Applications of assistive technology in skills development for people with Autism Spectrum Disorder: a systematic review

Aplicações da tecnologia assistiva no desenvolvimento de habilidades para pessoas com Transtorno do Espectro do Autismo: uma revisão sistemática

Aplicaciones de la tecnología de asistencia en el desarrollo de habilidades para personas con Trastorno del Espectro Autista: una revisión sistemática

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Abstract
The purpose of this systematic review was to present, through a critical approach, interpretation and evaluation, the current assistive technology research directions, and the range, capabilities and efficiency of mobile devices and their respective software applications and the virtual reality and augmented reality environments used for people with autism. The aim was to identify the assistive technology practices applied for the development of communication, social and vocational-employment skills for people with autism, and to evaluate their acceptability and effectiveness. Search in electronic databases resulted in a final selection of 63 studies that met the inclusion criteria of the review, covering a total of 406 participants with autism. Analysis of the data from the studies provided largely positive results.
Keywords: Autism spectrum disorder; Assistive technology; Mobile devices; Applications; Virtual environments, Augmented reality; Skills.

Resumo
O objetivo desta revisão sistemática foi apresentar, através de uma abordagem crítica, interpretação e avaliação, as atuais direções de pesquisa de tecnologia assistiva, e a gama, capacidades e eficiência dos dispositivos móveis e seus respectivos aplicativos de software e os ambientes de realidade virtual e de realidade aumentada usados para pessoas com autismo. O objetivo foi identificar as práticas de tecnologia assistiva aplicadas para o desenvolvimento de habilidades de comunicação, sociais e de emprego profissional para pessoas com autismo e avaliar sua aceitabilidade e eficácia. A busca em bancos de dados eletrônicos resultou em uma seleção final de 63 estudos que atenderam aos critérios de inclusão da revisão, abrangendo um total de 406 participantes com autismo. A análise dos dados dos estudos forneceu resultados amplamente positivos.
Palavras-chave: Transtorno do espectro do autismo; Tecnologia assistiva; Dispositivos móveis; Aplicativos; Ambientes virtuais; Realidade aumentada; Habilidades.

Resumen
El propósito de esta revisión sistemática fue presentar, a través de un enfoque crítico, interpretación y evaluación, las direcciones actuales de investigación en tecnología de asistencia, y el rango, capacidades y eficiencia de los dispositivos móviles y sus respectivas aplicaciones de software y los entornos de realidad virtual y realidad aumentada utilizados. para personas con autismo. El objetivo fue identificar las prácticas de tecnología asistencial aplicadas para el desarrollo de habilidades comunicativas, sociales y de empleo vocacional para personas con autismo, y evaluar su aceptabilidad y efectividad. La búsqueda en bases de datos electrónicas resultó en una selección final de 63 estudios que cumplieron con los criterios de inclusión de la revisión, cubriendo un total de 406 participantes con autismo. El análisis de los datos de los estudios arrojó resultados en gran medida positivos.
Palabras clave: Trastorno del espectro autista; Tecnología de asistencia; Dispositivos móviles; Aplicaciones; Entornos virtuales; Realidad aumentada; Habilidades.

1. Introduction

The rapid advancement of technology has revolutionized the field of special education, as ever more sophisticated, specialized devices and software applications are emerging that make use of a wide range of new technologies. In recent years, with the introduction of new methods, there has been an increase in the number of empirical studies on interventions for people with autism spectrum disorder (ASD) based on high-tech tools, such as mobile devices (iPad, iPod, smartphones, touch screen-based tablets), with their corresponding applications, and virtual reality (VR) and augmented reality (AuR) environments, aimed at the development a variety of skills, mainly social, communication and vocational skills.

Important advantages of the use of mobile devices are their portability, accessibility and ease of use, the variety of communication applications available, offering targeted learning opportunities and individualization, and their affordability. (McNaughton & Light, 2013; Meder & Wegner, 2015). Consequently, these devices have changed the way services are provided, and acceptance by this population (Moore et al., 2000) of the attractive, versatile devices has inspired research design and pushed the commercial industry to produce increasingly technologically advanced devices to meet the complex and diverse needs of people with ASD (Meder & Wegner, 2015). However, a number of mobile devices and software technology applications are now commercially available for training programs in communication development, social and professional skills, many of them are not supported by empirical research and not empirically well- documented, such as the design of augmentative and alternative communication applications for mobile devices with the immediate result of reducing the expected benefits due to the unsuitability of the applications, insufficient technical characteristics, the lack of educational support (McNaughton & Light, 2013), or the breadth of options can be confusing for parents.

On the other hand, parents and educators of children with ASD report more positive interaction of the children with digital media than with human partners. This is considered to be due to the predictable social interaction offered by the devices, which reduces participant stress, and to the stability of the environment they provide, the range of visual stimuli, and the degree of consistency, which are absent from interaction with a human partner (Bauminger et al., 2007). In the past decade the areas of VR and AuR appear to be gaining research interest in terms of their potential in education, training and intervention for people with ASD (Bozgeyikli & Katkoori, 2018).

The current and projected range and variety of technologically advanced assistive technology (AT) products, and the number of commercially available devices and applications make well-documented research and evidence-based practice imperative. It is important to identify their potential benefits in meeting the needs and compensating for deficits of individuals with ASD, but also to investigate possible problems in their use.

ASD comprises a group of neurodevelopmental disorders characterized by persistent deficits in social interaction and social communication, and repetitive or stereotyped behavior (APA, 2013). These symptoms appear from early childhood and limit everyday functioning of people with ASD. The manifestations of the disorder vary, depending on the severity, the level of development and the chronological age of the individual (APA, 2013).

Severe social and communication deficits in people with ASD are often a deterrent to their involvement and participation in the community and an impediment to claiming an autonomous and dignified life. People with ASD record high rates of unemployment or underemployment; it is extremely difficult for adolescents and young adults with ASD to maintain and obtain employment, and few adults with ASD have been trained in paid employment skills (Seaman & Cannella-Malone, 2016). Additionally, the supported employment model is recognized as the most productive approach for this population group (Capo, 2001).

Many intervention methods and techniques have been developed in recent decades for people on the autism spectrum,

focusing on enhancing social and communication skills, educational and social inclusion. Programs, methods and techniques traditionally used for intervention in ASD include: Applied Behavior Analysis (ABA), the Treatment and Education of Autistic and Related Communication Handicapped Children (TEACCH) method, the Picture Exchange Communication System (PECS), the MAKATON Language Programme, Carol Gray's Social Stories, illustrated stories (Comic Strip Conversations), and teaching techniques-strategies, used in structured behavioral interventions, such as constant or progressive time delay, prompts, differentiated feedback, error correction, graduated guidance, task analysis, modeling, role-play and social scenarios (Syriopoulou-Delli, 2016). Some of them were used in combination with the technological tools in assistive technology interventions of present systematic review's studies (e.g. Kagohara et al., 2010; Achmadi et al., 2012; Hill & Flores, 2014; Alzrayer et al., 2017; Lee et al., 2018)

In recent years the use of AT for the cultivation of skills in individuals with ASD has become increasingly common, and relevant research demonstrates that people with ASD show more positive results from their contact with information and communication technologies (ICT) compared with the traditional methods of treatment and rehabilitation (Bauminger et al., 2007).

