Support Technology for Nonverbal Communication of Students With Autism Spectrum Disorder –Systematic Review

María Isabel Gómez-León, Universidad Internacional de La Rioja, Spain

The Paris Conference on Education 2023
Official Conference Proceedings

Abstract
In recent years there have been an exponential number of technological proposals designed for students with autism spectrum disorder (ASD) of which there is not always enough evidence to support their effectiveness. This can make it difficult for teachers and students to benefit from technology support that is more effective and tailored to the needs of these students. The aim of this review was to analyze and synthesize scientific evidence on the effectiveness of technological resources in improving the nonverbal communication skills of students with ASD. To this end, a systematic review of the scientific publications indexed in some of the most relevant databases was carried out following the criteria established in the PRISMA declaration. In total, the methodological quality of 43 articles that met the pre-established inclusion criteria was analyzed. A clear trend was found to encourage student inclusion through mobile technologies and low-cost, high-availability platforms that allow personalized real-time and remote interventions in natural contexts such as classrooms. However, future research should consider measuring the effectiveness of these technologies through more robust studies in terms of methodology.

Keywords: Education Technology, Autism, Autism Spectrum Disorder, Social, Emotional

Introduction

Nonverbal communication skills account for more than 60% of overall communication capacity and have been identified as the basis of socio-emotional competence and one of the largest deficits in the way children with autism spectrum disorder (ASD) socialize (Wall et al., 2021). The difficulties associated with this type of communication vary widely and include the understanding of facial expressions, the use of conversational gestures and the imitation of body movements (Gómez-León, 2019a, 2019b). For students with ASD understanding these subtleties in communication plays a fundamental role in building friendships and trusting relationships with others, especially during school years, It is therefore essential that school-based interventions respond to these needs, using the right tools. One of the resources that can be effective is the use of technology, which has a number of characteristics that favor its implementation in this population. Technology allows predictable, consistent programming and free of immediate social stressors, in addition, students can work at their own pace and level of understanding, lessons can be repeated until mastery is achieved and rewards are usually immediate and personalized, which increases the interest and motivation of students (Zervogianni et al., 2020).

The socio-emotional competence required in real life involves a combination of different skills of greater or lesser complexity, such as perspective-taking, emotional regulation, cognitive flexibility, or proper use of language. However, research has suggested that early deficits in the basic skills of social interaction, such as understanding and emotional expression, imitation and joint attention, give rise to cascade difficulties in acquiring more complex forms of social skills. So a significant part of the design of intervention technologies for children with ASD has focused on basic skills that support more complex forms of social skills (Berggren et al., 2018). In this sense, during the last years there has been an exponential number of technological proposals designed for children with ASD, of which there is not always enough evidence to support its effectiveness (Zervogianni et al., 2020). Kim et al. (2018) found that of 695 mobile apps labeled as «autism apps» only 4.9% had actual clinical evidence supporting their use or benefit. In addition, digital media that do have published evidence of effectiveness are rarely available to the consumer, so education professionals often turn to other sources of information to make decisions about the type of technology to use in the classroom, such as personal values and preferences or product website reviews (Zervogianni et al., 2020). This can make it difficult for students with ASD to benefit from the most effective and tailored digital support, moreover, inappropriate practice could lead to counterproductive and sometimes potentially harmful outcomes for the student.

To successfully integrate technology into any educational program, professionals should have a frame of reference that allows them to know what technology is available and what level of evidence can support its use in the classroom.

The objective of this review is to analyze and synthesize scientific evidence on the effectiveness of potentially viable technological resources for implementation in the classroom in improving understanding and emotional production skills, imitation and joint care of children and adolescents with ASD.

Method

A search was made for the scientific publications indexed in the databases Scopus, Web of Science, PubMed, ERIC, IEEE Xplore and ACM Digital Library following the criteria established in the PRISMA declaration (Page et al., 2021).

The terms (autism OR autism spectrum disorder OR ASD) AND (technology* OR tablet OR iPad OR iPod OR smartphone OR mobile device OR apple watch OR google glass OR virtual reality OR augmented reality OR computer OR avatar OR kinect OR eye tracker) were used AND (social* OR emotional* OR imitation OR joint attention).

Articles published in peer-reviewed journals or conference proceedings aimed at demonstrating the effectiveness of digital technology in improving emotional understanding and production, imitation and joint care of children and adolescents with ASD were included. Only primary studies were included and all designs (e.g., randomized control, inter- or intra-subject, case reports) without language restriction were considered. Following the evidence criteria established by Wong et al. (2015) revisions from 2000 to 2023 were included so that the intervention could have been replicated a sufficient number of times by independent researchers to justify its effectiveness.

Systematic reviews and meta-analyses were excluded, articles whose sample did not include children with ASD or did not report the results of ASD separately and those focused on training general interaction and social communication skills that did not present data on emotional recognition and production, imitation and joint care independently. Also excluded were those studies focused exclusively on the academic or cognitive results of the participants and whose purpose was not to check the effectiveness of the digital technology used. In addition, studies whose technology was not feasible, in terms of implementation, in the current educational context, such as immersive virtual environments CAVE (Cave Assisted Virtual Environment) or Blue Room, training through covert audio or neurofeedback were excluded.

