavioral treatment requiring intensive sessions, e.g., are not accessible to a vast majority of individuals with ASD due to intervention costs.

The causes of autism remain largely unknown, though there is evidence that genetic, neurodevelopmental, and environmental factors are involved. Deficit in social cognition and its components such as Theory of Mind (i.e., the ability to understand another's thoughts, beliefs, and other internal states), emotional contagion, and prosocial behavior were reported in persons with ASD [5,6]. Given the influence that, due to studies on the brain areas related to social cognition abilities [7], the social cognition model in ASD has in research and practice, it would be crucial to develop evidence-based intervention strategies based on social cognition skills.

To this aim, Information and Communication Technology (ICT) has great potential: ICT-based tools – typically enjoyed by individual with ASD since interaction with computer does not pose sever expectations and judgement issues and allows to discover conventions in a safe and predictable environment – can support the imagination of contexts, people and behaviors necessary for role-play, and offers replicability, possibility of modifiable multisensory stimulation, and capacity to implement individualized intervention (see, e.g., [8,9]). The literature generally agrees on the potential benefits of technology-enhanced approaches in supporting the learning process of emotional and mentalizing competencies in individuals with ASD. Anyhow it has to be said that, despite promising preliminary results, studies of ICT-based tools for the treatment of ASD have to be considered still at their infancy because of limitations on the complexity of the proposed tools (typically built ad hoc for a specific study) and on the size of the clinical groups involved in the evaluation (for example, out of the 38 ICT-based studies surveyed in [10], 20 involved a sample with a size below 10 or not even specified and only 3 have been evaluated with more than 30 persons), hence suffering, in summary, from the lack of real generalizable results and scholarly knowledge beyond the context of proof of concept studies.

We argue that it is necessary to enlarge the focus of technological interventions, aiming at systems able to support therapists in the multifaceted objective of

creating personalized learning material, customizing interventions, and monitoring/assessing progresses (possibly in a context of tele-rehabilitation). This would allow researchers to conduct longitudinal studies and to evaluate whether improvements reached in the interaction with a tool actually hold in real life situations.

In this paper we report on first steps in this direction, carried out under a participatory design approach by a multidisciplinary team, including psychologists, computer scientists, and persons with ASDs, aimed at developing *an integrated suite of tools for diagnosis, gamified technology-enhanced learning, and assessment*. In particular, in Section 2 we single out key features to be addressed when conceiving ICT-based tools for ASD treatment and sketch our vision to overcome limitations of the field. Then, in Section 3 and Section 4 we discuss a multidisciplinary study based on such a vision: Section 3 sketches the organizational situation to ameliorate, in terms of diagnostic/assessment measures currently used by therapists, while Section 4 discusses how moving from a paper-and-pencil to an ICT-based approach may help psychologists and therapists achieving an integrated technology-enhanced framework for diagnosis, treatment, and assessment. In Section 5, conclusions are drawn.

2 ICT and ASD: A Review of Strenghtness and Limits

In the last decade, research has explored a variety of ICT-based approaches to ASD with diverse goals: (i) as assistive technologies, to counteract the impact of sensory and cognitive impairments on daily life; (ii) as rehabilitation tools, to modify and improve the core deficit in social cognition, and (iii) as education tool, to help children acquire social and academic skills [11]. Initial fear that the use of technology might further isolate ASD sufferers who have problems in social relationships [12] have been overcome by evidences about success of ICTs to improve social interaction when used correctly [13]. While for extensive reviews we refer, e.g., to [10,11,14,15], here we want to single out key features to be considered when designing an ASD-oriented technology-enhanced treatment and discuss limitations to overcome.

Learning Benefits. A decision to be taken when designing a technology-enhanced tool able to teach aspects of social functioning to people with ASDs is about the social skills to be targeted. As underlined in [8], the skills chosen should be relevant to many different situations thus offering the opportunity to investigate generalization of skills between contexts. To date, studies related to technology-enhanced interventions have addressed a variety of social skills that are regarded essential for persons with autism, including the ability to recognize faces and emotions; to initiate, maintain, or terminate a behavior; to improve vocabulary and reading skill, spatial planning, functional activities of daily living; to enhance vocal imitation [15].

Sensory Channels. Multimediality, and the possibility of modifiable multisensory stimulation, is one of the main strenghts of technology-enhanced treatment. Computer graphic displays make abundant use of visually cued instructions, which are recommended for interventions in ASD [8] (e.g., baloons may be used as visual aids to suggest what characters in a scene are thinking or feeling).

Use of Avatars. Conversational avatars playing the role of an instructor are proven to advance the educational process [17] and to improve social skills [18]. Emotionally expressive avatars appears to be crucial [19], even better if they have voices [17].

