Scrutinizing Reviews on Computer Science Technologies for Autism: Issues and Challenges

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ABSTRACT Autism is characterized by a great diversity of disabilities and intensities observed in the development of individuals since their infancy. The search for treatment has increased, and new forms of interventions have emerged, including those involving technology. There are many and different technological solutions that aim to help these individuals learn and execute daily activities. The literature presents a large number of papers describing technologies for autism; however, given the volume of primary and secondary studies, it is difficult to have an overview of the existing solutions and gaps to deal with in future researches. Based on this problem, a literature systematic mapping on review studies about technologies to people with autism was carried out. A total of 33 literature review studies (which analyzed 1298 primary studies) were examined. We categorized these studies according to their area, the support offered, the skill to be developed, the user’s development phase, and the kind of technology used. Furthermore, we have also organized the research questions that were already covered in studies and their future works. This will help researchers to identify topics and challenges to be explored by new research.

INDEX TERMS Literature systematic mapping, tertiary study, autism, technology.

I. INTRODUCTION
It is estimated that 1 in every 160 children has an Autism Spectrum Disorder (ASD) [4] Autism is described as an invasive developmental disorder that causes life-long difficulties in the social and communicative fields [9]. These difficulties vary and depend on many factors, including the degree of cognitive impairment faced [5]. The treatment for autism should be structured according to the stage of life and specific difficulties faced by the patient [6]. With the progress of technology and its various fields of application, people with autism may rely on the use of technologies that help in the development of their capabilities [7]. These technologies are known as Assistive Technology systems. However, to develop technology for people with autism, it is necessary to understand their neurodiversity [14], [15].

The term “Assistive Technology” (AT) is applied to the range of equipment, services, strategies, and practices designed and implemented to ease the functional problems faced by people with disabilities [8], and can also help to improve their skills. This area of knowledge was considered one of the challenges to be addressed in computing research, given the inevitability of enhancing the user’s experience with computers, whether they face disabilities or not [2], [3], [28]. Thus, to meet the demand of users with different characteristics, including physical and cognitive limitations, the solutions need to consider the integration of multiple perspectives, such as computation, psychology, and neuroscience.

Computational research involving assistive technologies are very diverse. There are many studies aimed at developing hardware, software, robots, application with virtual reality, among others. A quick look at search indexers for the word “autism” in the computing area reveals 2169 studies in the last five years (search in the SCOPUS’ database, 2015-2019). When considering that other areas also produce studies involving technologies, this number is much higher.

In this article, our search was restricted to studies involving review and mapping, because an indirect strategy can identify how the researches in the area are characterized. Studies of review and mapping summarize which technologies are being used, how is the user’s experience, which skills are trained, which are the main limitations and future work of existing studies.

The literature review and mapping studies are essential because they reveal knowledge gaps, the state of the research in certain areas, the quality of the existing research, concepts,
problems and issues that have not yet been solved. There are two types of reviews and systematic mapping studies: secondary and tertiary. The term “systematic” is used to refer to studies that use a well-defined methodology to identify, analyze, and interpret evidence related to research questions [27]. Tertiary mappings seek to categories secondary studies that deal with a same research question; it is a review of literature reviews that answer, in a descriptive way, broader research questions.

This work presents a systematic literature mapping, whose goal is to identify, analyze and categorize literature review studies on computational solutions for autism. Tertiary studies for this topic were not found yet. Our motivation to conduct this mapping is that there is an enormous amount of primary and also secondary studies involving autism and computer science. Consequently, doing initial researches be much more laborious and time-consuming to generate well-grounded and practical results.

This mapping contribution is to provide for researchers a synthesis of secondary studies’ characteristics as well as, which problems (from autism) and solutions (technologies) they approached. This synthesis includes the main sub-areas worked, both concerning autism, seeking which the individuals’ characteristics and comorbidities are focused in those studies, and concerning computation, searching for the most used and developed technologies. Furthermore, the mapping presents an overview of research gaps that need to be explored in the future.

The paper is organized as follows: Section II summarizes some concepts and needs associated with individuals with autism; Section III presents the protocol of the systematic mapping; Section IV discusses the results and gaps identified; and Section V presents our final considerations and future work.

II. BACKGROUND

Autism is a syndrome characterized by qualitative deficits in social and communication skills, and the existence of stereotyped and recurrent behaviors [16]. It is named Autism Spectrum Disorder (ASD).

The delayed diagnosis brings harm to the individual since he/she will not receive the attention and help needed for the development of his/her abilities, besides being, in a way, misunderstood and stigmatized. The treatment for autism requires a team composed of multiple expertise: doctors, therapists, psychologists, among other professionals. People with autism may present varied symptoms and behaviors, which may be specific to the ASD or not [16]. Therefore, an individualized approach to diagnosis and treatment is essential.

In the first year of life, children with autism have difficulty using and understanding nonverbal communication [10]. While typical children learn to communicate through eye contact and observation, children with autism tend not to maintain eye contact with their parents or other people. Also, expressions, like pointing and sharing attention and objects, are limited among that audience. The delay in the development of the language ends up interfering directly in social interaction. The non-spontaneous use of verbal and/or non-verbal communication makes the social relations unilateral [11]. In general, researchers mention the lack of socio-emotional reciprocity, postural anticipation, and ocular contact, for example [12], [13].