The final selection consisted of 43 articles were classified into four categories: emotional recognition, emotional expression, imitation and joint attention.

Emotional Recognition

Children with ASD have difficulty recognizing facial expressions, these difficulties increase over time which, in turn, is related to greater difficulties in social situations (Wall et al., 2021). Most applications on computers or digital tablet for children with ASD work emotion recognition. These are based on media such as photos, drawings, audio recordings, videos or 3D characters. It has been shown that, although young children with ASD show poor performance in emotional recognition of human and nonhuman faces, teens with ASD show significantly better recognition when it comes to cartoons presented through the computer than when it comes to humans, being able to improve even, the performance of neurotypical adolescents in the *Mind Reading Eye Test* (Atherton & Cross, 2021).

The first applications created for emotional recognition required associating the facial expressions of the avatar (happy, sad, angry and frightened) with an emotion or a social situation with emotional connotation. In the experiment of Moore et al. (2005) the results showed that more than 90% of children with high functioning ASD were able to assign the appropriate emotional state to the animated characters. Golan et al. (2010) designed an interactive DVD called *The Transporters* aimed at young children that depicts social interactions between vehicles (train, tram, bus) with real expressive human faces. After watching the episodes, the child interacted with the system by matching faces with faces, faces with emotions or situations with faces. In their study, the children who participated in the intervention showed a significantly greater improvement in the ability to recognize facial expressions than those who did not receive intervention. Moreover, they were able to transfer this ability to real human characters. This result was found in two randomized controlled studies and one of subsequent intrasubject design with 25 (Young & Posselt, 2012), 77 (Gev et al., 2017) and 14 (Yan et al., 2018) preschoolers with ASD, respectively. Hopkins et al. (2011) and Rice et al., (2015) in two randomized controlled studies showed that practicing emotional recognition, the direction of the gaze and joint attention through the serious game *FaceSay* with interactive and realistic avatar assistants improved the recognition of emotions. Moreover, Rice et al., (2015), using the same application, found improvements in broader domains of cognitive and social skills.

Although the recognition of emotions is multimodal in nature, visual unimodal learning has most often been used. In this sense, LaCava et al. (2007) added audio support in the program *Mind Reading*, students not only improved in the recognition of facial and vocal emotions with educational software, but also improved interactions with their peers. Thomer et al. (2015) used an improved *Mind Reading* protocol that included interactive software instructions, live testing, and behavioral reinforcement. The authors found improvements in all measures: recognition of emotions in faces and voices and skills of coding and decoding emotions, although the sizes of the effect were only great in recognizing emotions in faces. Fridenson-Hayo et al. (2017) evaluated transculturally (in the UK, Israel and Sweden) the training with *Emotiplay*, a serious game aimed at teaching the recognition of emotions through faces, voices, body language and its integration into context in children with high functioning ASD. In the three samples, from 15, 38 and 36 participants aged six to nine years, significant improvements in emotional recognition were found, moreover, there were more widespread gains in socialization and reduction of autism symptoms.

Few games have been interested in body posture as an indicator of the emotion felt. *JeStiMulE* is a serious game validated in a design of independent measures. It is intended to work recognizing nine emotions through facial expressions, but also gestures and posture. The game is aimed at children and adolescents with ASD regardless of their level of cognitive functioning (Serret on al., 2014). There are two phases, a learning phase to teach children to associate facial expression, vocal, posture and gestures before an emotion. And a phase of the game in which the player is immersed in a 3D environment and during which he attends scenarios that must associate an emotion. The results showed that children progressed with the use of play and were able to generalize progress outside the context of the intervention. However, during the game, the children received no feedback on the quality of their responses, especially at times of imitation, nor on the quality of their emotional production on the plane of facial movements or prosody, something that Grossard et al. (2019) incorporated in later versions.

Most of these games have proposed working the recognition of emotions with avatars and preconstructed contexts, so there is a lack of communication in real time between children and guardians. To avoid this, Beaumont & Sofronoff (2008) created *The Junior Detective*, a training program in recognition of emotions and social skills. A randomized trial was conducted with several types of interventions: the computer game itself, but also group interventions that included the training of parents and professionals to generalize learning done on the computer through role play or exercises at home. In the study the children progressed in social skills, which remained five months after the intervention. However, no progress was observed in the recognition of facial expressions and body postures. Sturm et al. (2019) designed a hybrid Kinect game to promote collaboration between students with ASD and their neurotypical peers and encourage recognition of complex emotions. The game required two students to cooperate and interact with each other, not only within the game environment but also in the real world. The emotion recognition game had two phases: in the first the students independently assembled the pieces of a digital puzzle, in the second they had to communicate with each other to agree on the appropriate emotion according to the context and build the emotional face for the body they had assembled. Preliminary observations showed the effectiveness of emotion recognition modeling and collaboration by peers who had stronger social skills.