Assistive technology and ASD

The World Health Organization (WHO) defined AT as "assistive products and related systems and services developed for people to maintain or improve their functioning and thereby promote well-being" (WHO, 2016, p.1). AT is used with people with ASD to enable them to experience more independent learning. This technology facilitates the user's access to the environment and reduces the need for immediate support by a trainer or caregiver and support services (Ennis-Cole & Smith, 2011). It enables participation in education, the labor market and social life of people with difficulties in social functioning, such as those with ASD (WHO, 2016).

Widely used high-tech, AT tools used in interventions designed for people with ASD for their training and development of a variety of skills include: specialized computer hardware and software, personal digital assistants (PDAs), smart phones, customized telephones, touch tablets, mobile devices and applications, augmented and alternative communication (AAC) and generally assistive ICT (WHO, 2016), smart watches, multimedia applications, often enriched with animated tutors, intelligent mobile robots as social mediators, web-based learning environments, VR and AuR applications and environments, sensors, video-based interventions and action modeling, and audiovisual social scenarios.

Mobile electronic devices - Computer-based interventions

Computer technology is reported to be a highly effective teaching tool for people with ASD, who tend to do well with visual stimulus-based communication systems, while demonstrating significant learning benefits (Moore et al., 2000). Mobile technology offers opportunities for them to learn and acquire skills in authentic situations. Improvement in the portability and computing capabilities of electronic devices has increased research into the possibilities of using AT applications, running on palm computers, tablets and smartphones for people with disabilities. Earlier literature reviews (e.g., Kagohara et al., 2013; Ramdoss et al., 2011; 2012) document encouraging results and confirm the potential of digital technologies for improving the communication, social and vocational skills of people with ASD, and reducing their problematic behaviors. Kagohara et al. (2013) conducted a systematic review of 15 studies that involved mobile devices (e.g. iPhones, iPads, iPods) in teaching a wide variety of skills (academic, communication, leisure, employment and transitioning) for individuals with developmental disabilities (ASD and/or intellectual disability). Reviewers found that results were largely positive and these devices are viable

technological aids for this population which can be taught to use such technological tools. Ramdoss et al. (2011) reviewed studies involving computer-based interventions to teach communication skills to children with ASD and suggested that this kind of interventions is probable a promising practice, requiring more future research. Similar suggestions expressed Ramdoss et al. (2012) found mixed results in their systematic review of 11 studies involving the use of computer-based interventions to teach emotional and social skills to students with ASD.

Video based Interventions

Based on research, video modeling (VM) and video self-modeling (VSM) are considered effective intervention strategies for promoting skill acquisition among children and adolescents with ASD (Bellini & Akullian, 2007). VM as an educational tool involves creating a video of someone performing a target skill. The video is then shown to the learner and he is asked to perform the behavior or target skill (Cannella-Malone et al., 2006). VSM is a variation of the previous one, as the learner acts as a model for himself (Bozgeyikli & Katkoori, 2018). A meta-analysis of 23 studies (Bellini & Akullian, 2007) found that these strategies promote skill acquisition such as social-communication skills, functional skills, and behavioral functioning and the acquired skills are maintained over time and transferred across persons and settings. The reviewers suggested VM and VSM as an evidence-based practice (Bellini & Akullian, 2007). Video modeling has been used to teach such skills as play (D'Ateno et al., 2003; MacDonald et al., 2005), conversation (Sherer et al., 2001), vocational (Van Laarhoven et al., 2007; Allen et al., 2010; Burke et al., 2013), social communication (Grosberg & Charlop, 2014) Video prompting(VP) is a form of video modeling in which the target skill or task is broken down into steps that are then performed directly after viewing each clip of video (Seaman & Cannella-Malone, 2016) and has been effectively used to teach a wide range of target skills such as daily living and vocational skills among individuals with ASD (Bereznak et al., 2012; Burke et al., 2013).

Virtual reality environments

In recent years, virtual reality (VR) technology has become a popular tool for the education and rehabilitation of people with ASD (Bozgeyikli & Katkoori, 2018), providing real-time simulations in a controlled and secure learning environment (Parsons & Cobb, 2011). VR aims to "immerse" the user, so that the latter has the feeling, better the illusion, that he is completely, with his body and mind, in the virtual environment without being affected by the conditions of the real world around him. Immersion is enhanced by the use of special equipment (e.g. 3D glasses, HMDs), in order to eliminate environmental distractions, isolation from environmental stimuli and maintaining focus. A high degree of interaction is also provided through the monitoring of movement using special sensors (Bozgeyikli & Katkoori, 2018). VR technology is divided into three types: desktop computers, head mounted displays (HMDs) (Howard & Gutworth, 2020) and projection systems, cave automatic virtual environments (CAVEs) (Ip et al., 2018). The latter two, in combination with some form of motion monitoring, offer a substantial degree of immersion, as the users are completely surrounded by the virtual environment. Research on VR technology applications in the field of autism has expanded the possibility of human-computer interaction, providing opportunities for participation and social interaction of these individuals in the digital world (Rajendran, 2013). Parsons and Cobb (2011) conducted a systematic review on virtual reality technologies in the development of social skills and concluded that despite limited research, VR presents unique possibilities and benefits for people with autism because of simulations of authentic reality, through a controlled and secure environment.

Augmented reality environments

Augmented reality (AuR) overlaps with virtual objects in a real-world environment, allowing users to see and interact with the real world as digital content is added to it (Lorusso et al., 2018). The users of VR and AuR environments, through augmentation of the real world, interact with it in conjunction with the virtual environment. Studies have shown that in the short term, AuR applications on mobile devices can increase children's interest in interacting with their peers and lead to a better understanding of the rules of communication (Escobedo et al, 2012). Children with ASD can learn to interact with 3D virtual characters in augmented reality animated games to learn body language and facial expressions through role-playing (Lee, 2020). AuR is a new type of technology that has attracted the interest of researchers in recent years and needs further research to highlight its potential in skills development for people with ASD.

Augmentative and Alternative Communication (AAC)

PECS as method of alternative or augmentative communication is used in order to initiate communication interactions, increase the communication repertoire and enhance spontaneous communication of people with ASD or people who have no speech at all or have limited functional communication skills. A key educational tool is the Communication Book, a folder containing images, photographs and symbols placed on a Velcro strap. The method is graded in six stages which are taught sequentially in collaboration with the communication partner and each is built on the teaching of the previous stage (Syriopoulou-Delli, 2016). Teaching of AAC that is based on the PECS method but does not apply all the phases of the specific method is referred to as Picture Exchange (PE).

Devices such as iPods, iPads, in combination with augmentative and alternative communication (AAC) specific software applications can be used as speech-generating devices (SGDs), with a wide range of vocabulary, and a relatively unlimited number of screen pages and software images that can replace the PECS folder. Portability, small size and weight, high quality synthetic ratio and relatively low cost are significant advantages of these devices, along with social acceptance (McNaughton & Light, 2013). There is also some initial evidence of the potential positive impact of mobile devices on individuals who require AAC. Unfortunately, many AAC apps are not based on research evidence and may be not sufficient for the needs and skills of individuals with complex communication needs (McNaughton & Light, 2013) or individuals with ASD.

Many studies (e.g. Hill & Flores, 2014; Flores et al., 2012; De Leo et al., 2011) compare the teaching of PECS's phases with the teaching of AAC with mobile devices, through interventions that utilize simulated phases of a modified PECS protocol.