Technologies can bring people with ASD additional support in the development of skills [7]. Since there is no known cure for ASD, the use of the technologies can help to avoid the increase of the deficit of abilities and behaviors. With the use of technologies it is possible to exercise, for example, the repetition of activities that are common in the day-to-day routine, and direct the patient’s attention using a diversity of audiovisual resources [17]. There is a wide variety of application areas for the technology, including learning, emotions recognition and identification [18] to help social interactions [19], to assist in understanding and managing the daily routine [20] and to enable communication [21]. All of these applications are seen as essential skills and knowledge to be worked on individuals with ASD.

To support the diversity of ASD characteristics, the technologies tend to be complex and face various development challenges. Therefore, many of the studies are inclined to limit their scope by focusing on an audience with few comorbidities (often with mild autism) and only one kind of technology [22], [23]. Moreover, some studies emphasize the need for research that helps to define which technologies have the best applicability for which needs [24], [25].

III. SYSTEMATIC MAPPING PROTOCOL

This study was carried out following a systematic mapping protocol whose objective was to identify, analyze and classify review and mapping works related to the computer science literature on autism. The entire process of selection, classification and analysis of the studies was performed by two authors of this article, independently of each other, to avoid research bias. Face-to-face meetings were periodically carried out to integrate the results and resolve differences.

This mapping presents which technologies were researched and employed in autism, which areas and skills were focused, as well as which research questions, conclusions and future work were pointed out in the identified articles. Besides, the contribution of this mapping is to help new researchers in this area gain an overview of the current works and challenges for further research.

A. RESEARCH QUESTIONS

The Table 1 presents the research questions of this systematic mapping. To answer them two strategies were used: for RQ01 to RQ05, a subset of options for answers was predefined; and for RQ06 to RQ08, it was tried to infer themes from reading articles.

The RQs elaborated in this study were guided by the central goal of identifying studies involving computing for people with autism. In light of this objective, ample research
questions were defined and after reviewed in pilot tests, taking into consideration that to compile this field we don’t want to limit the kind of problem (demand from autism) or solution (technology).

**B. SEARCH STRATEGIES**

Two search strategies were used: (i) automatic search, using a search string in search bases; and (ii) snowball, selecting the references cited in the articles included in the automatic search.

The automatic search was performed in three of the main research bases in the Computer Science area: SCOPUS, ACM, and IEEE, in October 2018. To formulate the search string, some attempts were made to achieve a good return of significant articles, involving three subjects: terms associated with autism, technologies, and with literature review. Those attempts varied in two directions: changes in the string including words related to technologies such as assistive technology, robots, software, among others, and changes in the search fields - first, titles, abstracts and keywords were used.

The use of many terms together returned only a few articles, and there was no guarantee that all the possible technologies were included, so it was chosen to use a more open string without mentioning any specific technology. Besides that, the search considering the abstract field returned many false positives, since numerous articles mention in their abstract the word review, even when their focuses are not a review. After those attempts, it was observed that the meaningful articles had the words review and mapping in their titles or keywords. So, the string used in our search was:

(parts OR autistic) AND (review OR mapping OR survey)

That string was searched in titles and keywords considering the syntax rules of each of the three search databases previously mentioned. In Scopus, it was searched only into the Computer Science area.

**C. INCLUSION, EXCLUSION AND QUALITY CRITERIA**

After the searches, the titles and abstracts of the articles were read, and excluded those that did not present all of the inclusion criteria (IC) or had some exclusion criterion (EC), listed in Table 2. When there was doubt, the authors include it for its entire reading in the next phase. These same inclusion and exclusion criteria were also applied to the articles identified using snowball. Then, the selected articles were fully read to be classified. In this stage, some works were still excluded because they were primary studies or books.

To evaluate the quality of the studies included [29], it was checked whether the works met at least one of the quality criteria defined in Table 2. The studies that did not meet the minimum required were excluded from the mapping. The first two quality criteria were chosen because they are minimal characteristics to understand the study’s capacity of replication; the third criterion indicates the amplitude of the studies; and the fourth criterion indicates if the work provides to us a clear way to compare the studies that it reviewed.

**IV. RESULTS AND DISCUSSION**

The application of the string in the databases returned 152 articles in Scopus, 19 in ACMLibrary and 13 in IEEExplore, totaling 184 articles. After the elimination of duplicates and the application of the inclusion and exclusion criteria, 23 articles were selected and included in our systematic mapping. The second search, using snowball, identified 348 articles out of which 14 were selected. Thus, a total of 37 articles were included for evaluation. The 37 articles were entirely read and mapped to respond initially to our quality criteria and subsequently, to the research questions. Table 3 illustrates mapping stages and respective outputs.

The Figure 1 presents the distribution of the 37 studies per year of publication and search strategy through which each one was identified. The years are organized in descending order from left to right. The articles were published between 2010 and 2018. There are review studies in all of the years,
although there is only one study in 2010 and 2015, while in 2014 there are seven studies. The studies obtained using the automatic search are shown with a white background, while the studies obtained with the snowball strategy are identified with a gray background. Works with a gray font are studies excluded for not meeting the quality criteria [S18], [S24], [S25], [S33].