Augmented reality allows you to overlay virtual data in real world images to draw attention to the social keys that allow you to acquire the skills of recognition and emotional production. The combination of real and virtual elements can favor the generalization of learning to the real world. The augmented reality *Ying mobile app* was used for emotion recognition using three-dimensional characters depicting a parody. The child had to find out what emotion the character would have in a given situation. The application showed its effectiveness in eight children between two and six years with ASD (Alharbi & Huang, 2020). Augmented reality also includes the representation of one's own body, which can help the development of body awareness in students with ASD. In the studies of Chen et al. (2015) and Chen et al. (2016), a system was designed using an augmented reality mirror through which three and six teenagers with ASD, respectively, could see themselves with virtual 3D facial expressions. The data indicated that intervention could improve appropriate recognition and response to facial emotional expressions seen in the situational task.

Mantzio et al. (2015) found that the benefits of technology were only seen in children with high-functioning but not low-functioning ASD. The author questioned whether the results could be generalized to the entire population with ASD. In this sense, Tanaka et al. (2010) found an improvement in the holistic processing of faces in adolescents with ASD of different degree of functioning. Improvement was observed after a 20-hour facial recognition training using *Let's Face It!* However, in a later study he found that, although adolescents were able to label basic facial emotions, they showed difficulties in generalizing emotions through different identities (Tanaka et al., 2012). Moreover, while neurotypical participants showed a more holistic coding for the eyes than for the mouth on expressive faces, participants with ASD exhibited the inverse pattern. This suggests that difficulties in generalizing learning may be related to the type of analytical and holistic facial processing strategies used by students with ASD.

Emotional Expression

Carter et al. (2014) compared human intervention with a human-controlled avatar for emotional expression training in twelve children with ASD aged four to eight. Verbal and gestural communication of children with ASD was found to be stronger with the therapist and weaker with the cartoon character of the software. However, Frolli et al. (2022) found in a sample of 60 children with high functioning ASD, aged 9 and 10, that the virtual reality intervention was more effective in the use of secondary emotions than the intervention with a therapist.

To train emotional expression, a series of experiments with video models have been established, a technique that shows desired video behaviors to develop social skills. So et al. (2016) performed an intervention on 20 children with low functioning ASD. School-age children were taught to recognize, imitate and produce 20 gestures by video modeling through a robotic animation presented through a computer. The children recognized, imitated and produced more gestures adapted to different social contexts after the training. In addition, they were able to generalize their gestural skills to a novel environment with a human researcher. In a later study they used social robots to teach children to recognize and produce gestures that express feelings and needs (So et al., 2017). After the intervention, children were more likely to recognize gestures and gesture accurately in trained and untrained scenarios. They also generalized the recognition skills acquired to person-to-person interaction. However, there was no solid evidence showing that children in the intervention group could produce precise gestures in person-to-person interaction.

Few serious games have been found for the production of facial expressions adapted to a given social context. *LifeIsGame* aims to teach children with ASD to recognize facial emotions by automatically analyzing real-time facial expressions and synthesizing virtual characters. It also offers the ability to make the game more challenging by hiding the eyes or mouth of the avatar. The game offers different modes to users, including the evaluation of the expression made by a character, manipulate the facial expression of a three-dimensional avatar and physically perform a facial expression consistent with a story told without an avatar model. Fernandes et al. (2011) verified the effectiveness of this game in the emotional expression of two children with high functioning ASD.

One of the limitations of these programs is that most focus only on predefined body language and facial expressions limited by the training system. To avoid this, recent research has created the *Kinect Skeletal Tracking* system that allows trainers to control virtual 3D characters so they can produce in real time the full range of natural body language and appropriate facial expressions. The data showed that this system helped three children with ASD from seven to nine years to improve their social interaction (Lee, 2021).

Anishchenko et al., (2017) developed an application for learning the perception and production of facial expressions using a computer vision algorithm. This algorithm, recently designed for facial expression analysis, provides the child with indicators that help him to evaluate the quality of his production and improve it. The clinical trial was conducted in 19 children with ASD aged 6 to 12 years. It was shown that after the intervention improved the skills of participants in the recognition of emotions. The ability to transfer newly developed skills to children’s daily lives was also investigated. The questioning of the parents 6 months after the intervention shows that 10 of the 19 children were able to recognize emotions and change their behavior in everyday life. *JEMImE* aims to train emotional production in a virtual 3D environment with social situations (Dapogny et al., 2018). This app also uses an algorithm that provides the child with real-time facial expression feedback. During the training phase, 23 children with school-age ASD showed a significant progression in the production of facial expressions (Grossard et al., 2019).

Imitation

Imitation has two essential functions for adaptation: it serves to learn and it serves to communicate without words. Lack of understanding and imitation of another person’s action is one of the main problems when interacting with a child with ASD, However, the appropriate stimulation of imitation can favour behaviours that share a common objective and adapted to the social context.

