REVIEW

ICT and autism care: state of the art

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Purpose of review

Over the past 10 years, the use of information and communication technologies (ICTs) has increased in regard to the treatment of individuals with autism spectrum disorders (ASDs). ICT support mechanisms (e.g. computers, laptops, robots) are particularly attractive and are adapted to children with ASD. In addition, ICT algorithms can offer new perspectives for clinicians, outside direct apps or gaming proposals. Here, we will focus on the use of serious games and robots because of their attractiveness and their value in working on social skills.

Recent findings

The latest knowledge regarding the use of ICT in the forms of serious games and robotics applied to individuals with ASD shows that the field of serious games has already achieved interesting and promising results, although the clinical validations are not always complete. In the field of robotics, there are still many limitations on the use of ICT (e.g. most interaction are similar to the wizard of Oz), and questions remain concerning their eventual effectiveness.

Summary

To describe the implications of the findings for clinical practice or research, we describe two large projects, namely, JEMImE and Michelangelo, as examples of current studies that are aimed at enhancing social skills in children with ASD by including novel algorithms with clinical insights in robots or serious games.

Keywords

autism spectrum disorder, information and communication technologies, serious games, social robots, social skills

INTRODUCTION

Autism spectrum disorders (ASDs) are developmental disorders characterized by deficits in social interaction, communication and repetitive behavior. Among these deficits, all social skills, which include social initiation, social interaction rules, emotion production and recognition, can be affected. As a consequence, integration into society is a major ASD burden [1]. ASD patients may also present with different difficulties that can affect attention and executive learning [2], general cognition or oral language [3]. Academic skills are often impaired, thus impacting academic achievement [4].

Information and communication technologies (ICTs) have opened new ways to help people with ASD. These technologies allow creation of real-life situations in a controlled area and offer clinicians different supports to work with [5]. Moreover, the presentation of information seems to be particularly adapted to individuals with ASD, and some studies have found that persons with ASD are particularly interested by ICT [6].

Information and communication technology-based interventions can be classified into three main categories [7]. First, iPod and iPad apps aim to facilitate specific aspects of social life. Despite some promising apps (e.g. Rubycube or the Social Detective app), most available apps have received limited empirical clinical validation [7]. Second, serious games can be described as ‘digital games and equipment with an agenda of educational design and beyond entertainment’ [8]. Finally, ICT interventions include the use of robots with children with ASD [7,9–11]. In this subdomain, clinical validation is also limited, as many studies have focused on the development of novel social skills for robots, thus

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KEY POINTS

- ICTs are particularly attractive to children with ASD and are adapted to their needs.
- Serious games and robots are two support mechanisms that are particularly used for the treatment of social skills in children with ASD.
- Previous studies showed benefits in using ICT for the treatment of social skills.
- The field needs more robust studies to conclude that ICT is effective and that the skills learned during treatment can be generalized to real life.

narrowing down the expectation of social training [10].

The present study aims to briefly review the recent literature about the use of ICT in the form of serious games and robotics applied to individuals with ASD. ICT can be used to not only train abilities but also to compensate difficulties. We do not describe assistive technologies (see [12] and [13] for a review), but rather focus on serious games and robotics studies with a treatment agenda. Then, to illustrate how ICT research can integrate clinician insights into multidisciplinary research, we describe two large projects, namely, JEMImE and Michelangelo, as examples of current studies that seek to enhance social skills of children with ASD by including novel machine learning algorithms based on clinical expectations.

SERIOUS GAMES

Generality

Serious games can be described as a combination of education and entertainment. At present, many applications exist on portable devices that aim to be playful and to teach a targeted skill. However, most of these applications have not been the object of specific research in a clinical population and cannot be evaluated (see [14] for a list). Here, we focus on serious games created and evaluated on other platforms such as computers, multitouch tabletops, and screens. Generally, the object of their training can be separated into two distinct areas. On the contrary, we found serious games teaching a specific cognitive domain (e.g. executive function) and academic skills (e.g. reading). On the contrary, there are several serious games that teach the core difficulties of ASD, such as social skills and emotion recognition.

Regarding the efficacy of serious games in both domains, Grynszpan *et al.* [15] recently reviewed the literature and performed a meta-analysis to measure clinical impact through a nonspecific variable (standardized effect size) in individuals with ASD. The results showed that the use of ICT has a significant impact on the targeted skills. However, no study has evaluated the maintenance of treatment effects and the generalization to real life. Equally, the researchers could not contend that the use of ICT is more adapted to a subgroup of children with ASD. Finally, the authors reported that the use of ICT seems more efficient when a professional is involved during the session than when the child has to play alone at home.

Since this review, an interesting study described the use of the game SEMA-TIC [16], which aims to teach literacy skills. SEMA-TIC was developed by the Cobtek laboratory and is novel in the literature because it aims to teach literacy to children with poor functional language skills and ASD. The design of the game is thought to specifically increase the motivation of these individuals. The game includes feedback and reinforcements that align with the interests of the children, such as bright, moving objects and illustrations from mechanics. The player can follow his/her progression with a colored gauge, which gives him/her visual information. In addition, each game is thought to train specific literacy skills, such as word recognition, alphabet knowledge, syntactic rule, and so on. A 23-week study enrolled 25 children and showed good game usability and adaptability in the targeted population. The children exposed to SEMA-TIC (experimental group) improved their literacy skills on the targeted exercise significantly better than children in the control group. Moreover, three of the trained children were able to decode words after training.

