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Fábio Junior Alves
Federal Institute of Education, Science, and Technology of South of Minas Gerais (IFSULDEMINAS)

Emerson Assis De Carvalho
Federal Institute of Education, Science, and Technology of South of Minas Gerais (IFSULDEMINAS)

Juliana Aguilar
Utah State University

Lucelmo Lacerda De Brito
Federal University of São Carlos

Guilherme Sousa Bastos
Federal University of Itajubá

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Applied Behavior Analysis for the Treatment of Autism: A Systematic Review of Assistive Technologies

FÁBIO JUNIOR ALVES [1,2], EMERSON ASSIS DE CARVALHO [1,2], JULIANA AGUILAR [3], LUCELMO LACERDA DE BRITO [4], AND GUILHERME SOUSA BASTOS [2], (Member, IEEE)

[1]Department of Computing, Federal Institute of Education, Science, and Technology of South of Minas Gerais (IFSULDEMINAS), Machado 37750-000, Brazil
[2]Institute of Systems Engineering and Information Technology, Federal University of Itajubá, Itajubá 37500-903, Brazil
[3]Department of Special Education and Rehabilitation, Utah State University, Logan, UT 84322, USA
[4]Department of Psychology, Federal University of São Carlos, São Carlos 13565-905, Brazil

Corresponding author: Fábio Junior Alves (fabio.alves@ifsuldeminas.edu.br)

ABSTRACT Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that may lead to significant impairment in social communication, repetitive patterns of behavior, and possible fixed and restricted interests. Applied Behavior Analysis (ABA) is a well-supported and evidence-based treatment for the delays attributed to ASD. Assistive technologies, such as gamification, software apps, computer-based training (Web), and robotics; provide a standardized method of implementing ABA techniques. This review provides a synthesis of the main characteristics of these technologies. The assessed proposals focused on technologies such as Distributed Systems, Image Processing, Gamification, and Robotics. The primary objectives of these tools sought to improve social behavior, attention, communication, and reading skills. Some common limitations found in the literature was a failure to accurately define their target audience, and a failure to comply with the dimensions of ABA as defined by Baer, Wolf, and Risley in 1968.

INDEX TERMS Autism spectrum disorder, applied behavior analysis, assistive technologies.

I. INTRODUCTION

The psychiatrist Eugene Bleuler first described the term autism in 1911, to designate the loss of contact with reality, which caused a great difficulty or impossibility of communication [1]. In 1943, psychiatrist Leo Kanner again used the term in his work presenting eleven cases of children who had an innate inability to establish affective and interpersonal contact [2]. In addition to the inability to establish socio-affective connections and excessive resistance to changes in the environment, the individuals with ASD observed by Kanner also had severe difficulties in using language to communicate [2]. A year later, Hans Asperger described cases of children with some characteristics similar to autism who also manifested difficulties in social communication, however, they presented the differential of having normal intelligence [3].

Currently, according to the Diagnostic and Statistical Manual of Mental Disorders DSM-V, autism spectrum disorders (ASD) belongs to the category of neurodevelopmental disorders. Individuals within the spectrum may have deficits in communication and social interaction (as in verbal or non-verbal languages, socioemotional reciprocity, etc.) and repetitive and stereotyped behaviors with fixed and restricted interests (such as simple motor stereotypes, echolalia, etc.) [4]. In addition, the DSM-V classifies these deficits according to different levels of intensity: mild, moderate or severe [4].

Studies show that in the last few years, the number of children diagnosed with ASD has been causing global concern. According to the Centers for Disease Control and Prevention - CDC,[1] a body linked to the United States government, in 2004 it was estimated 1 case for every 125 children in the United States (USA), in 2020 was estimated 1 case for every 54 American children, this represents an increase of 131%. A worldwide statistical data estimate that 1 out of 64 children in the United Kingdom, 1 out of 38 children in South Korea, and over 10 million of the general population in India have been diagnosed with ASD [5]–[7].