To date, several systematic reviews and meta-analyses have been published of findings from empirical studies and reports of interventions for people with ASD or other developmental disabilities using AT (e.g. Ramdoss et al., 2011; 2012; Kagohara et al., 2013; Stephenson & Limbrick, 2015; Bozgeyikli & Katkoori, 2018; Baragash et al., 2019; Parsons, 2016). These have typically covered one type of technology, or focused on one type of skills or range of skills that can be enhanced with high-tech tools, while others did specifically cover people with ASD. Most of them set specific, but differing goals, defined different variables and drew corresponding conclusions. The majority reported clearly encouraging findings on the use of these tools, although relatively few apps have been examined and suggested continuation of research into high-tech support.

For example, Stephenson and Limbrick (2015) researched the use of mobile touch-screen devices, mainly as SGDs by people with developmental disabilities. Bozgeyikli and Katkoori (2018) presented advantages and challenges of VR for individuals with ASD exploring the usefulness of this technology as a training tool in a variety of skills (social, safety, life

skills) and found that most of the studies concentrated on social and social-communication skills training via both immersive and regular VR systems and used humans for tutorials. Finally, a 2019 meta-analysis of 16 single-subject studies (Baragash et al., 2019) examined the effectiveness of AuR applications in improving the learning and acquisition of social, living, learning and physical skills of individuals with special needs, such as ASD, attention deficit hyperactivity disorder (ADHD), intellectual disabilities (ID) and physical disabilities (PD). The results indicated that AuR apps had a large effect across the studies, mainly in promoting academic skills and positive social behaviors, especially for individuals with ASD. Reviewers concluded that AuR technology can support individuals with special needs learn a variety of skills effectively, access competitive employment and have an independent living.

In fact, AuR has not been studied in a research systematic review framework for people with ASD exclusively. Also, this systematic review focuses only on the development of communication, social and vocational skills through the use of mobile devices, VR and AuR environments, describes and critically interprets the findings and formulate research questions, based on the current literature, that are expected to answer important issues, some of which do not have been commented on by previous studies. At the same time, it extends the criteria of the research as it includes recent empirical studies, up to the first three months of 2020.

Objectives

The aim of this review was to present, with interpretation and evaluation, current research data concerning the effectiveness of the use of mobile devices and their software applications, and VR and AuR environments, in the development of communication, social and vocational skills in people with ASD. Specifically, the range, scope and capabilities of AT applications that are successfully used in interventions to enhance and develop specific skills were explored, in order to identify current research trends and potential gaps and propose future studies aimed to develop effective applications to enhance the skills of people with ASD.

This systematic literature review focused on empirical studies, published up to March 2020, concerning the use of mobile devices and applications supported by them, and VR and AuR applications, and specifically on their contribution to the development of communication, social and vocational-employment skills. The review was based on the following research questions:

1) What is the frequency of publication of relevant empirical studies over time?

2) What are the age groups of the target populations and the sample sizes in the empirical studies under consideration?

3) In which context and under what conditions did the interventions take place?

4) What type of device, AT application and form of intervention were used, and how often do they appear in the studies?

5) What was the target behavior observed in each empirical study, and overall?

6) What were the results from the implementation of the specific technological solution/technological tool in each study, and overall?

7) Was communication through an application on a mobile device more effective than communication using traditional augmentation and alternative communication methods/systems?

8) Was maintenance and generalization of the acquired skills evaluated in the studies?

9) What are the advantages and disadvantages of using these technological tools, as demonstrated by the empirical

studies?

10) Which environment is most effective in promoting and enhancing the social interaction of people with ASD, VR, AuR or collaborative VR?

11) Are the technological tools a more effective means than human interaction for the expression of social and communication behaviors by individuals with ASD? What is the role of human intervention (e.g. prompting) in the outcome, type and quality of person-device interaction?

2. Methodology

The methodology of this systematic literature review, was based on the model of Barbara Kitchenham (2004). The collection, analysis and interpretation of research data for the preparation of the review followed a number of steps: a) systematic search of electronic databases, b) identification and screening of potential studies, c) selection of studies after application of initial inclusion and exclusion criteria, d) export of descriptive features and coding of possible variables, e) data extraction, f) qualitative analysis.

Electronic databases: Eric, Scopus, Science Direct, Pub Med, Google Scholar, IEEE-Xplore, PsycINFO, Wiley Online Library, and ACM Digital Library were searched to identify appropriate studies, using the keywords: autism, ASD, Autism Spectrum Disorder, social skills, social interaction, communication, video modeling, AAC, vocational skills, rehabilitation, employment, iPad *, iPod *, tablet, Smartphone, virtual reality, virtual environments, augmented reality, computer-based intervention, touch screen, ICT, Assistive technology, digital technologies, with a search filter for the years 2000-2020.

Eligibility and inclusion criteria were defined to assess the quality of the research papers. Primary studies conducted in the years 2000-2020, published in English, in peer-reviewed journals, books, or scientific conferences, focusing on the use of mobile devices and AT applications for people with ASD (at least one participant with ASD), aged from preschool to adulthood could be included. Exclusion criteria were publications based on purely theoretical research, literature and systematic reviews, and duplicate publications. In addition, studies were excluded that did not present accurately the studied variables or data or provide detailed analysis, in order to avoid inaccuracy and generalization in the conclusions (Figure 1).

Figure 1 Literature search procedure based on PRISMA flowchart
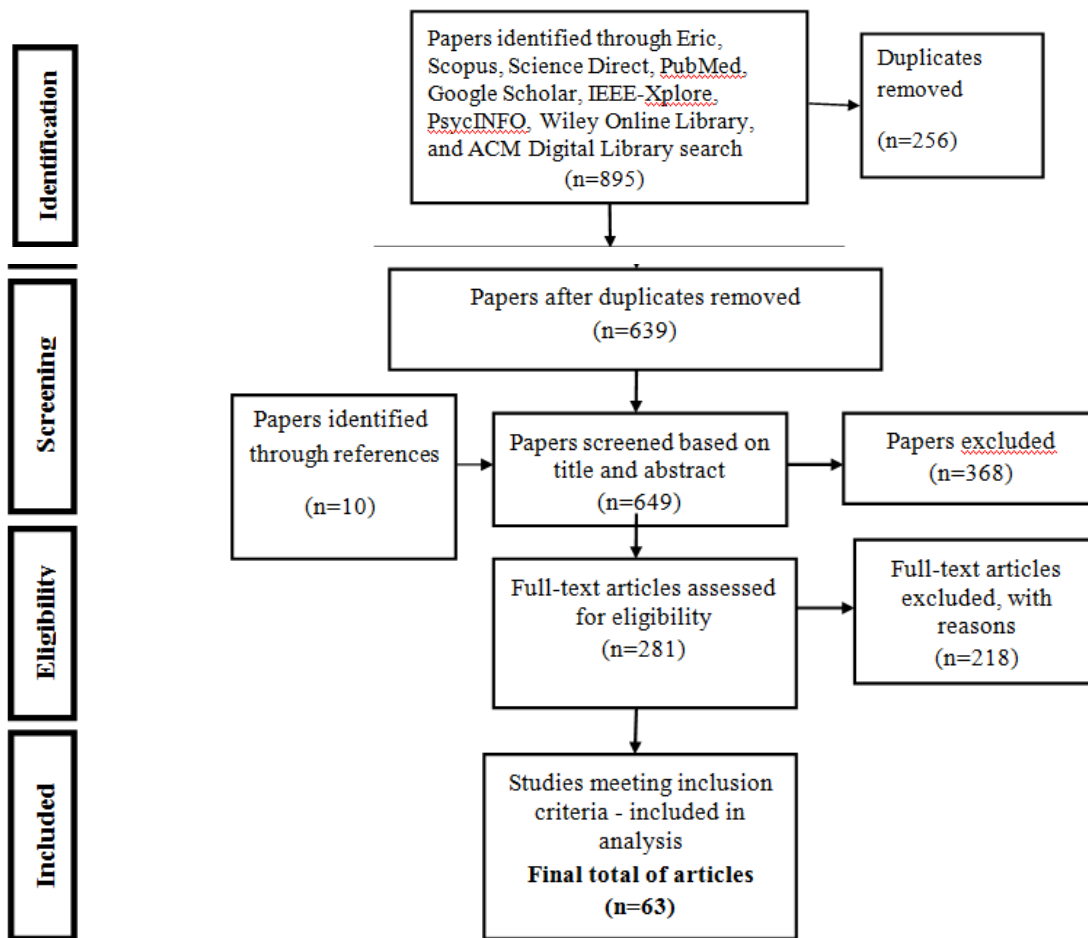
Source: Authors.