Malinverni et al. (2017) developed a *Kinect*-based virtual environment game for children with high-functioning ASD called Pico's Adventures. Through the programmed movement this game aimed to encourage children to initiate interaction with peers and increase imitation, cooperation, role-playing and emotional recognition. The results showed that the game was effective in promoting social behaviors of ten children with ASD, from four to six years. This game reflects an interesting application to develop a programmed movement game that promotes prosocial behaviors in children with autism. However, the effectiveness of the game in generalizing target abilities to the real world has not been evaluated.

Goliath (Bono et al., 2016) is a platform that seeks to stimulate imitation and joint attention. To progress the child needs to interact with the instructor, who can control what is proposed to the child. For the imitation tasks, six games were designed with different levels of difficulty: imitating a sound, vocal imitation, imitation action sequences, imitation construction and imitation of sentences or sound sequences. For joint attention were created four games, also with different levels of difficulty and conditions, which concern joint attention in the image, in the video, in a drawing task, and finally in an exercise of cooking recipes for two. The study by Bono et al. (2016) with 10 children aged 5 to 9 years showed a rapid improvement in performance in tasks based on imitation and joint attention. However, another study found no significant differences between children aged five to eight years who used the game with their usual treatment and those who did not use it (Jouen et al., 2017).

Joint Attention

Joint attention refers to a triadic interaction in which both agents focus on a single object. This interaction involves following the gaze or looking simultaneously and seeing the behavior of other agents as intentionally driven. Children with ASD have difficulty sharing care or interests with others, reducing their chances of social interaction.

Grynszpan et al. (2012) analyzed the social gaze patterns often reported in children and adolescents with ASD and designed a computer system that leverages the ability of an eye tracker or real-time tracking of users' eye movements. His device allowed videos to be displayed on the screen completely blurred except for a clear viewing window located around the user's focal point. The movements of the child's eyes thus moved the window of vision that served as feedback to control the look. The objective was to capture with the viewing window the emotional state of the face and deduce the correct interpretation of its message. For example, if the character said "*What luck!*" with a disappointed expression, the message conveyed should be understood as ironic. The results were promising, but more research is needed to prove their effectiveness. In *ECHOES* (Bernardini et al., 2014), children interact with a virtual character in the context of social situations through a screen with eye tracking. Children were rewarded when they produced behaviors that manifested a non-verbal communication, such as eye contact or tracking the look of the virtual face. The interaction was structured around a series of routine real-world activities at school and at home. The results with 29 children aged 4 to 14 years with ASD in the school context showed that *ECHOES* helped to practice and acquire joint care and social communication skills. Lahiri et al. (2011) developed a similar dynamic eye tracking system. This system called «Virtual interactive system with adaptive response technology sensitive to the look» (*Virtual Interactive system with Gaze-sensitive Adaptive Response Technology, VIGART*) monitored the child's gaze in real time and provided individualized feedback during their interaction with a virtual agent. Data from six adolescents with ASD indicated an improvement in social care for agents.

The use of mobile devices in the classroom provides advantages such as low cost and greater flexibility of use and availability. However, the results in terms of their effectiveness in improving joint care are not sufficiently proven. Lozano et al. (2017) in a case study with a four-year-old with ASD found an increase in joint care after a seven-session intervention through educational applications on a digital tablet. In another study, Guzman et al (2022) found no difference in attention time when eleven children with ASD aged five to nine interacted with the *AppTEA* application or when they did not. Alcorn et al. (2011) employed an autonomous virtual agent through the simplified version of *ECHOES* to develop joint care skills in 32 school-age children. The virtual character «looked» at the child with ASD participating in the game, then looked at the flower, sometimes pointing at it. Children could point to the correct flower on the screen or two of which were not designated by the virtual agent. Both precision and reaction time data suggested that the children were able to successfully complete the task by pointing to the right flower. However, the study does not report any change in participants' skills due to the short training session. Pérez-Fuster et al. (2022) used the Pictogram Room augmented reality application on six children with low-functioning ASD between 3 and 8 years old. The aim of the intervention was to improve joint care, eye tracking and pointing. Different activities were carried out to encourage body language and recognition of oneself through a *Kinet* sensor. The results showed the effectiveness of the application in joint care skills. Improvements were maintained over time and generalized to real-world situations (Pérez-Fuster et al., 2022).

MOSOCO was one of the first mobile assistive apps to use augmented reality and eye tracking to help students with ASD practice social skills like eye contact in real-life school situations (Escobedo et al., 2012). If *MOSOCO* inferred that eye contact was not achieved correctly it showed a warning with an image and a text message that suggested to the child what to do (e.g., «*look your partner in the eye*»). Once it detected that both students had made eye contact, it made a sound and highlighted the next step. The application was effective in increasing the number and practice of social interactions in three students with ASD from 8 to 11 years.