In recent decades, Applied Behavior Analysis (ABA) has become a well-supported and evidence-based treatment for the behaviors associated with ASD [8], [9]. Baer, Wolf, and Risley (1968) [10] published a paper suggesting seven

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[1]https://www.cdc.gov/ncbddd/autism/data.html

dimensions for studies conducted in the scope of ABA: *applied*, *conceptually systematic*, *analytical*, *behavioral*, *effective*, *generalized*, and *technological*. The *applied* dimension involves a significant behavior change for the subject, directed towards socially relevant behaviors. Regarding the *behavioral* dimension, it describes that the focus of this dimension is on the observable events of behavior that can be directly or indirectly measured. In the *analytical* dimension, the guarantee is obtained that the intervention will produce behavior change, as it proves the relationship between behavior and the environment. The *technological* dimension describes the procedure clearly and objectively, making it descriptive for therapists, teachers, parents to ensure its replication. The *conceptually systematic* dimension refers to the use of well-defined concepts of applied behavior analysis, relating procedures according to the principles of behavior. The *effective* dimension, on the other hand, demonstrates that the intervention guaranteed a change in behavior in a socially appropriate way because if the change did not occur, it means that the intervention was not adequate. Finally, *generalization* is a dimension that requires the newly obtained behaviors to occur in different environments, have lasting effects, and ensure that behaviors are adaptable for life. These seven dimensions are fundamental to define and qualify ABA intervention processes [11].

In addition to ABA techniques, [6] and [12] point out that another way to contribute to the intervention process of individuals with ASD is to employ the use of technologies. According to [13], since 1970, researchers have sought to insert computers in the treatment of children with ASD. Technology provides a positive effect on development and learning compared to other instructional methods. Research reports some potential benefits in using technology for the treatment of ASD to be: controllable, structured, adaptable, and stimulating [14]–[16].

According to [17], individuals with ASD are generally interested in dealing with technology that includes images, audio, and videos. Recent research reports that a technology can contribute to the intervention process by improving learning, communication, social interaction, and other subgroups of behaviors, through a positive and favorable environment [16]–[21]. However, if the technology is not well designed, it can generate interaction barriers for the individual with ASD to use it autonomously or, in extreme cases, it can cause discomfort and unnecessary stress to the individual [22], [23]. To employ technologies that support learning in individuals with ASD, it is essential to understand how information should be presented to them, consider their cognitive profiles, behavioral developmental deficits, strengths and preferences, and to provide an environment suited to their style of learning [24], [25].

A systematic literature mapping on review studies about technologies to ASD people carried out by [26] has identified some requirements that have not yet been satisfactorily met. They identified some areas that are possibly worth researching are studies focused on specific intervention methods, such as ABA, as well as assistive technologies. Assistive technologies refer to the range of equipment, services, strategies, and practices designed to improve the functional skills faced by people with disabilities, promoting independence and inclusion [27].

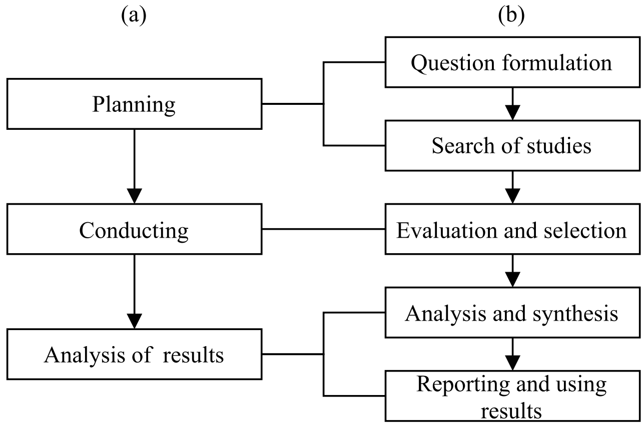

FIGURE 1. Phases of this SR.

Thus, taking into account the above information that: 1) there is an increase in the ASD prevalence nowadays; 2) the effectiveness of ABA in improving autistic behaviors; 3) the positive effect of using well-designed technology on the development and learning process of ASD children; 4) the well-known interest of ASD individuals in dealing with technological devices; and 5) the need for studies focused on specific intervention methods such the ABA; this systematic review aims summarize and analyze the existing literature to provides a map for the development of assistive technologies for the treatment of ASD based on the principles of ABA.

II. RESEARCH METHODOLOGY

A systematic review (SR) is a scientific research method that uses rigorous criteria and a well-defined methodological sequence to develop a central question [28]. Through this approach, we developed a research protocol to assist in the search for papers in well-defined scientific databases, enabling other researchers to follow the same methodology or to evaluate the adequacy of the defined standards.

According to [29], an SR is arranged in five consecutive stages: 1) question formulation; 2) search of articles; 3) evaluation and selection; 4) analysis and synthesis; and 5) report of results. Reference [30] describe the main phases of a SR as: 1) planning; 2) conducting the review; and 3) analysis of the results, which after being included in a more significant phase (packaging) generate the results expected by its executor. The conduction flow of our SR followed the steps proposed by [30], Figure 1(a), together with the corresponding steps proposed by [29], Figure 1(b).