Figure 1 depicts the flowchart, based on the PRISMA guidelines (Moher et al., 2009), which presents the search and selection process for this review.

The first search yielded 895 results, which, after application of the above criteria resulted in a final selection of 63 research articles that were subjected to processing, coding and evaluation for the purposes of this research study. Especially, duplicate were removed (n=256) and the remaining studies were checked based on their title and summary. Articles, conference papers, book chapters that described the use of portable electronic devices and AT technologies that were of interest to the present study were included, but publications that were bibliographic reviews or purely theoretical or studies that did not concern people with autism were excluded. Thus, after removing 368 publications, 271 articles were read in more detail where required, as it was not clear from the title and summary only, to exclude studies that did not meet the criteria. At this stage, articles were searched from reference lists of the studied articles and another 10 articles were added. Therefore, a number of 281 articles were read, fully studied in their entirety to determine whether they met the criteria of suitability and inclusion in the present study. Finally, after removing 218 publications, which only described the operation and usage of device or were theoretical without accurate data and general conclusions, the selection process for this review led to a total of 63 research articles.

The selected articles were studied in terms of their descriptive characteristics and their most important features, after which the relevant information was extracted and potential variables were defined, coded and categorized, in order to facilitate

the process of answering the research questions and reaching safe conclusions.

Key variables were created that describe the main characteristics of the primary studies: a) sample size, b) age of participants, c) independent variable (type of technology), d) dependent variables (target-behavior), e) results of intervention, f) setting, g) context, h) maintenance, and i) generalization.

The participants were divided into 4 categories according to age: a) infant-preschool age (under 6 years old), b) school age or middle childhood (6-12 years old), c) adolescence (13-18 years old), d) adults (older than 19 years).

The variable "setting" consisted of 5 categories: a) school, b) home, c) clinic-experimental laboratory-research/educational center, university d) community (e.g. playground), e) workplace.

For the variable "context" there were two categories: a) controlled, "artificial", i.e., simulated instructional conditions (e.g., school, experimental laboratory), and b) natural, non-simulated conditions (e.g., home, community setting, work environment).

The independent variables define the type of technological tool and application used in the empirical study, and the type of intervention applied (e.g., video modeling, AAC, visual cues, behavioral techniques, etc.). The independent variables related to the type of technological tool consisted of two categories: a) mobile devices, b) VR and AuR technologies.

The dependent variables define the target behavior, and for this review were categorized into: a) initial communication skills (e.g., request, label), b) social- communication skills (e.g., conversation, comments, greetings), c) social skills (e.g., collaboration, social cognition, social judgments, joint attention, persistence in social initiation, turn-taking, compliment behaviors) and d) vocational-employment skills (e.g., using a copy machine, sorting mail, job interview, cleaning, money management).

3. Results

In the 63 studies identified by the search and selection process, extending from 2002 to March 2020, a total of 406 subjects with ASD participated. Of these, 44 (70%) focused on mobile electronic devices, of which 30 were published in 2010-2015, mainly in 2012-2014 (Table 1), while 19 studies (30%), related to VR and AuR technologies and environments, of which 12 were published in the last 5 years and 3 in the previous decade (Table 2).

In terms of age, 104 of the study subjects were in the preschool age group, 95 were of school age, 88 were adolescents and 119 were adults. In most studies the sample size ranged from 1 to 4 subjects, and only a few studies reported a sample of more than 10 subjects, while in 11 studies the interventions were applied to groups of participants (Table 1 and 2). Regarding the setting, 45 (72%) of the studies took place in a simulated instructional setting (e.g., school classroom, laboratory) and 18 (28%) in a natural setting (home, workplace or outdoors) (Table 1 and 2). In 60% of the studies the maintenance of the acquired skills was tested, while generalization of the skills in a different context was tested in 25 studies (40%) (Table 1 and 2). The maintenance of the skills was usually checked four to eight weeks after the intervention, but there were studies where it was checked six months later. In the studies of Alexander et al. (2013), Lorah et al. (2014), Grosberg and Charlop (2014) the level of maintenance reached 100% and in the studies of Waddington et al. (2017), Sng et al. (2017) and Grosberg and Charlop (2014) generalization in different contexts and people reached 100%. There were also studies where not all participants reached the desired level of maintenance or generalization, based on a criterion, usually 80% (e.g. Burke et al., 2010; Cheng and Ye, 2010; Waddington et al., 2014).

Table 1 Studies using mobile electronic devices for enhancement of communication, social and vocational skills in people with autism spectrum disorder (N=44): basic characteristics, variables, results.

Study	Number / Age of participants	Type of device/App/Intervention	Target behavior	Setting/ Context	Mainte-nance	Generali-zation	Results
Achmadi et al. (2012)	2/ 13, 17	iPod Touch Proloquo2Go Behavioral techniques (BT)	Initial communication skills	School / controlled	Yes	No	Successful for all participants Independent request
Alexander et al. (2013)	7/ 15-18	iPad 2 Video modeling (VM)	Vocational skills	School / controlled	Yes (100%)	Yes (3/7)	Successful for 5/7 participants
Alzrayer et al. (2017)	3/ 8-10	iPad 2 Proloquo2Go Behavioral techniques (BT)	Initial communication skills	School / controlled	No	Yes	Successful for all participants Independent request
Bereznak et al. (2012)	3/ 15-18	iPhone Video-self prompting, BT	Vocational skills	School / controlled	Yes	No	Performance increase for 2/3 participants
Burke et al. (2010)	6/ 18-27	iPhone iPod Cue system VM	Vocational skills	Workplace/ natural	Yes (2/6)	Yes	Successful acquisition skills
Burke et al. (2013)	4/ 19-28	Tablet, Video ToTe, Video prompting, VM	Vocational skills	Workplace/ natural	Yes	Yes	Successful acquisition of skills
Couper et al. (2014)	9/ 4-12	iPod Touch iPad Proloquo2Go BT	Initial communication skills	School, home, clinic, hospital university/ controlled & natural	Yes	No	Successful for 7/9 participants Independent request on 3 AAC systems
De Leo et al. (2011)	3/ 10-15	Smartphone Pix Talk communication system	Initial communication skills	School / controlled	No	No	Successful for all participants Making spoken sentences
Dundon et al. (2013)	1/ 5	iPad Go Talk Now Free/MLT My choice Board	Initial communication skills	School / controlled	No	No	Successful for participant Independent request
Fletcher- Watson et al. (2016)	54/ under 6 2 Groups	iPad game Find me app	Social skills	Home / natural	Yes	No	Non-statistically significant differences between groups
Flores et al. (2012)	3/ 8-11	iPad Pick a Word BT	Initial communication skills	School/ controlled	No	No	Mixed results
Gentry et al. (2012)	3/ 20, 21, 60	iPod Touch PDAs, device apps	Vocational skills	Workplace/ natural	Yes	No	Successful for 2/3 participants
Gentry et al. (2015)	55/ 18-60 2 Groups	iPod Touch PDAs Apps	Vocational skills	Workplace/ natural	Yes	No	Significant group differences
Grosberg and	4/ 7-9 ASD + 3	iPod Touch	Social skills	Community/	Yes	Yes	Successful 100%,