Serious games to teach social skills

A large part of the recent research on serious games in ASD has dealt with games that try to teach social skills to patients. This interest is supported by two facts: the development of social skills represents a challenge for the integration of individuals with ASD [1]; and ICTs provide very good support in creating social situations in an immersive way [5], contrary to the classic therapy in an office.

In a recent review, Grossard *et al.* [17▪] listed 31 serious games that aim to teach social interaction. We separated those games into two groups: the first group was composed of 15 games that teach social skills, such as joint attention, collaboration or adaptation to social context; and the other group included 16 games that teach emotion recognition

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and production. Regarding the games to teach social skills, half of them try to teach collaboration due to ICTs that force collaboration. The other half uses virtual reality to work on how a player must adapt to a given context (e.g. how to sit in a restaurant) [18]. In the second group, a large part of the serious games focus only on emotion recognition. Although emotion recognition is multimodal in nature [19], most of these games only propose static visual stimuli. Four games try to teach emotion production, but only one of them aims to train this skill in a social situation [20]. Of the 31 games reviewed, we found that only a minority included a study trying to assess the clinical interest of the game with evidence-base methodology [17▪]. In Table 1, we summarize, for both domains (social skills training and emotion recognition), the games that also reported a clinical study. We also added Emotiplay, which is a serious game developed within a European project that was reported recently [21▪].

Most of the games present limitations regarding the evidence of their clinical benefits. Studies are often conducted with individuals with ASD and high IQs, omitting a large population of individuals with ASD. The studies do not include large samples of patients nor do they have control groups. However, in addition, most of the games are not attractive in terms of design and do not use the large possibilities offered by ICT regarding playability. Most of the games only use static images, do not include virtual environments and do not involve the player as a regular game does. This is particularly the case for the games that target emotion recognition and production, whereas games targeting social skills are often more attractive. However, the games targeting social skills were evaluated with weaker methodologies, contrary to the games targeting emotion recognition and expression. Despite these limitations, we believe that the use of serious games to train people with ASD is promising. Accessibility has not been a major focus but may also impact the way ICT can be used. The GOLIAH team (Table 1) is currently computing a novel version of the game e-GOLIAH that will be able, via a web platform, to provide easy use for families at home in combination with automatic gaming information that will be sent to therapists to follow a child's progress [32].

The JEMImE project

As said previously regarding serious games that teach emotion, these games usually lack education of emotion production and social context. In this context, we are developing a novel serious game called JEMImE [33], which aims to train facial expression production in social contexts in children with ASD. The game is the next step of JeStimule (Table 1). It is designed to be not only fun and engaging but also to provide the player with several visual indications to understand and progress in the game, such as in the training part, different gauges of emotion that fill with pieces and when they are full, the game stops; and a wallet in the game part; when it's full, the game stops. The specificity of the game in terms of ICT research is the computation and implementation of an algorithm (Fig. 1a) that provides feedback in real time regarding the quality of the child's production. This feedback allows the children to correct their productions instantly in response to the colored gauges that represent a specific emotion (Fig. 1b). The performance of the algorithm has been evaluated recently and reached excellent performance, with an average accuracy of 82% [34]. A study evaluating the usability of JEMImE by children with ASD is currently underway. Initially, the results seem to indicate that children have fun playing JEMImE and that they quickly learn how to adapt their productions to meet the expectations of the algorithm. However, we must now develop more social scenarios to significantly increase training duration and settle a clinical study.

AUTISM SPECTRUM DISORDER AND SOCIAL ROBOTS

Generality

The use of robots for people with ASD began 20 years ago, and has specifically increased over the past 10 years [35]. Different robots exist, and their characteristics depend on the research interaction. The robots can take humanoid, nonhumanoid, animal, or biomechanical forms. The possibility of controlling them, their capacities to move, to offer feedback and rewards, and to socially interact do not allow the same type scenario when one wants to settle an experiment or a therapy session with a child–robot interaction [10]. However, what is the purpose of researching the use of a robot with a child with ASD? This is not an easy problem to grasp. However, the literature can be classified as follows: research aiming to induce a targeted behavior, such as joint attention, imitation, emotional expression, or spontaneous interaction; research used to teach special tasks to the children; and less research attempting to study the quality and quantity of interactions between a child and a robot [10], which could help clinicians in their diagnosis [11].

Social robots and autism spectrum disorder

As for serious games, children with autism seem to have greater interest in robots than typical children

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Table 1. Description of the main serious games targeting social interaction