Wearable technology such as watches or smart glasses is a novel advance capable of providing potentially more discreet, naturalistic and real-time strategies through which to support students with ASD. O'Brien et al., (2021) tested the feasibility of using smartwatches (*Apple Watch*) on eight children between the ages of six and fifteen with ASD to increase joint attention to the task. Through a case series design it was proven that the children could follow the directives of scene signals that a mentor sent through images in real time. However, the study was limited to one session and therefore lacks data on the generalization and maintenance of results.

Recent research uses Google Glass hardware to direct the attention of children with ASD to the keys that can guide them to a better understanding of facial expressions (Liu et al., 2017; Voss et al., 2019). Through a mobile application the instructor can control participation activities at a distance and in real time. The system tracks faces, classifies partner emotions, provides listening and verbal cues, and provides immediate social cues for reinforcement. In a randomized clinical trial, Voss et al. (2019) demonstrated that the *Superpower Glass* intervention implemented through *Google Glass* promoted joint attention, eye contact, emotion recognition and social interaction in 40 children with ASD aged 6 to 12. Moreover, the effects were maintained until at least six weeks after treatment. *Face Game* and *Emotion Game* are two apps designed to help children look at the face and eyes and recognize facial emotion, respectively. *Face Game* detects human faces in real time by superimposing them with an augmented reality cartoon face to attract the child's attention. When he has succeeded he gradually fades revealing the underlying human face. At this time, reward him with points, if the child looks at more socially relevant regions, such as the eye region, the reward is greater. Its effectiveness has been shown in two eight- and nine-year-old ASD students, who improved joint attention, eye contact and social engagement (Liu et al., 2017).

Conclusion

The use of technology offers new options in teaching those teachers who aim to improve the socio-emotional competence of students with ASD. There is a tendency to design mobile, low-weight and controlled technologies in real time and at a distance with a clearly inclusive approach. Studies have highlighted the positive impact of serious gaming and the virtual and augmented reality used in combination with other technologies, including smart phones and glasses, mirror-based systems and Kinect sensors.

Some projects aim to: empower children to recognize and reproduce facial expressions, voice tones and body gestures through interactive games, text communication, animations and video and audio clips; create technologies that can capture the orientations of the users' eyes and guide them towards the relevant social keys in natural contexts and at a distance; combining multiple technologies that help students assess the quality of their production and improve it in real time; upgrading network-based remote control platforms allowing teachers greater customization, availability and ease of use at a lower cost.

However, future research should consider measuring the effectiveness of these technologies through more robust studies in terms of methodology, i.e., large and heterogeneous samples (in terms of age and severity of symptoms) control groups, longer processing periods and data on the generalization and maintenance of results.

References

Alcorn, A., Pain, H., Rajendran, G., Smith, T., Lemon, O., Porayska-Pomsta, K., ... & Bernardini, S. (2011, June). Social communication between virtual characters and children with autism. In *international conference on artificial intelligence in education* (pp. 7-14). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-21869-9_4

Alharbi, M., & Huang, S. (2020). An Augmentative System with Facial and Emotion Recognition for Improving Social Skills of Children with Autism Spectrum Disorders. In *2020 IEEE International Systems Conference (SysCon)* (pp. 1-6). IEEE. http://doi.org/10.1109/SysCon47679.2020.9275659

Anishchenko, S., Sarelaynen, A., Kalinin, K., Popova, A., Malygina-Lastovka, N., & Mesnyankina, K. (2017, February). Mobile Tutoring System in Facial Expression Perception and Production for Children with Autism Spectrum Disorder. In *VISIGRAPP (5: VISAPP)* (pp. 319-324). https://doi.org/10.5220/0006146003190324

Atherton, G., & Cross, L. (2021). The Use of Analog and Digital Games for Autism Interventions. *Frontiers in psychology*, *12*, 669734. https://doi.org/10.3389/fpsyg.2021.669734

Beaumont, R., & Sofronoff, K. (2008). A multi-component social skills intervention for children with Asperger syndrome: the Junior Detective Training Program. *Journal of child psychology and psychiatry, and allied disciplines*, *49*(7), 743–753. https://doi.org/10.1111/j.1469-7610.2008.01920.x

Berggren, S., Fletcher-Watson, S., Milenkovic, N., Marschik, P. B., Bölte, S., & Jonsson, U. (2018). Emotion recognition training in autism spectrum disorder: A systematic review of challenges related to generalizability. *Developmental neurorehabilitation*, *21*(3), 141–154. https://doi.org/10.1080/17518423.2017.1305004

Bernardini, S., Porayska-Pomsta, K., & Smith, T. J. (2014). ECHOES: An intelligent serious game for fostering social communication in children with autism. Information Sciences, 264, 41-60. https://doi.org/10.1016/j.ins.2013.10.027