Virtual Environments (VE). Computer-generated representations of environments with realistic appearance appear promising for teaching social understanding, due to their capability of illustrating scenarios representing situations that may not be feasible in therapeutic settings, of promoting role-play, and of allowing participants to take a first-person role for skill-learning in virtual social situations [8,20,21]. Studies report that, by reproducing a "virtual cafè" to teach social skills, the speed of execution of social tasks in the VEs improved after the repetition of the task and learned skills were transferred into a VE proposing a situation with similar demands (on the bus) [8]. It is argued that the realism of the simulated environment increases the probability that the person with ASD transfers learned skills into everyday live ([8,22]), though longitudinal studies that support such an hypothesis are missing.

Gamification. Interaction with VEs is generally perceived as playful and it is proved that subjects learn while they play [23]. Not surprisingly, a great number of pilot studies on VEs are based on serious games (e.g., [8,9,24]). The gamified approach to learning requires to design situations at different levels of social complexity and to define criteria for progressing in the game. While most studies are designed to chain learning based only on performance aspects (i.e., on correctness of the answers), some proof-of-concept studies proved that an adaptive approach including also criteria based on physiological markers of engagement (e.g., pupil dilation and blink rate) contributes to improved performance of participants, while leaving the generalization of skill improvements in real-life an open question [9].

Devices. Though traditionally technology-enhanced treatment has been based on desktop computers with mouse and possibly joystick [20], most of the recent research projects use touch screens [11, 25]. Authors in [26] conducted a systematic review of studies involving iPods, iPads, and related devices in teaching programs for individuals with developmental disabilities. The 15 studies were largely positive and showed that these devices are viable technological aids for such individuals. These results appears important since they open the possibility of accessible low-cost technology enhanced treatments possibly in a tele-rehabilitation context.

Limits. As underlined by [15], recent literature tends to emphasize the potential of technology more than its demonstrated effectiveness: technology-based treatment

is still perceived as "emerging" rather than "established", and the clinical validity is still a matter of debate, the main flaws being lack of statistical significance in the clinical group they are based on, limited complexity of the tools, designed ad-hoc for the pilot studies and not supporting creation of learning material, and lack of longitudinal studies proving the transfer of acquired skills from ICT-based tools to daily life.

Our Vision. We argue that, in order to move from potentiality to proven effectiveness, it is necessary to take one step backward and put new basis for more systematic research. This requires, first of all, to analyze the work of researchers, therapists, and operators in ASD diagnosis, assessment, and treatment, and conceive technology-enhanced approaches that allow them to pursue the multiple objectives of (i) improving the organization of their work, (ii) testing and comparing in a systematic way the diverse options that computers offers, e.g. with respect to (multi)sensory channels and physiological markers of engagement (e.g., by eye trackers), (iii) applying technology-based treatments, and (iv) evaluating them in longitudinal studies. Furthermore, a multiplatform approach including also low cost ICT devices, would allow to reach – through tele-rehabilitation - individuals with ASD that, for various reasons, remain otherwise marginalized and not treated.

3 The Organizational Situation

To address these goals we launched a multidisciplinary project based on the cooperation between the Department of Information Engineering, Computer Science and Mathematics, the Department of Applied Clinical Sciences and Biotechnology, and the Center for Autism of the University of L'Aquila, and the Abruzzo Regional Reference Center for Autism. The team includes three psychologists, one medical doctor, three computer scientists, five young persons with ASD in the age range 15-23 involved according to a participatory design approach, and their families involved as informant. According to our vision, the first phase of the project has been focused on a collaborative analysis of the organizational situation, e.g., of diagnosis and assessment practices, to single out possible weakness to ameliorate. This study was conducted through semi-structured interviews with therapists, focus groups with persons with ASD and their families, and field studies.

The Organizational Situation. Following state-of-the-art approaches, individuals that arrive to the ASD centers undergo a number of standardizes clinical measures to possibly diagnose ASD (e.g., the Autistic Diagnostic Observation Schedule-2 (ADOS-2) [27] and the Autism Diagnostic Interview-Revised (ADI-R) [28]). Once diagnosed as having ASD, individuals undergo a number of cognitive and social cognitive measures, administered as paper-and-pencil tasks (Table 1 sketches some of them to give an idea of aims, structures, content, and demands on the participants).

Table 1 Paper-and-pencil social cognition measures, typically administered in random order.

Main social cognition tasks (summary)
Emotion Attribution Task [29]. It assesses the ability to represent the emotions of others. The participant is presented with 58 short stories (typically no longer that one or two sentences) describing an emotional situation (e.g., "Charles is lying in the forest. A poisonous spider falls on his chest") and is required to provide an emotion (by writing it down) describing how the main character might feel in that situation.
Advanced Theory of Mind Task [29,31]. It consists of 13 very short stories of different type (e.g., Lie, Joke, Pretend) accompanied by two questions regarding comprehension (e.g., "Is it true what the character said?") and justification (e.g., "Why did he say that?").
Social Situation Task [29]. It consists of 25 medium size stories including a number (1 to 3) of social situations that the participant is asked to judge as "normal", "a bit weird", "quite weird", or "extremely weird".
Attribution of intentions [32]. It consists of fifty 3-picture comic strips illustrating everyday social scenarios. After each strip the participants is presented with three pictures illustrating alternative endings of the story and is asked to select the one that best complete the story from a logical point of view.
Eyes task [30]. The participant is given 36 photographs depicting the ocular area in an equal number of actors and actresses. At each corner of each photo, four mental state descriptors are printed, only one of which correctly identifies the depicted person's mental state.