The articles were written by authors from institutions in different countries. The most significant number of authors are from the United States (9), United Kingdom (6) and Malaysia (4). The publication vehicles that have showed up more often are the Research In Autism Spectrum Disorders (4), the International Journal of Social Robotics (2) and the Autism journals (2). There are others 29 publication vehicles, in which there was only one work published each.

The Table 4 shows how each of the 37 studies was mapped according to the quality criteria, and in the last column, there is the number of citations found for each one of them (from Scopus). Only 4 (10.81%) studies did not meet the quality criteria, while 33 (89.19%) corresponded to it, of which 17 (45.94%) works matches all of the criteria defined. Moreover, 29 articles explicitly reported the number of primary studies or software (both from app stores and websites) that they reviewed, totaling 1298 solutions.
FIGURE 2. Classification of the 33 studies analyzed.
A. ANSWERS TO THE RESEARCH QUESTIONS

The research questions presented in Section III-A are answered below. Figure 2 summarizes the classification for all of the 33 included studies, considering the questions RQ01 to RQ05. The alternatives exposed in each classification topic (highlighted by different colors) emerged from reading the articles.

1) RQ01-WHAT ARE THE RESEARCH AREAS FOCUSED ON ARTICLES?

The works’ area of focus varies from one to many, depending on the goals defined by the authors. In the sample, 29 of 33 papers are related to the area of Education, proposing the teaching or training of some skills such as speaking, writing, and comprehension. Some articles report the involvement of multiple professionals from different fields, thus forming a multidisciplinary area of study (18). It was also identified papers focusing on Human-Robot Interaction (8), Human-Computer Interface (7), Psychology (7), and Medicine (3).

2) RQ02-WHAT TYPES OF SUPPORT DO THE ARTICLES OFFER?

Many of the studies seek to offer more than one type of support for autism, the types of support are: diagnosis (1), teaching (22), research (9), assistive technology (3), social interaction (14), therapeutic intervention (22), and support for caregivers (1). There are some correlations between the area and the type of support, for instance, many of the works in the area of Education have been classified as teaching, therapeutic intervention, or social interaction. Works in the medical field provide support for research, diagnosis, and therapeutic intervention. Many of the papers that cover the area of Psychology focus on therapeutic intervention and social interaction. Furthermore, studies classified as assistive technology have concentrate on activities of the daily living [S09], [S10], [S15]. Studies classified as support to research include: user’s engagement time in a given technology [S06], influence models in the educational process [S05], [S09], ways of improving the conduction of studies and development of Virtual Reality systems [S03], [S14], [S23], studies on the
user’s experience and usability [S07], and deficits of research involving robots [S11].

3) RQ03—WHAT ARE THE SKILLS FOCUSED ON ARTICLES?
As mentioned previously, the technologies can bring better dynamics to the treatment, diagnosis, or entertainment of the patient. The studies focus on one (2) or multiple (31) skills to be developed in individuals with autism. The skills covered in the papers are social (25), communication (17), cognitive (16), learning (11), attention (6), self-care and safety (1). There was also one work that did not restrict the skills; its focus is on user experience research [S07].

Social skills, the most cited skill, include practices of dialogue, writing, and speech. Researchers have evaluated systems intending to mitigate adverse effects that may arise when an individual with autism relates to others [S23]; to reduce anxiety [S21]; and to improve the learning of new vocabulary [S09, S27]. Vocabulary learning enhances the patient’s relationship with his partners and helps him/her not to be excluded from interpersonal relationships. Therefore, many articles on social abilities also deal with communication (15), cognitive disabilities (12) and learning (8).

4) RQ04—WHAT ARE THE TECHNOLOGIES FOCUSED ON ARTICLES?
The articles explore a diversity of technologies; 23 popular terms associated with hardware and software technologies were identified in the papers. The leaves of the tree in Figure 3 show these terms. Bold terms are those into technology category in Figure 2.

Although the terms software and hardware are abstract, they were used as subcategory to highlight those articles have any emphasis on software, hardware or both. The terms TEL, CAL, ICT, CBI, and CAI are used to represent computer science technologies, predominantly the computer, but not restrict to it. The use of these terms evidences the attention on investigating more than one kind of technology. The most cited technologies involve the use of robots (12) or virtual reality (12). Robots are especially cited when the target audience is children. Many users, especially children, have a significant interest in robots and can communicate better with this technology [S7]. Many characteristics about the user’s interaction [S10, S15, S17, S22, S26, S22, S34] are taken into account, and robots are considered to provide a form of learning that induces improvements in communication, social interaction, attention, and behavioral skills. Robots are used, in general, in clinical contexts [S11, S30], being considered a cognitive companion. There is a significant concern by some studies to demonstrate the role of this technology in the development and rehabilitation of children [S12].