Name	Population	Targeted skills	Design	Playability	Results
Games targeting emotion recognition and production					
Junior detective program [22]	Children with AS	Emotion recognition and social skills in context	RCT (49 patients)	Game in 3D allowing a good immersive experience	Improvement in social skills after training and at 5 month follow-up
FaceSay2 [23]	Children with ASD	Facial expression recognition and joint attention	RCT (49 patients)	Static photos not allowing a real game experience	Significant improvement in emotion recognition for the individuals with HF-ASD after training
JeStimule [24]	Children with ASD	Emotion recognition in context	Open trial (33 patients)	Game in 3D allowing a good immersive experience	Significant effect of session × task × emotion interaction for avatars and near significance for pictures of real-life characters
Let's Face it [25]	Children with ASD and AS	Emotion recognition	RCT (42 patients)	Static photographs, not allowing a real game experience	Significant improvement in attention to eyes and mouth in the treatment group
LifeIsGame [20]	Individuals with ASD	Emotion recognition and production in context	Qualitative study	Use of an avatar in 3D	Participants enjoyed playing the game. No assessment
MindReading [26]	Individuals with HF ASD	Emotion recognition in context	2 non-RCTs (experiment 1 : 19 children with ASD and 2 control groups with 22 children with ASD and 24 typical children; experiment 2: 13 children in each group – ASD expe, ASD control and typical control	Films and written examples, not allowing a real game experience	Improvement in emotion recognition only in close but not distant generalization tasks
The transporters [27]	Children with ASD	Emotion comprehension in context	non-RCT (56 children)	Series of videos with QCM at the end	Improvement in emotion recognition
Emotiplay [21■]	Children with HF ASD	Emotion recognition	non-RCT (89 children)	3D environment and short games with photos	Improvement in all emotion recognition measures and parents reported reductions in autistic symptoms
Games targeting social skills					
Cooperative Puzzle Game [28,29]	Children with HF ASD	Collaborative skills	2 open group studies (22 boys with ASD in experiment 1 and 16 boys with ASD in experiment 2)	Puzzle game with enforced collaboration on a multitouch tabletop	Higher number of 'negotiation moves'
ECHOES [30]	Children with ASD	Joint attention and symbol use	Open group study (19 children)	Interaction with an avatar who can adapt his responses to the child's behavior	The children responded significantly more often to the practitioner after the sessions
Teachtown [31]	Children with ASD	Social, adaptative and emotional skills, language	non-RCT study (40 children)	Software educational program with photos and video. Not an immersive game	The treatment group performed better than the control group on the Brigance Inventory of Early Development, but these differences were not significant
Goliah [32]	Children with ASD (IQ > 60)	Imitation and joint attention	Study 1: Non-RCT (24 patients) Study 2: Open 6-month study with EEG correlates	Short tasks with enforced collaboration on 2 tabletops connected to each other	Improvement in both groups with no significant superiority of the training group

AS, Asperger syndrome; ASD, autism spectrum disorders; HF, high functioning.

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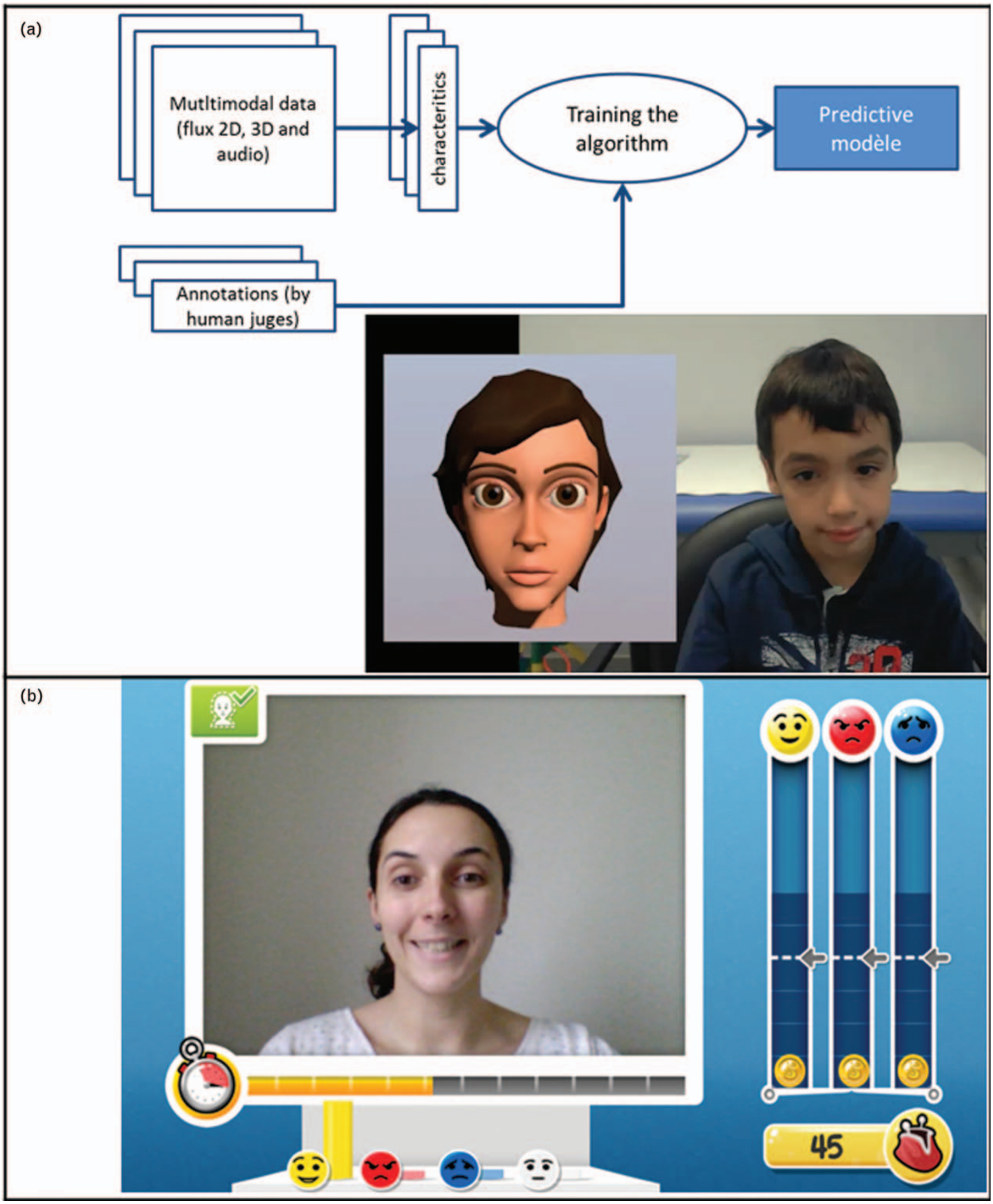