Charlop (2014)	typically developing (TD)	VM, portable VM intervention PVMI		natural	(100%)	(100%)	persistence in social initiation
Grosberg and Charlop (2017)	6/ 6-11 ASD + 12 TD	Smartphone Text message prompts	Social communication skills	Home/ natural	Yes	Yes	Successful, increase 9-18 phrases
Hill and Flores (2014)	3/ 3-9	iPad Proloquo2Go BT	Initial communication skills	School/ controlled	No	No	Successful for 2/3. Mixed results
Hurcade et al. (2013)	8/ 10-14	Tablet 4 Open Autism apps	Social skills	Community/ natural	No	No	Successful, Improvement in social interaction
Kagohara et al. (2010)	1/ 17	iPod Touch Proloquo2Go BT	Initial communication skills	School/ controlled	Yes	No	Successful 100% independent request
Kagohara et al. (2012)	2/ 13, 17 2 studies	iPod Touch iPad Proloquo2Go BT	Initial communication skills	School/ controlled	Yes (1st) No (2nd)	No	Both interventions successful, label
Kellems and Morningstar (2012)	4/ 20-22	iPod VM, written instructions	Vocational skills	Workplace/ natural	Yes	Yes	Completion of work steps
Kim and Clarke (2015)	2/ 4, 5	iPad/ audio prompts I Take turns	Social skills	Home/ natural	No	No	Successful for 1/4 participants, Turn-Taking
King et al. (2014)	3/ 3-5	iPad 1 Proloquo2Go BT	Initial communication skills	School/ controlled	No	No	Different levels/phases of skill acquisition (request)
Lorah et al. (2013)	5/ 3-5	iPad 2 Proloquo2Go BT	Initial communication skills	Educational-research center/ controlled	Yes (4/5)	No	Independent request - Mixed results
Lorah et al. (2014)	4/ 4-6	iPad 2 Proloquo2Go BT	Initial communication skills	School/ controlled	Yes (100%)	No	Successful-independent request, distinction
Macpherson et al. (2015)	5/ 9-11	iPad 2 Portable VM	Social skills	Community/ natural	No	Yes	Successful-compliments, gentle gestures
Mancil et al. (2016)	3/ 4-5	iPod Touch Proloquo2Go BT	Initial communication skills	School & community/ natural & controlled	Yes	Yes	Functional communication
Nepo et. al (2017)	3/ 31-44	iPod Touch My talk, BT	Initial communication skills	Educational training center/ controlled	No	Yes	Successful, independent request
Ribeiro and Raposo (2014)	4/ 5-11	2 tablet & TV Com Fim (cooperative game)	Social communication skills	Therapeutic center/ controlled	No	No	Successful, Enhancement of communicative intention

Shih et al. (2014)	2/ 17	Laptop touch screen CRARAP System prompts	Initial communication skills	School/ controlled	Yes	Yes	Significant improvement in spontaneous request
Sigafoos et al. (2013)	2/ 4-5	iPad 1 Proloquo2Go BT	Initial communication skills	Clinic/ controlled	Yes	Yes	Successful, independent request expression
Sng et al. (2017)	1/ 7	iPad Conversation coach app, written scripts, prompts	Social communication skills	School/ controlled	Yes	Yes (100%)	Successful, On- Topic responses, conversation
Sng et al. (2020)	3/ 8-10	iPad Conversation coach app, written scripts, prompts	Social communication skills	School, clinic, community/ controlled & natural	No	Yes	Successful for 2/3 participants On- Topic responses, conversation
Strasberger & Ferreri (2014)	4/ 5-12	iPod Touch PACA peer assistance	Initial communication skills	School/ controlled	Yes	Yes	Successful, request, communication
van der Meer et al. (2011)	1/ 13	iPod Proloquo2Go BT	Initial communication skills	School/ controlled	Yes	No	Successful100% Independent request
van der Meer et al. (2012a)	4/ 6-13	iPod Touch Proloquo2Go BT	Initial communication skills	School/ controlled	Yes	No	Successful on all ACC systems (3) independent request
van der Meer et al. (2012b)	4/ 5,5-10	iPod Touch Proloquo2Go BT	Initial communication skills	School/ controlled	Yes	No	Successful mixed results independent request- 2 AAC
van der Meer et al. (2012c)	4/ 11	iPod Touch Proloquo2Go BT	Initial communication skills	School, home/ controlled & natural	Yes	No	All participants: request in at least one ACC system (3)
van der Meer et al. (2014)	1/ 10	iPad Proloquo2Go BT	Social communication skills	Home/ natural	Yes	Yes	Increase request – Verbal request
Van Laarhoven et al. (2007)	1/ 18	Pocket PC VM	Vocational skills	Workplace/ natural	No	No	Successful skills acquisition
Waddington et al. (2014)	3/ 7-10	iPad 2 Proloquo2Go BT	Social communication skills	University clinic/ controlled	Yes (2/3)	Yes (2/3)	Successful, request, social communication
Waddington et al. (2017)	1/ 8	iPad 2 Proloquo2Go BT	Initial communication skills	Clinic, school, home/ controlled & natural	No	Yes (100%)	Successful 100% in all contexts

Ward et al. (2013)	1/ 5	iPad Go Talk Now Free/ MLT	Initial communication skills	School/ natural	No	No	Successful independent request
Wendt et al. (2019)	3/ 14,16,23	iPad Speak all! BT	Initial communication skills	Clinic/ controlled	Yes	Yes	Successful for request- Mixed results for speech
Xin and Leonard (2015)	3/10	iPad SonoFlex, BT	Social communication skills	School, academic brake time/ controlled & natural	No	No	Start requests, answers, social comments, spontaneous functional communication

VM: Video Modeling, BT: Behavioral techniques, TD: typically developing. Source: Authors.

Table 1 shows the type of mobile electronic device used according to each study, the basic characteristics of the studies using mobile device, the variables, and the outcome measures observed. The majority (n=38) of the studies using mobile electronic devices utilized tablet computers (iPad, iPod, iPod Touch, iPod Touch PDAs), with the iPad being used in 50% of them. Six studies used iPhone, smartphone or laptop. Additionally, 4 studies using AuR Technology utilized mobile devices (tablet, smartphone). In 26 studies the tablets functioned as SGDs, within the AAC, with the application Proloquo2Go appearing in 17 interventions in combination with behavioral teaching techniques (e.g. time delay, graduated guidance, prompts), mainly ABA-based instructional procedures. Generally, behavioral techniques utilized for the whole of interventions. Other interventions used a variety of commercially available or freeware applications (e.g. Go Talk Now, My Talk, Pick a Word) while some were developed by researchers, such as the Windows-based Pix Talk software application (De Leo et al., 2011) while other studies that were used to develop vocational-employment skills utilized interventions using video modeling and video prompting.