Virtual Reality improves the patients’ quality of life and to train skills, such as the recognition of facial expressions and emotions [S22], reading [S20], and communication [S10, S29, S34, S35]. Studies report that the patient feels safe undergoing experiences with Virtual Reality, and that brings a series of positive personal returns. However, despite the proven effectiveness of this technology [S20], it is reported that its access is still limited, and its use ends up being very restricted. Virtual Reality simulations target not only learning but also the measurement of attention indicators [S6, S36] and anxiety rates [S21], which are controlled to later provide improvements in assessment and treatment. Virtual reality simulations seek to impact in three main contexts: social [S04, S14, S17, S23, S34, S35], daily life activities [S03, S15], and security [S03].

Augmented Reality and wearable were also identified among the technologies cited by the studies. Through augmented reality that blends the real with virtual elements, users interacted with the projection of multiple images on a table. With the use of these technologies, users learned about objects and keywords as well as the association between them [S03]. Considering wearable, biases have been used to obtain information about the status of users during therapies [S17]. The sensors can measure for example information related to how the body reacts when subjected to a state of anxiety. Capturing this information is important to help correct certain states or behaviors [S29] that can happen through instructions from robots or mobile applications.

Another technology that assists in treatment of people with autism is the Serious Game. Games support teaching while they provide entertainment for the patient. The use of games has impact on the development of the patients’ language [S09, S17], communication [S20], social skills [S13], daily life skills [S13, S21] and behavioral skills [S13, S17]. There is a great advantage in using games because there are no limitations regarding the environment in which the technology can be inserted (home, school, or clinic) and its easy access. The skills to be worked on are also numerous, as well as the devices in which the game works, such as desktops, mobile devices [S8], and others. However, there are still scope limitations in the games, for example, lack of support for patients with a sensory disorder and in teaching first aid [S16].

Mobile (3) and web applications (1) have been the main focus into few studies, although they have been cited with other technologies, such as serious games, CAI, CBI, CAL, TEL and ICT. These last one involve multiple technologies to enhance the learning and development. For example, Computer Assisted Instruction (CAI) uses technologies such as games and speech recognition software [S09, S37]; Computer-based intervention (CBI) uses video, virtual reality and interactive programs [S10, S27]; Computer Assisted Learning (CAL) [S19] and Enhanced Technological Learning (TEL) [S29] use multi-touch, affective computing, virtual agents; Innovative Information Communication Technologies (ICTs) uses robots, head devices, mobile devices, speech devices, tactile prompt and multimedia devices [S17].

5) RQ05—WHAT ARE THE STAGES OF THE INDIVIDUAL’S DEVELOPMENT FOCUSED ON ARTICLES?
When considering the impact of the technologies, the participation of the real users is fundamental. All of the studies
evaluated whether the articles that they reviewed included patients with autism in the technology assessment process. Regarding the individual’s developmental stages, in Table 5, 15 articles did not restrict age, while 12 were restricted to children, 4 were restricted to children and adolescents, and 1 to adolescents. However, it was identified that even when there was no age restriction, the solutions analyzed by the studies were mostly for children. The Table 5 shows the quantity identified for each age and highlights that no work focuses on adults.

6) RQ06—WHAT ARE THE ARTICLES' RESEARCH QUESTIONS?
For an overview of the problems addressed in the studies, their research questions were classified into six categories, as shown below. Those categories bring together questions that have been explicitly defined in the articles or questions that it was inferred from reading them.

Treatments and Interventions
- What are the most accepted therapy methods for child?
- What are the objectives of the clinical intervention?
- What are the types of participants and variables in clinical treatments?
- How to evaluate intervention studies?
- What are the innovations and impact of clinical technological innovations for autism?
- How to develop social communication skills?
- What are the tools of social interaction and skills?
- What can be analyzed in learning using technology?
- What are the behavioral improvements using technology?
- What are the studies, variables, and evaluation in the use of technology for communication?

Robots
- What is the current and future role of robots?
- How to develop imitation and attention skills using robots?
- What is assistive social robotics?
- Is there a plan to generalize trained skills?

Virtual Reality
- What are the design guidelines for this type of application?
- What are the common characteristics of skills training systems?
- What are the characteristics of the studies’ participants?
- What are the configurations of Virtual Reality systems?
- What are the negative side effects?
- What is found about Virtual Reality utilization and effectiveness?
- Is there any use of this technology for teaching?
- What kinds of attention are studied in Virtual Reality?
- What are the behavioral measures of attention?
- Is there empirical evidence of the effectiveness of this technology?

Serious Games
- Can Serious games be used to rehabilitate children with autism?
- How do Serious Games improve learning?
TABLE 6. Words used in strings described by authors.

| Terms          | Words                                                                 |
|----------------|----------------------------------------------------------------------|
| Autism         | autism, autism spectrum, ASD, autism spectrum disorder, Asperger, Asperger syndrome, developmental disorder, neuro-behavioral disorder, behavioral disorder |
| Disability     | cognitive disabilities, mental impairments, intellectual disabilities, multiple disabilities, developmental disability, mental retardation |
| Skill          | attention, social interaction, social skill, social initiation, empathy, communication, language problems |
| Age            | children, child, children with autism                                |
| Support        | education, treatment, therapy, special education, therapy skills, training, intervention, behavioral, pediatric, pediatric |
| Technology     | virtual reality, virtual environment, hdm, 3d, mixed reality, video, video modeling, video recorder, video-based instruction, game, games, video games, serious game, educational games, computer games, video games, game-based learning, app, application, computer, application, iPad, tablet, iPod, smartphone, telephone, phone, mobile, personal digital assistant (PDA), handheld, Palm, PalmP, system, computer-based system, wearable, device, technology, information technology, innovative technology, electronic sensing, computer technology interactive, assistive technology, design, software design, software, user, interface, robot, robotics, robot-assisted behavioral intervention (RBI), computer-based intervention (CBI), computer-based software, computer interventions, computer, computer-assisted, computer-based, interactive, interactive multimedia, multimedia, UX, signs, internet, short message service, pager, hardware, computer architecture, audio recorder, electronic, app store, platform |
| Other          | methodology, methodological, model, usability, evaluation, participatory, presence, collaborative, case-study, challenges, pretend play, perspective taking, script fading |