FIGURE 1. JEMImE game. Due to the creation of an algorithm of facial expression recognition (a), the player can receive real-time feedback on his/her production (b).

[36]. Robots present some characteristics that make them less anxiety-inducing for people with ASD. They interact in a simple manner and make social situations less complex [37]. This is why researchers focus their experiments on robots and children with ASD in order to work on social and communication skills [35]. These researchers generally target joint attention, imitation, and social behavior, and less often language. Very few studies have focused on the reduction in stereotypes, but the results are actually promising [38▪]. Given the number of experiments and robotics platforms, it is not within the scope of this brief review to summarize all the literature. At a glance, Table 2 presents the main

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Table 2. Main robots used with individuals with ASD during the years of 2017 and 2018

Robots	Description	Targeted skills
Nao [39–53] 	50 cm tall 25 degrees of freedom 2 cameras Microphones Speakers Touch sensors LEDS Sonars Wi-Fi and ethernet connection Software allows personalization Can be used in classroom, hospital, etc.	Joint attention Imitation Turn taking Eye contact Pointing Basic academic skills Facial expressions Verbal communication Improve spontaneous social interaction Improve robot responses to children's affective state and engagement
Kaspar [54■,55,56,57] 	Semiautonomous Software allows creation of new scenarios Child sized Touch sensors Head, arm and hand movements Customizable Speaker	Support interaction Support simple facial and body expressions, gestures and speech Learn about socially acceptable tactile interaction Imitation Turn taking Collaboration skills Hygiene or food learning
Charlie [58] 	Low cost (200 USD) 2 degrees of freedom in arms 2 degrees of freedom in the head 1 webcam 1 speaker Can be connected to a PC via USB Can detect hands and head	Joint attention Imitation Turn taking
TEO4 [59] 	80 cm tall 2.5 h autonomy Possibility to stick different faces magnetically Dedicated to children with ASD Distance sensors Touch sensors 1 camera Autonomous reactions but can also be driven by an operator Can move and speak	Teo was used in the krog project [60] as a companion for the child during game sessions on a large screen. It reacts when it is touched.
Riby [59] 	The new version of the TEO robot Dedicated to adults with ASD 130 cm tall Sonar sensors	Engaging interaction

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Table 2 (*Continued*)

Robots	Description	Targeted skills
R50-Alice « Mina » [41,61] 	69 cm tall 32 degrees of freedom with 11 degrees of freedom in the head of which 8 are for facial expression and 3 are for neck movements Speaker	Facial expression production Facial expression recognition Imitation
QT Robot [62] 	Screen as his face 14 degrees of freedom for upper-body gestures 3d camera 1 microphone Connection by Wi-Fi	Training emotional abilities Body language Increasing the efficiency of therapy by encouraging an active and engaged interaction
IRobiQ [63] 	45 cm tall Speakers 1 touch screen Touch sensors Sonars sensors IR sensors 1 RGB camera in the head LEDS	IrobiQ showed the following four emotions with the different shapes of its mouth: happiness, sadness, surprise, and shyness. It is a commercial robot that had access to many children's songs that were accompanied by adjustable arm movements
CARO [63] 	93 cm tall 1 touch screen Touch sensors Depth camera RGB camera LEDS	Caro is specially designed to engage in emotional interplay that is focused on emotions that are expressed through the eyes of children with ASD
KiliRo [64,65] 	Semiautonomous 2 degrees of freedom in each leg Head can move down, up, right and left Tail can move right and left One speaker attached on the robot	Improves learning and social interaction abilities

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robots used in relation to autism in 2017 and 2018. Previous studies were reviewed in [9–11,38▪].

Some studies reported that the maximum child engagement appears with nonhumanoid robots. However, humanoid robots elicit a better generalization of the skills learned by the child during the child–robot interaction [66]. A key limitation in the use of robotics is the fact that most of the interactions provided thus far are similar to the wizard of Oz, meaning that an operator is teleoperating the robot during the child–robot interaction [10]. In comparison with serious games, the clinical application of robotics in ASD is still limited, although progress has been great in recent years. An interesting achievement is the formulation of a deep learning algorithm for the automatic perception of the affective state and engagement of children during robot-assisted autism therapy that can offer a better tailored robot response to tackle the heterogeneity among individuals with ASD [53].