A. RESEARCH QUESTIONS

To cover every topic of interest in this SR, we formulated four research questions. These questions considered relevant and

TABLE 1. Research questions.

ID	Research Question (RQ)
RQ1	What technologies (technological formats) are being employed to create ABA-based tools for ASD treatment?
RQ2	What behavior(s) did the technology seek to optimize for individuals with ASD?
RQ3	Did the studies seek to identify the Intelligence Quotient (IQ) and ASD level of the investigated people?
RQ4	Did the intervention process implemented by the technology follow the principles of ABA?

general aspects important for this study and guide the development of this SR to meet the proposed objective. Table 1 shows our research questions.

B. DATA SOURCES AND SEARCH STRATEGIES

We conducted this SR with scientific papers published in the most comprehensive electronic databases of scientific research in health and technology: ACM Digital Library, ERIC Institute of Education Sciences, IEEE Xplore, Sage Journals, PubMed, and Scopus. We selected articles written in English because it is the internationally adopted language in the scientific area. Additionally, we selected articles without defining an initial year of publication, but 2019 was the end date.

C. ARTICLE SELECTION

Once we chose the databases to search, we determined the specific search strings to find articles to answer the research questions and defined the inclusion, exclusion, and quality criteria to refine and filter the articles found.

1) SEARCH STRINGS

A search string was created based on the keywords (applied behavior analysis, autism, and technology and its synonyms). The final search string was:

```
("applied
behavior analysis") AND
↪ ("autism") AND ("software" OR
↪ "technology" OR "digital
↪ information and communication
↪ technologies" OR "computational
↪ environment" OR "computational
↪ System" OR "computational Systems"
↪ OR "computer" OR "app" OR "game" OR
↪ "games" OR "gamification" OR "game
↪ play" OR "artificial intelligence"
↪ OR "machine learning" OR
↪ "deep learning" OR "robot")
```

Due to the individual characteristics of each database, we adopted different strategies to execute the search string. In IEEE, ACM, and PubMed databases, we performed searches without filtering, searching the entire text. In Scopus, Sage Journals, and ERIC databases, we conducted searches by filtering titles and abstracts.

2) STUDY SELECTION CRITERIA

Based on the research questions, we defined the Inclusion Criteria (IC) listed in Table 2, the Exclusion Criteria (EC) presented in Table 3, and the Quality Criteria (QC) contained in Table 4. The QCs were based on standards in [31]. An association of these criteria was used to define when a particular work would be included or excluded from the SR.

TABLE 2. Inclusion criteria.

Criteria	Description
IC1	Technologies designed for conducting ABA interventions with individuals with ASD.
IC2	Technologies designed for conducting ABA interventions with the general population, including individuals with ASD.
IC3	Technologies for learning concepts and the process of conducting ABA interventions with individuals with ASD.
IC4	The study must be published in English.

TABLE 3. Exclusion criteria.

Criteria	Description
EC1	It did not propose ABA-based technology for the treatment of individuals with ASD.
EC2	It did not propose an ABA-based technology for the treatment of individuals with ASD, only assessed an existing tool.
EC3	Technology for conducting interventions with individuals with ASD that did not use the ABA principles in its implementation.
EC4	Technology for conducting ABA interventions with individuals with ASD that were not presented in a scientific format.
EC5	Different idioms from those defined in the SR planning protocol.

TABLE 4. Quality criteria.

Criteria	Description
QC1	Is there a clear statement of the research goals?
QC2	Is there a description of the context in which the research was conducted?
QC3	Is the research methodology adequate?
QC4	Are the results reported clearly?
QC5	Is there a link between data, interpretation and conclusion?
QC6	Did the results add value to the research area?
QC7	Is work just a clipping of a complete one?

D. DOCUMENT SELECTION

We found a total of 86 papers, as shown in Figure 2. The first step was to export them to Start,[2] a software that helped us to manage the classification process. Secondly, we removed the duplicate papers, leaving 68 articles. After reading the abstract (and other sections, when necessary), we applied the inclusion and exclusion criteria, resulting in a total of 26 papers. Once a study adhered to an inclusion criterion with a consensus among the researchers, we classified it as acceptable for a full reading. Otherwise, when a work adhered to an exclusion criterion with consensus among the researchers, we classified it as excluded. In the absence of consensus, we placed such works on hold, and its inclusion or exclusion was defined thought meetings between the researchers. Finally, we performed a complete reading of all the papers.