- What are the characteristics of Serious Games?
- What are the Serious Gaming platforms?
- What are the types of interaction?
- What are the types of games?

**Human-Computer Interaction**

- How to engage the target audience in the studies?
- How to develop a solution in HCI?
- What are the problems of UX?
- What are the contingency plans?

**General Technologies**

- Which technologies are available?
- What are the models of computer applications and recent applications of information and communication technologies for autism treatments?
- What are the technological solutions to problems faced by people with ASD?
- What are the research on computer-aided instruction?
- What are the opportunities and challenges in mobile applications?
- What are the common characteristics of computer-aided learning?
- What are the benefits of computer-based intervention?

7) RQ07-WHAT ARE THE SEARCH AND CLASSIFICATION CRITERIA USED ON THE ARTICLES?

It was identified that 28 of the 33 studies clearly defined the selection criteria used to choose the reviewed studies. Among the 28 studies, 18 reported having performed an automatic search using a search string. The Table 6 lists the terms used in these strings. The terms were organized into seven categories associated with autism, disabilities, technologies, skills, age, support type and other. This organization can help in the elaboration of other search strings and thus to develop new literature systematic reviews.

Regarding the classification criteria, the included articles presented 44 criteria. However, only 28 papers organized the results using these classification criteria, while 5 reported their results without a clear organization. Table 7 shows all of the criteria identified and their number of occurrences. These criteria show us general characteristics to be observed in studies on technologies for ASD, and which can be used to compare solutions in this area. The most used criteria are Contribution, Characteristics of participants, Age, Ability, Size of the sample, Analysis method, and Technology.

8) RQ08-WHAT ARE THE MAIN CONCLUSIONS AND FUTURE WORK SUGGESTED ON THE ARTICLES?

There are some challenges recurrently cited in the articles, such as regarding the participation of a multidisciplinary team and evaluation for multiple and diverse people with ASD, considering the technology use as in laboratories as in real environments, such as residences, hospitals and clinics. These aspects mainly concern the analysis of the technology effects in improving the life of individuals with autism, and thus the possibility of generalizing the results achieved.

Other concerns more specific are also cited, as following. The use of CBI, RBI, and CAL shows positive results [S10],
TABLE 7. Criteria for the classification of articles in the analyzed studies.

| Criteria                  | Citation | Criteria                  | Citation |
|---------------------------|----------|---------------------------|----------|
| Contribution              | 14       | Procedures                | 1        |
| Char. of Participants     | 19       | Negative and collateral effects | 1       |
| Age                       | 10       | Discovered                | 1        |
| Ability                    | 9        | Modality                  | 1        |
| Size of the sample        | 8        | Tools                     | 1        |
| Analysis Method           | 7        | Problems                  | 1        |
| Technology                 | 6        | Support                   | 1        |
| Context                   | 3        | Limitations               | 1        |
| Generalization            | 3        | Findings                  | 1        |
| Purpose                   | 3        | Ranking                   | 1        |
| Number of studies         | 3        | Virtual Reality Benefits  | 1        |
| Target Behavior           | 2        | Conclusions               | 1        |
| Focus of the study        | 2        | Robot Feature             | 1        |
| Configuration             | 2        | Behavior of the robot     | 1        |
| Strategy                  | 2        | Method of data collection | 1        |
| Evaluation                | 2        | Type of attention         | 1        |
| Platform                  | 2        | Validity                  | 1        |
| Treatment                 | 2        | Engagement                | 1        |
| MARS                      | 2        | Functionality             | 1        |
| Type of robot             | 2        | Aesthetics                | 1        |
| Training                  | 1        | Information               | 1        |
| Duration of training      | 1        | Severity                  | 1        |

However, it is not clear which type of technology gives better support to a particular kind of learning strategy [S15]. It is necessary to analyze and compare the quality of multi-platform applications that support teaching [S02]. Regarding education, future works include: studies that show the impact that the technological intervention brings to learning in the real world [S21], search for diversified teaching strategies [S35], and use Computer-Assisted Instruction (CAI) in other academic areas beyond educational contexts to determine which model and environment are the most effective [S37].

Human-Computer Interaction (HCI) is an important area to consider when implementing systems for users with autism. It is imperative that the systems have appropriate interfaces, as well as a functional diversity that may be appropriate for each particular user [S05]. To improve interaction studies, usability and user experience, a set of guidelines has been proposed [S07] and involves knowing well the characteristics of the user, and other essential points. It is crucial to include individuals with autism in the validation or evaluation of the proposed technologies [S19] and the researchers have to perform the documentation in a clear way, presenting the results of the studies, their weaknesses, among other topics that can be used in the future for the development of more adequate techniques and methods. One future work in this area is to identify ways to improve also human-to-human interaction as human-computer interaction is investigated [S06].