The Michelangelo project

The FP7 Michelangelo project is a European project involving partners in Malta, the UK, Ireland, Italy, and France. One task was dedicated to the design of GOLIAH – a serious game that aims to improve joint attention and imitation that was based on the Early Start Denver Model agenda [67]. Two experiments were also performed to investigate scenarios for controlled social interactions between children with ASD and the Nao robot. The first experiment was designed to induce the behavior of joint attention with the child. Nao proposed different behaviors to solicit a response from the child: the robot could look at a picture, look at it and point it, or point to it and ask the child to look at it. During the experiment, automatic measures were collected with three-dimensional (3D) cameras, and specific algorithms were used to assess the child's movements. The results showed that, contrary to some expectations, children with ASD more easily produced joint attention behavior with a human partner than with Nao. However, the experiment showed us that children with autism produce more micromovements and are more unstable in their posture than typical children [51]. The second experiment targeted motor imitation and imitation learning. Children had to imitate movements that the robot produced randomly. The robot was able to recognize when

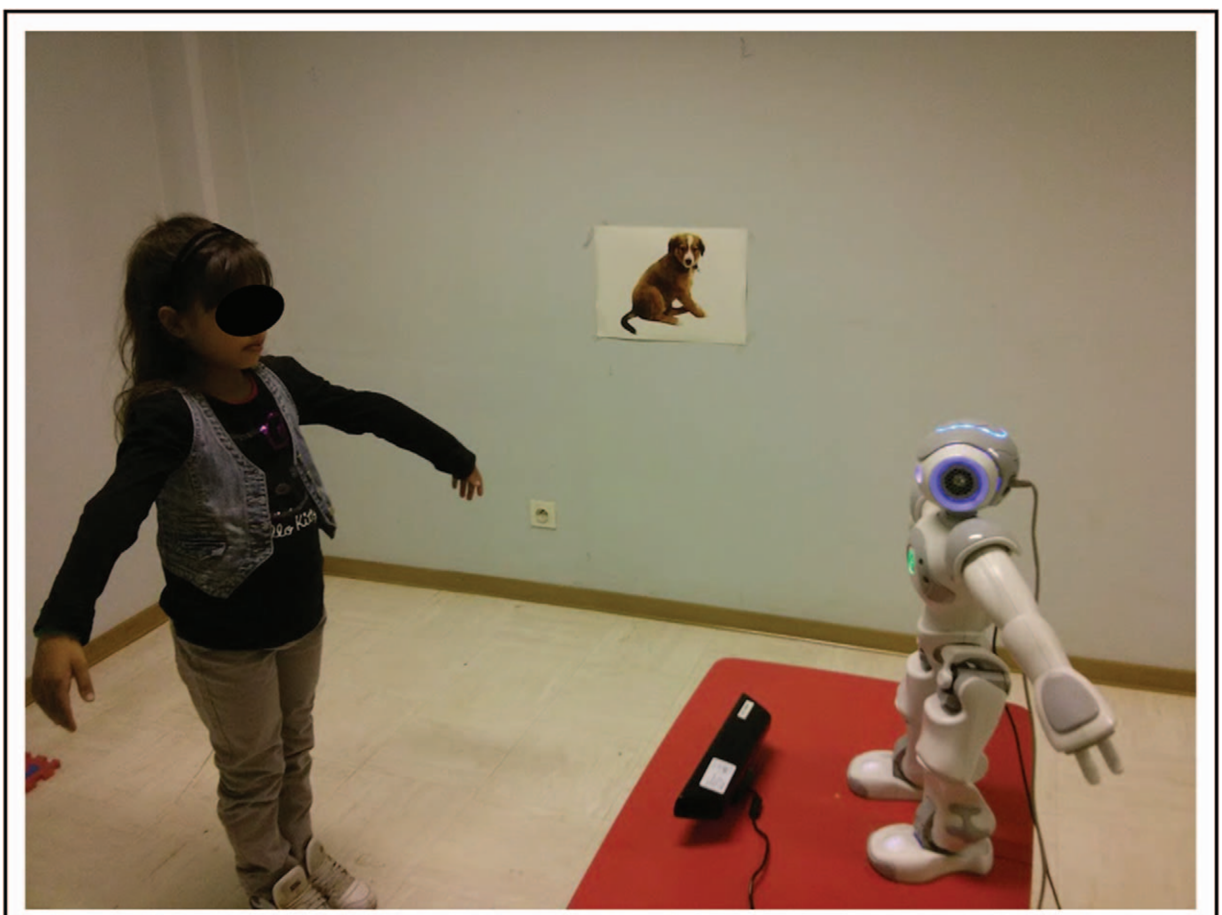

FIGURE 2. Nao imitating a child's movement. Reproduce from [68].

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he/she was imitating. After 2 min of interaction, the robot learned to imitate, and the two roles could be exchanged: the child proposed the movement and the robot imitated him (Fig. 2). When we compared how the robot was able to learn with adults, with typically developing children, and with children with ASD, we found that, despite adequate learning in the three groups of partners, the number of computational neurons recruited to allow learning increased significantly during interaction involving children with ASD [52]. In other words, it seems that the robot was able to identify a form of social signature in ASD children motricity.

To conclude, regarding robotics, the use of robots with ASD individuals seems to be relevant to research on social and communication skills. A recent review found that participants with ASD often show better performance when interacting with a robot than when interacting with a human [38■]. Individuals with ASD demonstrate some social skills with robots that typical children only use with humans. However, even if some researchers are optimistic, the studies published so far indicate that autonomous interactions between robots and children remain limited [10]. Moreover, most studies included very few children and were not adequately powered to show a possible generalization of the targeted skills.