Bono, V., Narzisi, A., Jouen, A. L., Tilmont, E., Hommel, S., Jamal, W., Xavier, J., Billeci, L., Maharatna, K., Wald, M., Chetouani, M., Cohen, D., Muratori, F., & MICHELANGELO Study Group (2016). GOLIAH: A Gaming Platform for Home-Based Intervention in Autism - Principles and Design. *Frontiers in psychiatry*, *7*, 70. https://doi.org/10.3389/fpsyt.2016.00070

Carter, E. J., Williams, D. L., Hodgins, J. K., & Lehman, J. F. (2014). Are children with autism more responsive to animated characters? A study of interactions with humans and human-controlled avatars. *Journal of autism and developmental disorders*, 44(10), 2475–2485. https://doi.org/10.1007/s10803-014-2116-8

Chen, C. H., Lee, I. J., & Lin, L. Y. (2015). Augmented reality-based self-facial modeling to promote the emotional expression and social skills of adolescents with autism spectrum disorders. *Research in developmental disabilities*, *36C*, 396–403. https://doi.org/10.1016/j.ridd.2014.10.015

Chen, C.-H., Lee, I-J., & Lin, L.-Y. (2016). Augmented reality-based video-modeling storybook of nonverbal facial cues for children with autism spectrum disorder to improve their perceptions and judgments of facial expressions and emotions. *Computers in Human Behavior, 55*(Part A), 477–485. https://doi.org/10.1016/j.chb.2015.09.033

Dapogny, A., Grossard, C., Hun, S., Serret, S., Bourgeois, J., Jean-Marie, H., ... & Bailly, K. (2018, May). JEMImE: a serious game to teach children with ASD how to adequately produce facial expressions. In *2018 13th IEEE International Conference on Automatic Face & Gesture Recognition (FG 2018)* (pp. 723-730). IEEE. https://doi.org/10.1109/FG.2018.00114

Escobedo, L., Nguyen, D. H., Boyd, L., Hirano, S., Rangel, A., Garcia-Rosas, D., ... & Hayes, G. (2012, May). MOSOCO: a mobile assistive tool to support children with autism practicing social skills in real-life situations. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 2589-2598). https://doi.org/10.1145/2207676.2208649

Fernandes, T., Alves, S., Miranda, J., Queirós, C., & Orvalho, V. (2011, October). LIFEisGAME: A facial character animation system to help recognize facial expressions. In *International Conference on ENTERprise Information Systems* (pp. 423-432). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-24352-3_44

Fridenson-Hayo, S., Berggren, S., Lassalle, A., Tal, S., Pigat, D., Meir-Goren, N., O'Reilly, H., Ben-Zur, S., Bölte, S., Baron-Cohen, S., & Golan, O. (2017). 'Emotiplay': a serious game for learning about emotions in children with autism: results of a cross-cultural evaluation. *European child & adolescent psychiatry*, 26(8), 979–992. https://doi.org/10.1007/s00787-017-0968-0

Frolli, A., Savarese, G., Di Carmine, F., Bosco, A., Saviano, E., Rega, A., Carotenuto, M., & Ricci, M. C. (2022). Children on the Autism Spectrum and the Use of Virtual Reality for Supporting Social Skills. *Children (Basel, Switzerland)*, 9(2), 181. https://doi.org/10.3390/children9020181

Gev, T., Rosenan, R., & Golan, O. (2017). Unique effects of The transporters animated series and of parental support on emotion recognition skills of children with ASD: Results of a randomized controlled trial. *Autism research: official journal of the International Society for Autism Research*, 10(5), 993–1003. https://doi.org/10.1002/aur.1717

Golan, O., Ashwin, E., Granader, Y., McClintock, S., Day, K., Leggett, V., & Baron-Cohen, S. (2010). Enhancing emotion recognition in children with autism spectrum conditions: An intervention using animated vehicles with real emotional faces. *Journal of autism and developmental disorders*, *40*(3), 269-279. https://doi.org/10.1007/s10803-009-0862-9

Gómez-León, M.I (2019a). A través de los ojos del niño con trastorno del espectro autista. EDU REVIEW. International Education and Learning Review, 7(1), 11-22. https://doi.org/10.37467/gka-revedu.v7.1876

Gómez-León, M.I (2019b). Conexión neuronal en el trastorno del espectro autista. *Psiquiatría biológica, 26*(1), 7-14. https://doi.org/10.1016/j.psiq.2019.02.001

Grossard, C., Hun, S., Dapogny, A., Juillet, E., Hamel, F., Jean-Marie, H., ... & Cohen, D. (2019). Teaching facial expression production in autism: The serious game jemime. *Creative Education*, 10(11), 2347. https://doi.org/10.4236/ce.2019.1011167

Grynszpan, O., Nadel, J., Martin, J. C., Simonin, J., Bailleul, P., Wang, Y., Gepner, D., Le Barillier, F., & Constant, J. (2012). Self-monitoring of gaze in high functioning autism. *Journal of autism and developmental disorders*, *42*(8), 1642–1650. https://doi.org/10.1007/s10803-011-1404-9