In the field of WEB applications, it is reported that many of them do not have features that contribute to a better user’s engagement, and that they only allow to exercise a few skills at a time [S01]. Studies are necessary to show the effects of the use of these applications [S06]. The same limitations are reported for free mobile apps [S02]. In the case of paid mobile applications, it is reported that there is a greater coverage of skills, characteristics, and support. In this area, further studies are needed to evidence the effects of these technologies and the development of applications that have a low-cost for the population and that offer training for multiple skills [S20].

Regarding serious games, it has been reported that they are effective in the therapy and teaching of children with autism [S31]. The games can exercise sensory stimuli such as vision, hearing, smell, and oral, and the main platform for this technology is desktop computers [S13, S35]. The evaluation of the effectiveness of interventions using games is very limited because they are usually only made available in research laboratories [S28]. Important points that should be considered for the development of future games or new versions are that they need to be customize and for specific purposes [S16], besides showing the evolution of the user’s abilities [S19]. Future studies are related to the creation of evaluation methods according to the intervention purpose [S13], games that deal with cognitive limitations [S13], games that teach affective skills [S15] and game customization mechanisms based on the user’s behavior [S16].

Most Virtual Reality primary studies target only children. It is also reported that more reliable studies are needed to ensure Virtual Reality benefits. Most studies, not only those involving virtual reality [S05], include a very small audience of participants to validate the observed results and their potential is worthy of continuous research [S03], [S04], [S08], [S22], [S36]. Also, it is necessary to investigate the impact of the technology on the different levels of autism severity, on stimuli, and on modes of interaction [S14], [S23]. Virtual reality offers essential data related to user’s sustained attention, which impacts on the most diverse forms of learning [S06], but this is not always considered during the interventions.
In the Virtual Reality, it is seen the need for comparative studies to better identify its benefits [S03], whether the technology support for educational issues [S04], how measure and use the physiological signals on real-time attention [S10], how to set up the environment and the VR systems [S22] and to develop virtual scenarios [S23]. Also, it is expected to identify the therapeutic and social cost-benefit ratio of this technology [S36].

Concerning interactive robots, this technology brings advantages to individuals with autism and can play several roles, such as therapy agent, friend, or social mediator [S26], [S30]. Guidelines were developed to increase the effectiveness of robot intervention [S11]. However, it is emphasized that robots do not apply to all situations, for example, it is not known for sure whether the robot helps in improving the patient’s interaction with the therapist/people - they can only be used in specific cases [S12]. One of the studies reports that there is a failure related to the non-observation of quantitative data [S32] in primary studies.

Future works in robotics are related to imitation, joint attention and interactive involvement [S17] and the development of theories, models, methods and tools that aid in the understanding of the people-robot interaction [S26]. Besides those, studies on the cognitive processes and behavioral factors [S30], on defining variables to measure level of cognitive and linguistic functioning, degree of social impairment [S11], on the development of a robot architecture specific for clinical use [S32], and studies that meet clinical standards [S11] are required.

B. THREATS TO VALIDITY

The internal validity threats were mitigated as follows. Regarding the identification of the studies, it was performed two search strategies, the automatic search, and the backward snowball. Although the automatic search has searched only for titles and keywords, the snowball helped us to broaden the set of selected studies. However, there may still be important works for this research that are not found in the chosen bases or are not specific to the computation area. Regarding the correctness of the selection and classification of the included studies, these tasks were performed by two of the authors, that periodically got together to solve the existing conflicts.

As an external threat, it can be cited that the data analysis performed in this systematic mapping was made based on the interpretations of the data presented in the included studies and that the primary studies cited in them were not analyzed. This threat was mitigated by performing quality analysis of the articles, evaluating whether they present the criteria used to select the studies, and more than 75% of the articles presented our methodological quality criterion, even though many of them are not systematic reviews.

V. FINAL REMARKS

This article presents a systematic mapping of secondary studies that analyze technological solutions for autism. The search for the articles was done through search engines in three scientific bases and through a backward snowball approach. After the application of quality and classification criteria, 33 studies were categorized by area and type of assistance, technology analyzed, stage of development of the target audience, and skills in focus. Furthermore, their methodological issues were also mapped to provide an overview of search strings, research questions, classification criteria, conclusions and challenges cited by the included studies.