CONCLUSION

The use of ICT for individuals with ASD has increased over the past 10 years. ICTs present some characteristics, such as predictability, visual support, and a sequential presentation of information, which particularly align with the interest and needs of individuals with ASD. Moreover, children with ASD have a specific need for these supports. Equally, ICTs are particularly adapted to work on social and communication skills, such as imitation, joint attention, emotion production, and recognition, which are impaired in ASD. ICTs offer clinicians new ways to interact and work with people with ASD. Serious games and robots are two different support mechanisms that are particularly promising in terms of research, although the former domain has reached better clinical achievements than the latter one. However, the lack of robust studies with strong methodologies and the lack of proof for generalization do not allow evaluation of the benefits of ICT interventions in individuals with ASD.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:
■ of special interest
■■ of outstanding interest

1. Sasson NJ, Faso DJ, Nugent J, *et al.* Neurotypical peers are less willing to interact with those with autism based on thin slice judgments. Sci Rep 2017; 7:740700.
2. Craig F, Margari F, Legrottaglie AR. A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder. Neuropsychiatr Dis Treatment 2016; 12:1191–1202.
3. Demouy J, Plaza M, Xavier J, *et al.* Differential language markers of pathology in autism, pervasive developmental disorder not otherwise specified and specific language impairment research. Autism Spectr Disord 2011; 5:1402–1412.
4. Kim SH, Bal VH, Lord C. Longitudinal follow-up of academic achievement in children with autism from age 2 to 18. J Child Psychol Psychiatry 2018; 59:258–267.
5. Josman N, Ben-Chaim H, Friedrich H, Weiss P. Effectiveness of virtual reality for teaching street-crossing skills to children and adolescents with autism. Int J Disabil Hum Dev 2008; 7:49–56.
6. Bernard-Opitz V, Sriram N, Nakhoda-Sapuan S. Enhancing social problem solving in children with autism and normal children through computer assisted instruction. J Autism Dev Disord 2001; 31:377–384.
7. Boucenna S, Narzisi A, Tilmont E, *et al.* Interactive technologies for autistic children: a review. Cogn Comput 2014; 6:722–740.
8. Park JH, Abirached B, Zhang Y. A framework for designing assistive technologies for teaching children with ASDs emotions. In: CHI'12 Extended Abstracts on Human Factors in Computing Systems. ACM: New York; 2012. pp. 2423–2428.
9. Diehl JJ, Schmitt LM, Villano M, Crowell CR. The clinical use of robots for individuals with autism spectrum disorders: a critical review. Res Autism Spectr Disord 2012; 6:249–262.
10. Huijnen CA, Lexis MA, Jansens R, Witte LP. Mapping robots to therapy and educational objectives for children with autism spectrum disorder. J Autism Dev Disord 2016; 46:2100–2114.
11. Scassellati B. How social robots will help us to diagnose, treat, and understand autism. In: Robotics Research. Springer; 2007. pp. 552–563.
12. Stasolla F, Boccasini A, Perilli V. Assistive technology-based programs to support adaptive behaviors by children with autism spectrum disorders: a literature overview. In: Supporting the Education of Children with Autism Spectrum Disorders. IGI Global; 2017. pp. 140–159.
13. Benssassi EM, Gomez JC, Boyd LE, *et al.* Wearable assistive technologies for autism: opportunities and challenges. IEEE Pervasive Comput 2018; 17:11–21.
14. Shoaib M, Hussain I, Mirza HT, Tayyab M. The role of information and innovative technology for rehabilitation of children with autism: a systematic literature review. In: Computational Science and its Applications (ICCSA), 17th International Conference on IEE; 2017. pp. 1–10.
15. Grynszpan O, Weiss PLT, Perez-Diaz F, Gal E. Innovative technology-based interventions for autism spectrum disorders: a meta-analysis. Autism 2014; 18:346–361.
16. Serret S, Hun S, Thümmler S, *et al.* Teaching literacy skills to French minimally verbal school-aged children with autism spectrum disorders with the serious game SEMA-TIC: an exploratory study. Front Psychol 2017; 8:1523.
17. ■ Grossard C, Grynspan O, Serret S, *et al.* Serious games to teach social interactions and emotions to individuals with autism spectrum disorders (ASD). Comput Educ 2017; 113:195–211.

This review lists 31 serious games to teach social skills and proposes two different scales to evaluate serious game on methodology and on playability

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18. Mitchell P, Parsons S, Leonard A. Using virtual environments for teaching social understanding to 6 adolescents with autistic spectrum disorders. J Autism Dev Disord 2007; 37:589–600.

19. Vannetzel L, Chaby L, Cautru F, *et al.* Neutral versus emotional human stimuli processing in children with pervasive developmental disorders not otherwise specified. Res Autism Spectr Disord 2011; 5:775–783.

20. Fernandes T, Alves S, Miranda J, *et al.* LIFEisGAME: a facial character animation system to help recognize facial expressions. In: International Conference on ENTERprise Information Systems. Berlin: Springer, Heidelberg; 2011. pp. 423–432.

21. ▪ Fridenson-Hayo S, Berggren S, Lassalle A, *et al.* 'Emotiplay': a serious game for learning about emotions in children with autism: results of a cross-cultural evaluation. Eur Child Adolesc Psychiatry 2017; 26:979–992.

The only studies in serious games proposing a cross-cultural evaluation.