Guzman, G., Gago-Galvagno, L., Quiroz, N., Serafini, M., Pallia, R., & Risk, M. (2022). Uso de una aplicación de tableta personalizada para evaluar la comunicación en niños con TEA: AppTEA. *Aloma: Revista de Psicologia, Ciències de l'Educació i de l'Esport, 40*(1), 55-64. https://doi.org/10.51698/aloma.2022.40.1.55-64

Hopkins, I. M., Gower, M. W., Perez, T. A., Smith, D. S., Amthor, F. R., Casey Wimsatt, F., & Biasini, F. J. (2011). Avatar assistant: improving social skills in students with an ASD through a computer-based intervention. Journal of autism and developmental disorders, 41(11), 1543-1555. https://doi.org/10.1007/s10803-011-1179-z

Jouen, A. L., Narzisi, A., Xavier, J., Tilmont, E., Bodeau, N., Bono, V., ... & Cohen, D. (2017). GOLIAH (Gaming Open Library for Intervention in Autism at Home): a 6-month single blind matched controlled exploratory study. *Child and adolescent psychiatry and mental health*, *11*(1), 1-14. https://doi.org/10.1186/s13034-017-0154-7

Kim, J. W., Nguyen, T. Q., Gipson, S. Y. M. T., Shin, A. L., & Torous, J. (2018). Smartphone apps for autism spectrum disorder—Understanding the evidence. *Journal of Technology in Behavioral Science*, *3*(1), 1-4. https://doi.org/10.1007/s41347-017-0040-4

Lacava, P. G., Golan, O., Baron-Cohen, S., & Smith Myles, B. (2007). Using assistive technology to teach emotion recognition to students with Asperger syndrome: A pilot study. *Remedial and Special Education*, *28*(3), 174-181. https://doi.org/10.1177/07419325070280030601

Lahiri, U., Warren, Z., & Sarkar, N. (2011). Design of a gaze-sensitive virtual social interactive system for children with autism. IEEE transactions on neural systems and rehabilitation engineering: a publication of the IEEE Engineering in Medicine and Biology Society, 19(4), 443–452. https://doi.org/10.1109/TNSRE.2011.2153874

Lozano, M. D. J., Sánchez, J. L. S., & Espinosa, M. P. P. (2017). Estudio de caso de la influencia del aprendizaje electrónico móvil en el desarrollo de la comunicación y el lenguaje con un niño con TEA. *Educar*, *53*(2), 419-443. http://dx.doi.org/10.5565/rev/educar.782

Lee, I. J. (2021). Kinect-for-windows with augmented reality in an interactive roleplay system for children with an autism spectrum disorder. *Interactive Learning Environments*, *29*(4), 688-704. https://doi.org/10.1080/10494820.2019.1710851

Liu, R., Salisbury, J. P., Vahabzadeh, A., & Sahin, N. T. (2017). Feasibility of an Autism-Focused Augmented Reality Smartglasses System for Social Communication and Behavioral Coaching. *Frontiers in pediatrics*, *5*, 145. https://doi.org/10.3389/fped.2017.00145

Malinverni, L., Mora-Guiard, J., Padillo, V., Valero, L., Hervás, A., & Pares, N. (2017). An inclusive design approach for developing video games for children with autism spectrum disorder. *Computers in Human Behavior, 71,* 535–549. https://doi.org/10.1016/j.chb.2016.01.018

Mantziou, O., Vrellis, I., & Mikropoulos, T. A. (2015). Do children in the spectrum of autism interact with real-time emotionally expressive human controlled avatars? *Procedia Computer Science*, *67*, 241-251. https://doi.org/10.1016/j.procs.2015.09.268

Moore, D., Cheng, Y., McGrath, P., & Powell, N. J. (2005). Collaborative virtual environment technology for people with autism. *Focus on autism and other developmental disabilities, 20*(4), 231-243. https://doi.org/10.1177/10883576050200040501

O'Brien, A. M., Schlosser, R. W., Yu, C., Allen, A. A., & Shane, H. C. (2021). Repurposing a smartwatch to support individuals with autism spectrum disorder: Sensory and operational considerations. *Journal of Special Education Technology*, *36*(4), 215-226. https://doi.org/10.1177/0162643420904001

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., ... & Alonso-Fernández, S. (2021). Declaración PRISMA 2020: una guía actualizada para la publicación de revisiones sistemáticas. *Revista Española de Cardiología*, *74*(9), 790-799. https://doi.org/10.1016/j.recesp.2021.06.016

Pérez-Fuster, P., Herrera, G., Kossyvaki, L., & Ferrer, A. (2022). Enhancing Joint Attention Skills in Children on the Autism Spectrum through an Augmented Reality Technology-Mediated Intervention. *Children*, 9(2), 258. https://doi.org/10.3390/children9020258

Rice, L. M., Wall, C. A., Fogel, A., & Shic, F. (2015). Computer-Assisted Face Processing Instruction Improves Emotion Recognition, Mentalizing, and Social Skills in Students with ASD. *Journal of autism and developmental disorders*, *45*(7), 2176–2186. https://doi.org/10.1007/s10803-015-2380-2