The contribution of our work was to identify the state of research involving technology and autism is two directions: first, in a direct way and transverse to analyzed studies’ goals, how the review and mapping studies are characterized; and second, in an indirect way, how these studies describe the primary studies, i.e., a big picture of which are the more approached requirements and technologies for autism. Therefore, this article helps new researchers quickly visualize the area and make decisions on how to manage further secondary studies in this area. Besides, aiding also to know requirements that have not yet been satisfactorily met by primary studies, such as:

- There is a need for technologies and studies that involve (or be focused on) older people (besides children) and take into consideration their needs.
- There is a need for investigating: which are the effects of the use of technologies in the short, medium and long term considering aspects of different areas, and how to generalize their results.
- There is a need for involving a multidisciplinary team that considers different perspectives within a technological application.
- Technologies for people with autism should be adaptable and accessible since there is a diverse spectrum of needs. They also need to provide a proper fault tolerance mechanism to keep the patient engaged and not leave him frustrated, angry, anxious, etc.
- These technologies need to provide a feedback mechanism for reporting technology usage data, also including biometric data for patient monitoring and technology assessment.
- There is a need to develop studies better documented and publicly open so that other teams can continue, complement, or evaluate the technologies already developed.

Considering the results of the mapping study, it is proposed as future work the cataloging of what types of technology have been employed for which user characteristics, regarding disabilities, age, intervention methods, etc. There is a need to develop parameterization and adaptation mechanisms so that the technologies created can meet a greater variety of user characteristics, also considering the individuals’ preferences. Another potential point for future work is the validation of the impact of technology with an expressive audience of users to identify patterns where it is most efficient. Regarding review studies, it was not find neither studies focused on specific intervention methods such as Applied Behavior Analysis (ABA), Treatment and Education of Autistic
and Related Communication Handicapped (Teacch), Picture Exchange Communication System (PECS), sensory integration or nutritional aspects and assistive technologies; areas that are possibly worth researching.

**APPENDIX A**

**LIST OF PAPERS ANALYZED**

| S01 | A. Larco, E. Diaz, C. Yanez and S. Luján-Mora, “Autism and Web-Based Learning: Review and Evaluation of Web Apps.” In: World Conference on Information Systems and Technologies, Springer, Cham, 2018. p.1434-1443, 2018.
| S02 | A. Larco, F. Enríquez and S. Luján-Mora, “Review and evaluation of special education iOS Apps using MARS.” In: IEEE World Engineering Education Conference (EDUNINE), IEEE, p.1-6, 2018.
| S03 | L. Bozgeyikli, A. Raij, S. Katkoori and R. Alqssemi, “A survey on virtual reality for individuals with autism spectrum disorder: Design considerations.” IEEE Transactions on Learning Technologies, v. 11, n. 2, p.133-151, 2017.
| S04 | R. Bradley and N. Newbutt, “Autism and virtual reality head-mounted displays: A state of the art systematic review.” Journal of Enabling Technologies, v. 12, n. 3, p.101-113, 2018.
| S05 | G. Constain, C. Collazos and F. Moreira, “Use of HCI for the development of emotional skills in the treatment of Autism Spectrum Disorder: a systematic review.” In: 13th Iberian Conference on Information Systems and Technologies (CISTI), IEEE, p.1-6, 2018.
| S06 | B. Banire, D. Al Thani, M. Qaraqe and B. Mansoor, “A systematic review: Attention assessment of virtual reality based intervention for learning in children with autism spectrum disorder.” In: 7th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), IEEE, p. 97-103, 2017.
| S07 | D. Çorlu, Ş. Taşel, S. G. Turan, A. Gatos, and A. E. Yantaç, A. E., “Involving Autistics in User Experience Studies: A Critical Review.” In: Proceedings of the 2017 Conference on Designing Interactive Systems. ACM, p.43-55, 2017.
| S08 | M. Shoaib, I. Hussain, H. T. Mirza and M. Tayyab, “The role of information and innovative technology for rehabilitation of children with autism: a systematic literature review.” In: 17th International Conference on Computational Science and Its Applications (ICCSA). IEEE, p.1-10, 2017.
| S09 | M. A. Dzulkifli, E. V. F. Abdul and A. W. A. Rahman, “A Review for Future Research and Practice in Using Computer Assisted Instruction on Vocabulary Learning among Children with Autism Spectrum Disorder.” In: 6th International Conference on Information and Communication Technology for The Muslim World (ICT4M). IEEE, p. 47-52, 2016.
| S10 | T.S Hong, S. Mohammaddan, S. T. S. Shazali, N. A. A. Mohtadzar and R. A. Bakar, “A review on assistive tools for autistic patients.” In: 2016 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES). IEEE, p.51-56, 2016.
| S11 | M. Begum, R. W. Sema and H. A. Yanco, “Are robots ready to deliver autism interventions? A comprehensive review.” International Journal of Social Robotics, v. 8, n. 2, p.157-181, 2016.
| S12 | T. Komendański, E. Mikołajewska, D. Mikołajewski, J. Dreszer and B. Bałaj, “Cognitive robots in the development and rehabilitation of children with developmental disorders.” Bio-Algorithms and Med-Systems, v. 12, n. 3, p. 93-98, 2016.
| S13 | S. Tsikinas, S. Xingolagos and M. Satratzemi, “Review on serious games for people with intellectual disabilities and autism.” In: European conference on games based learning. Academic Conferences International Limited, p. 696, 2016.
| S14 | S. Parsons, “Authenticity in Virtual Reality for assessment and intervention in autism: A conceptual review.” Educational Research Review, v. 19, p.138-157, 2016.
| S15 | W. Den Brok, et al., “Self-controlled technologies to support skill attainment in persons with an autism spectrum disorder and/or an intellectual disability: a systematic literature review.” Disability and Rehabilitation: Assistive Technology, v. 10, n. 1, p. 1-10, 2015.
| S16 | H. M. Zakari, et al., “A review of serious games for children with autism spectrum disorders (asd).” International conference on serious games development and applications. Springer, Cham, p. 93-106, 2014.
| S17 | S. Boucenna, A. Narzisi, E. Tilmont, F. Muratori, G. Pioggia, D. Cohen and M. Chetouani, “Interactive technologies for autistic children: A review.” Cognitive Computation, v. 6, n. 4, p. 722-740, 2014.
| S18 | M. Bakar, et al., “Review on training policy for teachers and parents in using humanoid for children with autism.” In: IEEE International Symposium on Robotics and Manufacturing Automation (ROMA). IEEE, p. 180-184, 2014.
| S19 | S. Fletcher-Watson, “A targeted review of computer-assisted learning for people with autism spectrum disorder: Towards a consistent methodology.” Review Journal of Autism and Developmental Disorders, v. 1, n. 2, p. 87-100, 2014.
| S20 | O. Grynszpan, P. L. Weiss, P. L., F. Perez-Diaz and E. Gal, “Innovative technology-based interventions for autism spectrum disorders: a meta-analysis.” Autism, v. 18, n. 4, p. 346-361, 2014.
| S21 | N. Aresti-Bartolome, and B. Garcia-Zapirain, “Technologies as support tools for persons with...
autistic spectrum disorder: a systematic review.”, International journal of environmental research and public health, v. 11, n. 8, p. 7767-7802, 2014.