Table 2 Studies using virtual and augmented reality technology for enhancement of communication, social and vocational skills in people with autism spectrum disorder (n=19): basic characteristics, variables, results

Study	*Number / Age of participants*	*Type of Technology/ Intervention*	*Target behavior*	*Setting/ Context*	*Mainte-nance*	*Generalization*	*Results*
Bozgeyikli et al. (2017)	9/ 29 ASD+ 9 TD 2 Groups	VR, HMD, Computer VR4VR, instructions, prompts	Vocational skills	Clinic-experimental laboratory/ controlled	Yes	Yes	Statistically significant differences
Chen et al. (2016)	6/ 11-13	AuR tablet, pc VM Story Book ARVMS	Social skills	Therapeutic center/ controlled	Yes	Yes	Successful-Attention to non verbal cues
Cheng and Ye (2010)	3/ 7-8	Computer VR colloborative computer, 3D social scripts	Social skills	School/ controlled	Yes (2/3)	No	Significant positive results, social cognition
Cheng et al. (2015)	3/ 10,5-11,5	VR, HMD, Computer 3D social situations	Social skills	School/ controlled	Yes	No	Improving social interaction
Escobendo et al. (2012)	3/ 8-11 + 9 TD	Smartphone AuR MOSOCO Visual support	Social skills	School- academic brake time/ natural	Yes	Yes	Successful Selective attention, social skills

Halabi et al. (2017)	3/ 4-6 + 7 TD 2 Groups	Cave, HMD, 3Dglassees Desktop Role play	Social communication skills	Clinic laboratory/ controlled	No	No	Higher performance in Cave system
Jyoti and Lahiri (2020)	20/ 4,5-7 + 20 TD, 2 Groups	ComputerVR Joint Attention (JA) training HCI, JA cues	Social skills	Clinic laboratory/ controlled	No	No	Effective intervention, Joint Attention
Kandalaft et al. (2013)	8/ 18-23	ComputerVR Second Life social scenarios	Social skills	University-research center/ controlled	Yes	No	Improvement in social functioning, statistically significant
Ke & Im (2013)	4/ 9-10 ASD + 7 adults	ComputerVR Second Life VR-SIT	Social skills	Home, School, Community/ natural & controlled	Yes	No	Improvement in interaction /communicative performance
Lee (2020)	3/ 7,5-8,5	Computer AR Kinect for Windows, social scenarios, role play	Social skills	School/ controlled	Yes Significant high performance	No	Significant increase in social interaction
Lee et al. (2018)	3/ 8-9	Computer AuR Tablet Concept map, social scenarios, role play	Social skills	Laboratory/ controlled	Yes	Yes	Appropriate responses, greetings
Leonard et al. (2002)	7/ 14-16	ComputerVR laptop, joystick Video, social scenarios, VE cafe	Social skills	Laboratory/ controlled	No	Yes	Significant difference in social judgment/ social cognition
Lorenzo et al. (2019)	11/ 2-6 2 Groups	AuR smartphone Quicker Vision app	Social skills	School/ controlled	No	No	Non-statistically significant differences between the 2 groups
Mitchel et al. (2007)	6/ 14-16	Computer VR, joystick 3 set video (café-bus)	Social skills	Laboratory/ controlled	No	Yes	Improving social interaction, social understanding
Parsons (2015)	6/ 10-13 + 8 TD	VR- CVE Interactive surfaces Block Challenge (cooperative game)	Social skills	School/ controlled	No	No	Mutual and cooperative responses
Smith et al. (2014)	26/ 18-31 2 Groups	VR system Computer VR-JIT, role play	Vocational skills	Laboratory/ controlled	Yes	No	Experimental group: higher performance in job interview
Zhang et al. (2018)	7/ 14 + 7 TD 2 Groups	CVE VR Computer 3 puzzle game	Social skills	Laboratory/ controlled	No	No	High cooperative behavior
Zhang et al. (2020)	20/ 14 + 20 TD	CVE VR Computer +IA GRETA, IA's verbal prompts	Social skills	Laboratory/ controlled	No	No	Successful collaboration-communication
Zhao et al. (2018)	12/ 12,5 + 12 TD, 2 Groups	Computer, VR Headphones, web camera CVE system, Leap motion controller	Social skills	Experimental laboratory/ controlled	Yes	No	Improved cooperation-communication

AuR: Augmented reality, VR: Virtual reality, IA: Intelligent Agent, CVE: collaborative virtual environments, HMD: head mounted display.
Source: Authors.

Table 2 shows the basic characteristics, the variables and results of the studies using VR or AuR technology. The majority of these applied interventions to a classic, non-immersive VR system using a computer, while 3 studies utilized an immersion system, 5 collaborative virtual environments and 5 AuR technology. Half of the studies implemented interventions with 3D social scenarios and visual support and the rest used training systems developed by the researchers, such as the VR-JIT (job interview training) (Smith et al., 2014), the VR-SIT (social interaction training) (Ke & Im, 2013), the HCIJA training (human computer intervention joint attention) (Jyoti & Lahiri, 2020), the ARCM (augmented reality concept map), a social network map (Lee et al., 2018), the VM story book (Chen et al., 2016), the VR4VR, a vocational rehabilitation programme (Bozgeyikli et al., 2017), the Kinect system (Lee, 2020) or role-play.

In terms of outcome, namely target-behavior, 32 studies (50.8%) focused on basic communication skills (e.g., independent request expression) and social communication (e.g., comments, greetings, conversation), 21 studies (33.3%) aimed at the development of social skills to enhance social interaction and understanding (e.g., cooperation, eye contact, turn-taking, mutual attention, non-verbal social cues) and 10 (15.8%) were related to the development of vocational skills (e.g., improving job performance, interviewing).

The results of the empirical studies, as summarized in Tables 1 and 2 were largely positive for all the skills studied. Indicatively, in the field of communication, the use of portable/mobile tablets (iPad, iPod και iPod Touch) with their relevant AAC applications (e.g. Proloquo 2Go, My Talk, Go Talk Now Free) and structured behavioral interventions were successful in leading to the expression of an independent request for preferred objects (Nepo et al., 2017· Sigafoos et al., 2013 ·Ward et al., 2013· Dundon et al., 2013· Shih et al., 2014) in up to 100% in some studies (Van der Meer et al., 2011; Kagohara et al., 2010; Waddington et al., 2017). Vocal responses were expressed by participants in some studies (King et al., 2014; Nepo et al., 2017). Wendt et al., (2019) taught two teenagers and an adult, with very limited speech, to request a multi-step request and speech production using an iPad, the apps Speak all! and a modified PECS protocol and achieved a significant increase in requests for all, but only one reached Phase V. In speech production the results were mixed, as only one, who had some phonemes, increased the spoken words to two, after researcher's behavioral interventions in phase IV aimed at provoking speech. An increase in communication intentions was observed in some studies, and responses to the topic of discussion, with 100% parallel generalization (Ribeiro & Raposo, 2014; Sng et al., 2017). On the other hand, some subjects had difficulties in distinguishing image symbols (King et al., 2014; Wendt et al., 2019), but others successfully expressed an independent request and navigated 2-4 pages by combining symbols (Achmadi et. al., 2012; Alzrayer et al., 2017; Waddington et al., 2014; Van der Meer et al., 2014). In some studies, participants gave successful answers to questions such as "what do you want?", "what is your name?", "what do you see;" (Strasberger & Ferreri, 2014; Kagohara et al., 2012) and some achieved high scores in naming and distinguishing symbols, 85% and 93% respectively, (Lorah et al., 2014), and in spontaneous functional communication using an iPad with SonoFlex app (Xin & Leonard, 2015). Additionally, in most comparative studies the results were mixed (e.g. Hill & Flores, 2014; Couper et al., 2014; Van der Meer et al., 2012a; Van der Meer et al., 2012c). These studies utilized mobile devices as Speech Generated Device (SGD-Speech Generated Device) supported by an AAC application and compared them with other AAC systems, such as PECS, Picture Exchange (PE) and Manual Sign (MS).