22. Beaumont R, Sofronoff K. A multicomponent social skills intervention for children with Asperger syndrome: the Junior Detective Training Program. J Child Psychol Psychiatry 2008; 49:743–753.

23. Hopkins IM, Gower MW, Perez TA, *et al.* Avatar assistant: improving social skills in students with an ASD through a computer-based intervention. J Autism Dev Disord 2011; 41:1543–1555.

24. Serret S, Hun S, Iakimova G, *et al.* Facing the challenge of teaching emotions to individuals with low-and high-functioning autism using a new serious game: a pilot study. Mol Autism 2014; 5:37.

25. Tanaka JW, Wolf JM, Klaiman C, *et al.* Using computerized games to teach face recognition skills to children with autism spectrum disorder: the Let's Face It! program. J Child Psychol Psychiatry 2010; 51:944–952.

26. Golan O, Baron-Cohen S. Systemizing empathy: teaching adults with Asperger syndrome or high-functioning autism to recognize complex emotions using interactive multimedia. Dev Psychopathol 2006; 18:591.

27. Young RL, Posselt M. Using the transporters DVD as a learning tool for children with autism spectrum disorders (ASD). J Autism Dev Disord 2012; 42:984–991.

28. Battocchi A, Gal E, Sasson AB, *et al.* Collaborative puzzle game-an interface for studying collaboration and social interaction for children who are typically developed or who have Autism Spectrum Disorder. 7th ICDVRAT with ArtAbilitation. ICDVRAT/University of Reading, UK; 2008. pp. 127–134.

29. Battocchi A, Pianesi F, Tomasini D, *et al.* Collaborative puzzle game: a tabletop interactive game for fostering collaboration in children with autism spectrum disorders (ASD). J Assist Technol 2010; 4:4–13.

30. Bernardini S, Porayska-Pomsta K, Smith TJ. ECHOES: an intelligent serious game for fostering social communication in children with autism. Inform Sci 2014; 264:41–60.

31. Whalen C, Moss D, Ilan AB, *et al.* Efficacy of TeachTown: basics computer-assisted intervention for the intensive comprehensive autism program in Los Angeles unified school district. Autism 2010; 14:179–197.

32. Jouen AL, Narzisi A, Xavier J, *et al.* GOLIAH (Gaming Open Library for Intervention in Autism at Home): a 6-month single blind matched controlled exploratory study. Child Adolesc Psychiatry Mental Health 2017; 11:17.

33. Grossard C, Hun S, Serret S, *et al.* The reeducation of emotional expressions for children with autism spectrum disorders thanks to information communication technologies: JEMImE project. Neuropsychiatrie de l'Enfance et de l'Adolescence 2017; 65:21–32.

34. Dapogny A, Grossard C, Hun S. JEMImE: a serious game to teach children with ASD how to adequately produce facial expressions. In: Automatic Face and Gesture Recognition (FG 2018). 2018 13th IEEE International Conference on IEE; 2018. pp. 723–730.

35. Aresti-Bartolome N, Garcia-Zapirain B. Technologies as support tools for persons with autistic spectrum disorder: a systematic review. Int J Environ Res Public Health 2014; 11:7767–7802.

36. Boucenna S, Narzisi A, Tilmont E, *et al.* Information communication technology (ICT) and autism: overview and focus on early developmental issues and social robotics. Cogn Comput 2014.

37. Goodrich MA, Colton M, Brinton B, *et al.* Incorporating a robot into an autism therapy team. IEEE Intell Syst 2012; 27:52–59.

38. ▪ Pennisi P, Tonacci A, Tartarisco G, *et al.* Autism and social robotics: a systematic review. Autism Res 2016; 9:165–183.

This review resumed the different social robots use in ASD, their application, and the remaining questions.

39. David DO, Costescu CA, Matu S, *et al.* Developing joint attention for children with autism in robot-enhanced therapy. Int J Soc Robot 2018; 6:1–11.

40. Anzalone SM, Xavier J, Boucenna S, *et al.* Quantifying patterns of joint attention during human-robot interactions: an application for autism spectrum disorder assessment. Pattern Recogn Lett 2018.

41. Taheri A, Meghdari A, Alemi M, Pouretemad H. Human–robot interaction in autism treatment: a case study on three pairs of autistic children as twins, siblings, and classmates. Int J Soc Robot 2018; 10:93–113.

42. Saadatzi MN, Pennington RC, Welch KC, Graham JH. Small-group technology-assisted instruction: virtual teacher and robot peer for individuals with autism spectrum disorder. J Autism Dev Disord 2018; doi: 10.1007/s10803-018-3654-2 [Epub ahead of print]

43. Zheng Z, Zhao H, Swanson AR, *et al.* Design, development, and evaluation of a noninvasive autonomous robot-mediated joint attention intervention system for young children with ASD. IEEE Trans Hum Machine Syst 2018; 48: 125–135.

44. Conti D, Di Nuovo A, Trubia G, *et al.* Adapting robot-assisted therapy of children with autism and different levels of intellectual disability: a preliminary study. In: Companion of the 2018 ACM/IEEE International Conference on Human-Robot Interaction. ACM; 2018. pp. 91–92.

45. So WC, Wong MKY, Lam WY, *et al.* Robot-based intervention may reduce delay in the production of intransitive gestures in Chinese-speaking preschoolers with autism spectrum disorder. Mol Autism 2018; 9:34.