Serret, S., Hun, S., Iakimova, G., Lozada, J., Anastassova, M., Santos, A., ... & Askenazy, F. (2014). Facing the challenge of teaching emotions to individuals with low-and high-functioning autism using a new serious game: a pilot study. *Molecular autism*, *5*(1), 1-17. https://doi.org/10.1186/2040-2392-5-37

So, W. C., Wong, M. K., Lam, C. K., Lam, W. Y., Chui, A. T., Lee, T. L., Ng, H. M., Chan, C. H., & Fok, D. C. (2017). Using a social robot to teach gestural recognition and production in children with autism spectrum disorders. *Disability and rehabilitation. Assistive technology*, *13*(6), 527–539. https://doi.org/10.1080/17483107.2017.1344886

So, W. C., Wong, M. Y., Cabibihan, J. J., Lam, C. Y., Chan, R. Y., & Qian, H. H. (2016). Using robot animation to promote gestural skills in children with autism spectrum disorders. *Journal of Computer Assisted Learning*, *32*(6), 632-646. https://doi.org/10.1111/jcal.12159

Sturm, D., Kholodovsky, M., Arab, R., Smith, D. S., Asanov, P., & Gillespie-Lynch, K. (2019). Participatory design of a hybrid kinect game to promote collaboration between autistic players and their peers. *International Journal of Human–Computer Interaction*, *35*(8), 706-723. https://doi.org/10.1080/10447318.2018.1550180

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., ... & Schultz, R. T. (2010). Using computerized games to teach face recognition skills to children with autism spectrum disorder: the Let’s Face It! program. *Journal of Child Psychology and Psychiatry*, *51*(8), 944-952. https://doi.org/10.1111/j.1469-7610.2010.02258.x

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., Brown, C., Stahl, S. S., South, M., McPartland, J. C., Kaiser, M. D., & Schultz, R. T. (2012). The perception and identification of facial emotions in individuals with autism spectrum disorders using the Let's Face It! Emotion Skills Battery. Journal of child psychology and psychiatry, and allied disciplines, 53(12), 1259–1267. https://doi.org/10.1111/j.1469-7610.2012.02571.x

Thomer, M. L., Smith, R. A., Lopata, C., Volker, M. A., Lipinski, A. M., Rodgers, J. D., McDonald, C. A., & Lee, G. K. (2015). Randomized Controlled Trial of Mind Reading and In Vivo Rehearsal for High-Functioning Children with ASD. *Journal of autism and developmental disorders*, *45*(7), 2115–2127. https://doi.org/10.1007/s10803-015-2374-0

Voss, C., Schwartz, J., Daniels, J., Kline, A., Haber, N., Washington, P., Tariq, Q., Robinson, T. N., Desai, M., Phillips, J. M., Feinstein, C., Winograd, T., & Wall, D. P. (2019). Effect of Wearable Digital Intervention for Improving Socialization in Children With Autism Spectrum Disorder: A Randomized Clinical Trial. *JAMA pediatrics*, *173*(5), 446–454. https://doi.org/10.1001/jamapediatrics.2019.0285

Wall, N. G., Smith, O., Campbell, L. E., Loughland, C., Wallis, M., Henskens, F., & Schall, U. (2021). E-technology social support programs for autistic children: Can they work?. *World journal of psychiatry*, *11*(12), 1239–1246. https://doi.org/10.5498/wjp.v11.i12.1239

Wong, C., Odom, S. L., Hume, K. A., Cox, A. W., Fettig, A., Kucharczyk, S., Brock, M. E., Plavnick, J. B., Fleury, V. P., & Schultz, T. R. (2015). Evidence-Based Practices for Children, Youth, and Young Adults with Autism Spectrum Disorder: A Comprehensive Review. Journal of autism and developmental disorders, *45*(7), 1951–1966. https://doi.org/10.1007/s10803-014-2351-z

Yan, Y., Liu, C., Ye, L., & Liu, Y. (2018). Using animated vehicles with real emotional faces to improve emotion recognition in Chinese children with autism spectrum disorder. *PloS one*, *13*(7), e0200375. https://doi.org/10.1371/journal.pone.0200375

Young, R. L., & Posselt, M. (2012). Using the transporters DVD as a learning tool for children with autism spectrum disorders (ASD). Journal of autism and developmental disorders, 42(6), 984-991. https://doi.org/10.1007/s10803-011-1328-4

Zervogianni, V., Fletcher-Watson, S., Herrera, G., Goodwin, M., Pérez-Fuster, P., Brosnan, M., & Grynszpan, O. (2020). A framework of evidence-based practice for digital support, co-developed with and for the autism community. *Autism: the international journal of research and practice*, *24*(6), 1411–1422. https://doi.org/10.1177/1362361319898331

Contact email: isabel.gomez@unir.net