S22 S. V. Wass and K. Porayksa-Pomsta, “The uses of cognitive training technologies in the treatment of autism spectrum disorders.”, Autism, v. 18, n. 8, p. 851-871, 2014.

S23 J. E. Irish, “Can I sit here? A review of the literature supporting the use of single-user virtual environments to help adolescents with autism learn appropriate social communication skills.”, Computers in Human Behavior, v. 29, n. 5, p. A17-A24, 2013.

S24 K. Buragga, A. Dhir and A. A. Boreqgha, “iPad 2013: A Leaning Tool for Students with Special Needs.”, In: International Conference on Human-Computer Interaction. Springer, Berlin, Heidelberg, p. 211-215, 2013.

S25 I. Giannopulu, “Multimodal interactions in typically and atypically developing children: natural versus artificial environments.”, Cognitive processing, v. 14, n. 4, p. 323-331, 2013.

S26 J. J. Cabibihan, H. Javed, M. Ang and S. M. Aljunied, “Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism.”, International journal of social robotics, v. 5, n. 4, p. 593-618, 2013.

S27 K. Khowaja, S. S. & Salim, “A systematic review of strategies and computer-based intervention (CBI) for reading comprehension of children with autism.”, Research in Autism Spectrum Disorders, v. 7, n. 9, p. 1111-1121, 2013.

S28 W. Chen, “Multitouch tabletop technology for people with autism spectrum disorder: A review of the literature.”, Procedia Computer Science, v. 14, p. 198-207, 2012.

S29 K. Avramides, S. Bernardini, M. E. Foster, C. Frauenberger, L. Kossoyvaki, and M. Mademtz, “State-of-the-art in TEL to support social communication skill development in children with autism: a multi-disciplinary review.”, International Journal of Technology Enhanced Learning, v. 4, n. 5-6, p. 359-372, 2013.

S30 J. J. Diehl, L. M. Schmitt, M. Villano, and E. R. Crowell, “The clinical use of robots for individuals with autism spectrum disorders: A critical review.”, Research in autism spectrum disorders, v. 6, n. 1, p. 249-262, 2012.

S31 H. A. M. Noor, F. Shahbodin and N. C. Pee, “Serious game for autism children: review of literature.”, World Academy of Science, Engineering and Technology, v. 64, n. 124, p. 647-652, 2012.

S32 B. Scassellati, H. Admoni and M. Mataric, “Robots for use in autism research.”, Annual review of biomedical engineering, v. 14, p. 275-294, 2012.

S33 V. Sakkalis, “Review of advanced techniques for the estimation of brain connectivity measured with EEG/MEG.”, Computers in biology and medicine, v. 41, n. 12, p. 1110-1117, 2011.

S34 F. D. D. Reed, S. R. Hyman and J. M. Hirst, “Applications of technology to teach social skills to children with autism.”, Research in Autism Spectrum Disorders, v. 5, n. 3, p. 1003-1010, 2011.

S35 A. L. Wainer and B. R. Ingersoll, “The use of innovative computer technology for teaching social communication to individuals with autism spectrum disorders.”, Research in Autism Spectrum Disorders, v. 5, n. 1, p. 96-107, 2011.

S36 M. Wang and D. Reid, “Virtual reality in pediatric neurorehabilitation: attention deficit hyperactivity disorder, autism and cerebral palsy.”, Neuroepidemiology, v. 36, n. 1, p. 2-18, 2011.

S37 R. C. Pennington, “Computer-assisted instruction for teaching academic skills to students with autism spectrum disorders: A review of literature.”, Focus on Autism and Other Developmental Disabilities, v. 25, n. 4, p. 239-248, 2010.

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