46. Desideri L, Negrini M, Malavasi M, *et al.* Using a humanoid robot as a complement to interventions for children with autism spectrum disorder: a pilot study. Adv Neurodevelop Disord 2018; 1–13.

47. Talaei-Khoei A, Lewis L, Kaul M, *et al.* Use of Lean Robotic Communication to Improve Social Response of Children with Autism; 2017. https://www.researchgate.net/profile/Jay_Daniel3/publication/318129979_Use_of_Lean_Robotic_Communication_to_Improve_Social_Response_of_Children_with_Autism/links/595b77010f7e9bf415b48660/Use-of-Lean-Robotic-Communication-to-Improve-Social-Response-of-Children-with-Autism.pdf.

48. González JC, Pulido JC, Fernández F. A three-layer planning architecture for the autonomous control of rehabilitation therapies based on social robots. Cogn Syst Res 2017; 43:232–249.

49. Palestra G, Cazzato D, Adamo F, *et al.* Assistive robot, RGB-D sensor and graphical user interface to encourage communication skills in ASD population. J Med Robot Res 2017; 2:1740002.

50. Rudovic O, Lee J, Mascarell-Maricic L, *et al.* Measuring engagement in robot-assisted autism therapy: a cross-cultural study. Front Robot AI 2017; 4:36.

51. Anzalone SM, Tilmont E, Boucenna S, *et al.* How children with autism spectrum disorder explore the 4-dimension (spatial 3D + time) environment during a joint attention induction task. Res Autism Spectr Disord 2014; 8:814–826.

52. Boucenna S, Anzalone S, Tilmont E, *et al.* Extraction of social signatures through imitation learning between a robot and a human partner. IEEE Trans Autonom Mental Dev 2014; 6:213–225.

53. Rudovic O, Lee J, Dai M, *et al.* Personalized machine learning for robot perception of affect and engagement in autism therapy. Sci Robot 2018; 3:eaao6760.

54. ▪ Robins B, Dautenhahn K, Nadel J. Kaspar, the social robot and ways it may help children with autism: an overview. Enfance 2018; 1:91–102.

A good recapitulation of the different uses of Kaspar.

55. Mengoni SE, Irvine K, Thakur D, *et al.* Feasibility study of a randomised controlled trial to investigate the effectiveness of using a humanoid robot to improve the social skills of children with autism spectrum disorder (Kaspar RCT): a study protocol. BMJ Open 2017; 7:e017376.

56. Robins B, Dautenhahn K, Wood L, Zaraki A. Developing interaction scenarios with a humanoid robot to encourage visual perspective taking skills in children with autism: preliminary proof of concept tests. In: International Conference on Social Robotics. Springer: Cham; 2017. pp. 147–155.

57. Wood LJ, Zaraki A, Walters ML, *et al.* The Iterative Development of the Humanoid Robot Kaspar: An Assistive Robot for Children with Autism. In: International Conference on Social Robotics. Springer, Cham; 2017; pp. 53–63.

58. Boccanfuso L, Scarborough S, Abramson RK, *et al.* A low-cost socially assistive robot and robot-assisted intervention for children with autism spectrum disorder: field trials and lessons learned. Autonomous Robots 2017; 41:637–655.

59. Romero M, Bonarini A, Brivio A, Rogacheva K. Incremental and radical innovation: design in robotics for autism. Teo and Riby robots. Evolutionary development. Design J 2017; 20(Suppl 1):S2375–S2388.

60. Gelsomini M, Bonarini A, Clasadonte F. Blending robots and full-body interaction with large screens for children with intellectual disability. IDC 2015; 315–354.

61. Pour AG, Taheri A, Alemi M, Meghdari A. Human–robot facial expression reciprocal interaction platform: case studies on children with autism. Int J Soc Robot 2018; 10:179–198.

62. Costa AP, Steffgen G, Lera FR, *et al.* Socially assistive robots for teaching emotional abilities to children with autism spectrum disorder. In: 3rd Workshop on Child-Robot Interaction at HRI; 2017.

63. Yun SS, Choi J, Park SK, *et al.* Social skills training for children with autism spectrum disorder using a robotic behavioral intervention system. Autism Res 2017; 10:1306–1323.

64. Bharatharaj J, Huang L, Al-Jumaily A, *et al.* Investigating the effects of robot-assisted therapy among children with autism spectrum disorder using bio-markers. In: IOP Conference Series: Materials Science and Engineering, Vol. 234. IOP Publishing; 2017. p. 012017.

65. Bharatharaj J, Huang L, Mohan RE, *et al.* Robot-assisted therapy for learning and social interaction of children with autism spectrum disorder. Robotics 2017; 6:4.

66. Ricks DJ, Colton MB. Trends and considerations in robot-assisted autism therapy. In: Robotics and Automation (ICRA), IEEE (Institute of Electrical and Electronics Engineers) International Conference; 2010. pp. 4354–4359.

67. Dawson G, Rogers S, Munson J, *et al.* Controlled trial of an intervention for toddlers with autism: the early start Denver model. Pediatrics 2009; 125:17–23.

68. Boucenna S, Cohen D, Meltzoff AN, *et al.* Robots learn to recognize individuals from imitative encounters with people and avatars. Sci Rep 2016; 6:; 19908. doi:10.1038/srep19908.

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