Regarding training in vocational skills, statistically significant differences in performance were observed after interventions with the technological tool. Work efficiency increased by up to 98%, the need for personal support from a job coach was reduced and most participants successfully completed the work steps that led to independent use of the device

(Bozgeyikli et al., 2017; Gentry et al., 2015; Burke et al., 2013; Smith et al., 2014).

Studies on the development of social skills showed an improvement in mutual social behavior, and statistically significant improvement in verbal and non-verbal interactions, and increase in scores on responses and greetings. A high degree of comprehension and recognition of facial or emotional expressions was recorded, and improved collaborative behavior, quantitative and qualitative increase of social interaction and enhanced focus on social indications (Lee, 2020; Lee et al., 2018; Chen et al, 2016; Escobendo et al., 2012; Grosberg & Charlop, 2014; Macpherson et al., 2015; Zhao et al., 2018).

4. Discussion

This systematic literature review identified 63 scientific articles on the effectiveness and potential benefits and disadvantages for individuals with ASD of using AT. Of the 63 studies, 60 were conducted in the last decade, indicating an increasing trend in research activity, due in part to the increasing rate of diagnosis of ASD, but also to the challenge for researchers in this field of the emergence of the Apple iPad in 2010, which revolutionized the field of mobile technology. More recently, VR and AuR technologies appear to be gaining attention, as 12 of the 19 relevant studies were conducted in the last 5 years.

Concerning the study subjects, there were small differences in numbers of participants between the age groups, with fewer adolescents (n = 88) and more adults (n = 119), but 55 of the adults participated in one study (Gentry et al., 2015). In general, small sample sizes were observed, making it difficult to generalize the results and draw safe conclusions. The majority (70%) of the studies were conducted under controlled conditions, in simulated settings, as observed by previous researchers (Kagohara et al., 2013; Mesa-Gresa et al., 2018). It is imperative to implement and assess interventions in natural contexts of the real world, outside the experimental laboratory and clinical practice, in order to facilitate the generalization of the acquired skills.

In most of the studies tablet computers were used, most frequently iPads (Stephenson & Limbrick, 2015), probably because of their flexibility, functionality and connectivity that make them popular with the general public (McNaughton & Light, 2013). The small number of applications used in the studies (e.g., Proloco2Go, Pix Talk, Conversation Coach, Pαca, Speak all!, My Talk, Go Talk Now Free, My Choice Board, SonoFlex) indicates the need to study a wider range of applications to provide adequate evidence of the effectiveness of electronic mobile devices and their ability to support interventions for people with ASD. In the research on VR and AuR technologies, very few studies used immersive environments, which may be related to their higher cost compared with non-immersive or desktop environments. Half of the studies used intervention with 3D social scenarios, role-play and visual support, which is considered more effective for the development of social skills, as these methods increase the motivation of learners and facilitate maintenance of the acquired skills and generalization in other contexts (Escobendo et al., 2012).

The outcome measures used in most of the studies were communication using mobile technology, and expression of an independent request. Social skills were observed for the interventions applied in a VR or AuR environment. Assessment of vocational skills was conducted in only a small number of studies (n=10), focusing on a narrow range of work activities, such as cleaning, storage, mail sorting and pre-professional skills (e.g. interviewing). The development of vocational skills is a crucial factor in claiming independence and the smooth integration of people with ASD in the community, and should be the target of future research in both types of technology. The skills repertoire is limited, especially in VR/AuR technologies, and research on more complex forms of communication is indicated, as field research has minimal. These findings are consistent with those of earlier systematic reviews (Kagohara et al., 2013; Bozgeyikli & Katkoori, 2018).

Overall, the results of the 63 studies in this review were positive, indicating that the various technological tools (mobile devices, AT applications, VR and AuR environments) can make a positive contribution to skills development and improve the quality of life of individuals with ASD, helping them to overcome the difficulties associated with the disorder. They can be viable and useful tools for training and development of communication, social and vocational skills for this population group, as was concluded following earlier systematic reviews and meta-analyses (Kagohara et al., 2013; Bozgeyikli & Katkoori, 2018; Stephenson & Limbrick, 2015; Baragash et al., 2019).

Most of the studies reviewed here presented measures of the social validity of the AT interventions, and some provided strong evidence of effectiveness. In the majority the results were positive, but the small sample in many of the studies and the lack of homogeneity do not allow generalization of the results to the rest of the ASD population, or drawing of safe conclusions. In addition, the limited number of studies covering certain categories, such as vocational skills, and the extremely narrow range of skills taught (e.g., requesting), did not include the full range of capacities of these modern technological tools, and further study is needed to substantiate the potential benefits of these technological solutions for people with ASD.

High-tech electronic devices that function as AAC tools, in conjunction with a well-established educational process, can benefit people with ASD in learning functional communication, based primarily on behavioral instructional strategies. Research results suggest that it may also facilitate speech production (Wendt et al., 2019 · Flores et al., 2012 · Lorah et al., 2013 · Nepo et al., 2017). The review findings indicate that individuals with ASD can be taught to use the technological applications for the development or enhancement of their skills. Adaptation-modification of the protocol of the PECS phases, in combination with the implementation of systematic teaching strategies, was shown to work effectively with all AAC systems (e.g. Lorah et al., 2013; King et al., 2014; Wendt et al., 2019), even leading to spontaneous speech (Frost & Bondy, 2002). Teaching more complex steps and forms of communication or teaching social communication (e.g. comments, greetings, answers to questions, conversation) in a more advanced and challenging form compared to the request aims to expand the development of the existing repertoire and provide greater independence and autonomy to the user, so it is an issue that needs special attention from the scientific community.

In general, research on VR and AuR records positive results. Some studies reported significant, and even dramatic, increases in the relevant scores (Zhao et al., 2018; Lee, 2020; Lee et al. 2018). In particular, research on AuR technologies produced encouraging results and information on the dynamics of these forms of intervention. Such applications were mostly used to promote social interaction and the development of social skills that facilitate the understanding of social greetings / signs by people with ASD, as well as the recognition of emotions and facial expressions. The promising dynamics of augmented reality are also supported by Baragash et al. (2019) in their meta-analysis that this technology can be used to promote positive social behaviors such as emotional recognition, communication and understanding common social cues, crucial factors for social interactions development.

The majority of research on collaborative virtual environments (CVE) showed positive effects on the development of communication, cooperation and social interaction. High scores in performance, improved collaborative behavior and a high level of communication were recorded (Cheng & Ye, 2010; Zhao et al., 2018; Zhang et al., 2018), suggesting that these environments are a promising technological tool for the development of communication skills by people with ASD, but these results were preliminary, based usually on feasibility studies. The studies were limited in number and with small samples of participants, which does not permit generalization of the results. Because of their structure, CVEs can have a greater impact on the generalization of mutual social behavior to other environments. It is difficult to make safe comparison between environments, however, as there was heterogeneity between the studies, which used different parameters (methodology,

research design, research tools, and sample size).