A snowballing process included two new articles. Five works were excluded due to not meeting the quality criteria. These proposals were excluded since they belonged to the

[2]http://lapes.dc.ufscar.br/tools/start_tool

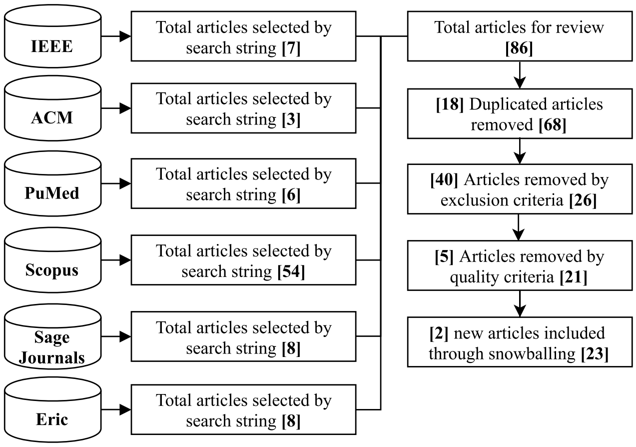

FIGURE 2. Steps of the selection process.

same authors and described the development stages of a same tool. Thus, we considered only the full work of these authors, which described the entire development and testing process of the tool. This SR was conducted with 23 articles that were successful in the selection and quality evaluation processes.

E. DATA SYNTHESIS

After reading all the selected papers, we tabulated them and filled out a data extraction form for each one. This form contains an overview of the work, some essential observations regarding its content and conclusions, as well as some basic information such as bibliographic data, publication date, summary, etc. Table 5 describes the main characteristics of the selected papers.

III. RESULTS AND DISCUSSIONS

This section presents the results of the analyzed works and answers the research questions. First, we performed an analysis of titles and abstracts to find the most relevant terms described in the papers. For this purpose, we used VOSviewer[3] software. The most relevant term was child; followed by autism and ABA.

Figure 3 shows the publication years' frequency distribution from 2008 to 2019. ABA-base technologies were proposed only after 38 years from the first proposal [13] to insert technology in the treatment of individuals with ASD. 73% of the studies were published in the last six years. This percentage is explained by the growth of approximately 130% in the average number of annual publications from 2013.

Answering the first research question **(RQ1 - What technologies (technological formats) are being employed to create ABA-based tools for ASD treatment?)**, most proposals were based on the following technologies: Robots, Gamification, Image Processing (webcam), Storyboards, Augmented Reality, and Web systems. Figure 4 presents the leading technologies used in the selected studies. Nearly 43% of the proposals were based on Web systems. These web applications were focused on online training programs and Support Systems for ABA Application (SSABAA). About

[3]http://www.vosviewer.com/

TABLE 5. Demographic characteristics.

ID	Author(s)	IC	Technology	Age	*RAIP	°CwA
1	[5]	IC3	◇TP⊗	-	△ and ▽	5
2	[6]	IC2	Robot	5-12	○	12
3	[32]	IC1	Robot	-	Caregiver	-
4	[33]	IC1	Robot	-	∧	‡
5	[34]	IC1	Game	7-12	-	10
6	[35]	IC3	◇TP⊗	-	∩	-
7	[36]	IC3	◇TP⊗	6-11	EAD	-
8	[37]	IC1	Webcam	-	-	1
9	[38]	IC1	Webcam	-	Caregiver	1
10	[39]	IC1	•SSABAA⊗	2-10	Tutor	7
11	[40]	IC2	Robot	5-8	∪	5
12	[41]	IC3	◇TP⊗	-	Teacher	-
13	[42]	IC1	Game	5-13	Tutor	10
14	[43]	IC3	◇TP⊗	-	Teacher	4
15	[44]	IC1	Others	5-9	Tutor	5
16	[45]	IC3	◇TP⊗	3-15	Student	11
17	[46]	IC2	Robot	8-12	Therapist	6
18	[47]	IC2	Robot	-	Therapist	‡
19	[48]	IC1	•SSABAA⊗	-	Teacher	-
20	[49]	IC1	Others	6-10	∪	4
21	[50]	IC1	Robot	8	Therapist	1
22	[51]	IC1	•SSABAA⊗	-	▽	-
23	[52]	IC3	◇TP⊗	-	△	-