Main Results of the Collaborative Analysis. A primary problem emerged from the analysis: while structure, content, and administration rules of the tasks would clearly allow a straightforward digitalization, no computer-based support is actually available, and operators have the burden of integrating results from clinical, cognitive, and social cognitive measures, in order to record them, analyze them, and plan treatment. A second type of problems is related to the relationship between the administering operator and the administered person, with the latter frequently showing discomfort for the presence of the former (e.g., in tasks including stories (particularly when of medium size) participants prefer to read the story by themselves and want to feel free to re-read (parts of) it before answering the questions). Other issues are related to long-term relationships with treated kids, with therapists reporting the difficulties, in some cases, to maintain a regular contact with them, e.g., for logistic and/or economic reasons.

4 From Paper-and-Pencil to Technology Enhancement

Starting from the results of the analysis, we planned a roadmap of interventions (not necessarily strictly sequential) aimed at modifying the organizational situation by introducing a multi-user ICT-based system conceived as a coherent suite of tools, envisioning an integrated diagnosis/assessment/treatment approach (see Table 2). As to the treatment, we are working under the theoretical premise that social skills may be learned through a suite of serious games addressing diverse deficits and conceived as gamified variants of some of the tasks included

in the assessment strategy (in particular, all tasks included in Table 1 are gamifiable), within the framework of an adaptive Technology-Enhanced Learning (TEL) approach.

Table 2 Areas of interventions for the development of the integrated suite.

The ICT-based interventions
Digitalization – Implementing digital (interactive) versions of the tests as is (basic step).
Sensory enrichment – Exploiting multimediality for exploring sensory alternatives (verbal, pictorial 2D, pictorial 3D, interactive pictorial 3D, audio, possibly in combination) for the tasks administration, to evaluate their differences in terms of contribution to the assessment and precision (e.g., the short stories of the "Emotion attribution task" may be rendered purely verbally, with or without audio, or by relying on dual coding (verbal plus pictorial), with or without audio, in 2D or 3D, with or without an instructional avatar).
Gamification – Translating "gamifiable" tests into serious games in order to achieve a coherent suite of games specialized for different skills. The playing environment includes a customizable conversational avatar guiding participants during the playing of the games, able to interact with objects and characters of the scenes, and providing individualized feedback based on participants' responses to contribute to the acquisition of social skills (e.g. "your friend would have felt more comfortable if you had paid more attention on how he is feeling. Try again and make him comfortable").
Use of interactive patterns – Exploiting visual patterns for supporting participants during tasks/games activities (e.g., stories of the "Social Situation Task" are broken down into episodes and visually represented by an interactive carousel thus allowing participants to freely browse them)
Multiple platforms/settings – Developing two versions of the games: in the full version adaptivity is based on both performances and physiological markers of engagement (requiring equipment available only in lab setting), while a light version relies on a performance-based adaptive mechanism and can run on accessible low-cost devices (e.g., tablet) thus allowing persons with ASD to continue the treatment at home. Operators may monitor players' activities and progresses.
Creation of learning material – Supporting experts in the creation and refinement of (learning) material.

The system is being implemented according to a multitier architecture able to decouple content and rendering. The definition of 3D scenes is based on the open-source WebGL library (http://www.webgl.org) a cross-platform, royalty-free web standard for a low-level 3D graphics API, based on OpenGL ES 2.0.

5 Conclusions

In this paper we discussed issues behind a radical change of perspective in the studies on technology-enhanced treatment for persons with ASD. Literature agrees on the potential benefits of technology-enhanced approaches to the acquisition of social skills, but so far studies have been focused on proof-of-concept prototypes and evaluated with limited clinical groups. We argue that, to move from "emerging" to "established" treatments with proven effectiveness, it is necessary

to take one step backward to put new basis for more systematic research starting from the analysis of the work of therapists and operators to conceive systems that, exploiting results that the field has achieved so far, support longitudinal studies on TEL systems for people with ASD. In the paper we sketched our vision and an ongoing project aimed at realizing an integrated suite of ICT-based tools able to support both operators in diagnosis/assessment activities and people with ASD in their treatment by a gamified adaptive TEL system. Particular attention is being put on accessibility of the tools to be able to deliver treatment regardless of barriers of distance, time, and cost.

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