It should be noted that research on VR and AuR, despite the positive findings, has been limited (Mesa-Gresa et al., 2018), both in numbers and in the range of severity of ASD studied. It is clearly an emerging technology and further research is needed in this field, with more subjects, due to heterogeneity of ASD symptoms and small samples of participants. Comparison with traditional forms of training for people with ASD should also be made.

In the comparative studies conducted to date, (e.g., between mobile devices as tools of AAC and traditional AAC systems, such as Manual Sign or Picture Exchange) the results have been mixed. Requests have been made by participants using all of the AAC systems, with a variety of preferences. Individuals with ASD can be successfully taught to make independent one- or multi-step requests for preferred objects/items in at least one, or even all, of the three systems (Van der Meer et al., 2012a; Van der Meer et al., 2012c). Most of the participants scored highly and succeeded in achieving the criterion for success using high-tech mobile devices. Previous experience can facilitate (Van der Meer et al., 2012b) and accelerate learning, especially if the AAC system is the participant's preferred choice (Couper et al., 2014). The capability to use the preferred system, and the ability to retain the acquired skill increase with experience (Van der Meer et al., 2012b).

A portable device intervention is considered successful when the individual can interact in real-world communication contexts and with real communication partners (Light & McNaughton, 2015). The ability to generalize the acquired skills in different contexts and with different people in the real world, and not only in a laboratory and under controlled conditions, is a critical factor and a condition for the success of any intervention or experimental process. It is apparent from this review that the target behaviors have not been evaluated in their entirety in all studies, particularly at the level of maintenance (60%) and generalization (25%).

Research on the application of technological tools has revealed advantages, but also some disadvantages in terms of their utilization by people with ASD. Mobile devices used as a technological solution for AAC, with a potentially unlimited number of icons and screen pages, are easier to use and transfer than communication folders in the picture exchange system, and lead to faster communication.

The synthetic speech output feature can capture the listener's attention and may act as verbal modeling, with the potential to lead to increased speech production (Lorah et al., 2013; Flores et al., 2012; Nepo et al., 2017; Wendt et al., 2019). The sound enhances the feedback and is likely to motivate the user. Because of their widespread use, availability and popularity with the general public, when tablets are used as SGDs, they are socially acceptable, and stigmatization is avoided, (Van der Meer et al., 2012c). Accessibility, in terms of availability, cost, easy storage and transport, make them more attractive than the traditional bulky specialized speech generators (Flores et al., 2012). In general, portable tablets lead to positive social behavior in people with ASD, and more frequent verbal interactions. Interaction with the computer is more predictable and controllable than interchange with a human partner. Social interaction, in the form of activities with mobile gaming applications, is easier and more comfortable, because it takes place in the context of a fun activity with the computer, which boosts self-confidence, reduces stress and increases engagement (Hurcade et al., 2013).

In the workplace, mobile devices are suitable for transferring video modeling and video prompts, with the addition of written or spoken instructions. They facilitate task analysis, and help the user with ASD to follow the steps of the work, especially when audio is included. The devices can be modified and individualized according to the needs of the employee, and are easily transported to the workplace, without leading to stigma (Kellems & Morningstar, 2012). Personal digital assistants, such as iPod Touch PDAs (Gentry et al., 2012; Gentry et al., 2015) are emerging as valuable workplace technology tools that enable the employee with ASD to work more independently, reducing the need for in-situ supervision by a work instructor or

job coach.

The disadvantage of these devices is that they require systematic, intensive training for the person with ASD to learn their operation. Speech activation can be a challenge for some people, as touching the screen or the speech output symbol in a very specific way may be difficult for some users who do not have well-developed fine motor skills. Alternative intervention strategies may be required to familiarize individuals with ASD with the device (Kagohara et al., 2010).

VR and AuR technologies and environments can simulate social scenes (e.g., the classroom), reproduce real-life scenarios, and offer multiple opportunities for individuals with ASD to practice and replicate skills in a safe, distraction-free learning environment. Specific instructions from the system facilitate interaction, communication and collaboration. (Bozgeyikli et al., 2017). Human co-workers often deviate from scheduled procedures, but virtual characters are controlled, programmed to exhibit the same expressions and perform the same behaviors in each session. This standardization allows trainees learning social skills to identify social cues. Individualization of the environment, visualization of abstract concepts, automation of performance recording, and instant feedback and evaluation are just some of the advantages of these technologies that make them a promising technology for people with ASD. Disadvantages are that not all the software provides rich images and graphics, and that special training and equipment are required to implement these technological solutions.

With the exception of a few studies (Jyoti & Lahiri, 2020; Halabi et al., 2017; Bozgeyikli et al., 2017; Zhang et al., 2020), where participants were trained in an automated technology system, in all the other studies the interventions were implemented in the presence of a human factor, namely a mediator, facilitator, trainer, communication partner or provider of prompts, instructions and feedback, who modified the interventions as part of an individualized educational process. The type, frequency and quality of human intervention and unique characteristics of each individual with ASD may affect the effectiveness of the features of each form technology, and explain, in part, the differences in performance. Future research should take these factors into consideration, including detection of the special characteristics, needs and learning profile of each individual, so that the successful combination of technology and human intervention can produce optimal results. It is apparent that each intervention needs to operate in a context of individualization, to allow the learner to interact with the technological tool with full potential.

These technological tools, as documented by the studies reviewed here, can contribute positively to the manifestation of social and communicative behaviors by people with ASD. They can play a strong supportive role in the rehabilitation, education and training of people with ASD in communication, social and vocational skills. AT, however, cannot replace human interaction in a real-life context, outside of clinical practice, where the presence of the human factor is necessary for the planning and implementation of interventions, and to ensure generalization of the acquired skills. The main goal of the interventions is to facilitate human interaction through technology and not its substitution. Real-life, authentic human interaction, by definition, concerns the real world and not experimental conditions or a simulated environment. The technological tools are the result of the invention of the human mind, acted and programmed in terms of their capabilities and autonomy by the human-operator, and their pre-eminent role is to act as auxiliary partners-assistants of people with ASD, to help them overcome difficulties arising from the inherent nature and characteristics of ASD and to achieve the smoothest adaptation into the community. During the past decade, the AT applications have become more versatile and user-friendly, opening up possibilities for more effective interventions. It is the human therapist, researcher, trainer who implements the interventions and controls the training or treatment, having evaluated the needs and capabilities of a person with ASD, with the ultimate goal of strengthening his/her functionality in everyday life, in the real world.

5. Final Considerations

This review identified and analyzed 63 primary studies published in the last 20 years and attempted to answer research questions concerning the effectiveness of AT tools for the development of communication, social and vocational skills in people with ASD. This study was subject to certain restrictions. Specifically, the qualitative analysis of the research material did not proceed to statistical analysis of the data in the context of a meta-analysis, leading to measures of statistical significance that would allow generalizations and safer conclusions for the general population. This was due to the small numbers of subjects in most studies, and the lack of homogeneity, both in the study subjects and the AT tools investigated. Future reviews could also investigate the effectiveness of AT in acquiring a wider range of skills by individuals with ASD.

Future research should be focused on a variety of AT applications, as new tools emerge, with larger samples of subjects, in order to identify their benefits, but also possible disadvantages and potential challenges they pose for people with ASD. Collaboration with institutes, services, institutions and organizations active in the field of ASD could lead to an increase in the number of participants in studies.

It is important to conduct high-quality research in this area, using stringent criteria, rigorous scientific design, and covering a wider range of skills in people with ASD. Future studies should have validity and provide sufficient, detailed data for reproducibility by other research teams, in order to prove the effectiveness of each intervention.

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