*Responsible for Aapplying the Intervention Process, °Children with ASD, ◇Training Programs, ⊗Web, •Support Systems for ABA Application, △Parents, ▽Behavior Analyst, ○Psychologist/Teacher, ∩Teacher/EaD, ∧Teacher/Therapist, ∪Parents/Therapist, ‡Sample size not reported

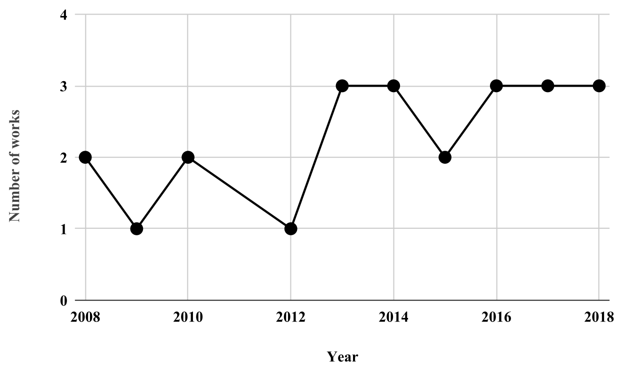

FIGURE 3. Year of publication.

77% of the works designed to interact directly with children were based on Robots, Gamification, and Image Processing. These systems were primarily intended to train children with ASD on skill acquisition.

Figure 5 denotes what behavioral or developmental areas the technological formats addressed. All of the web based programs (training programs and SSABAA) were intended to train therapists, psychologists, behavior analysts, and caregivers (parents and family members) on the implementation of a behavior analytic techniques. 66% of the works related to the SSABAA (Support Systems for ABA Application) focused on providing tools to assist professionals in defining therapy activities, providing resources to monitor and collect session data, as well as providing follow-up. The remaining technologies were intended to be used by ASD children. These programs focused on techniques/programs to improve specific skills such attention, social behavior, communication, and/or reading.

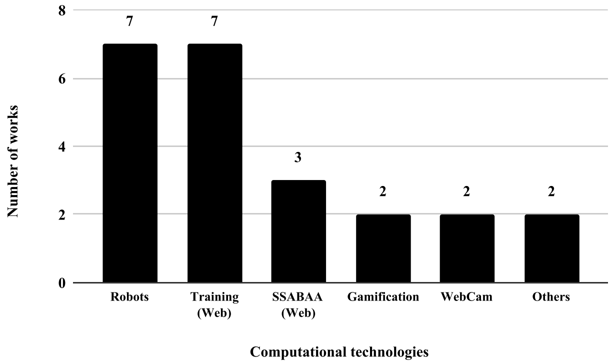

FIGURE 4. Technological basis of the proposed tools.

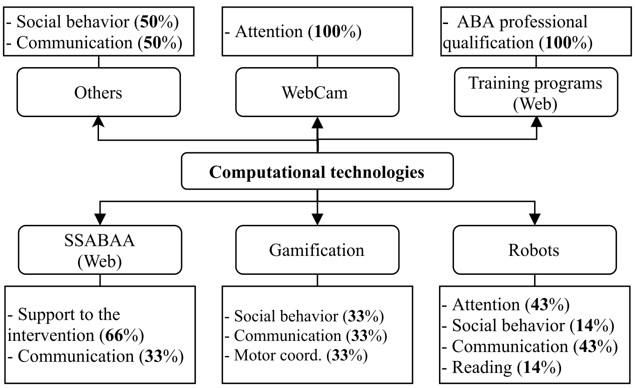

FIGURE 5. Addressed domains vs. technological basis.

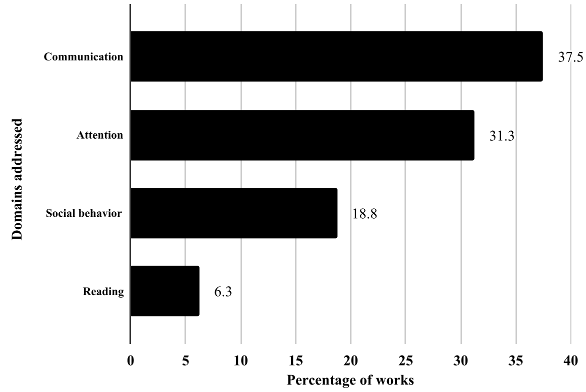

FIGURE 6. Commonly addressed domains.

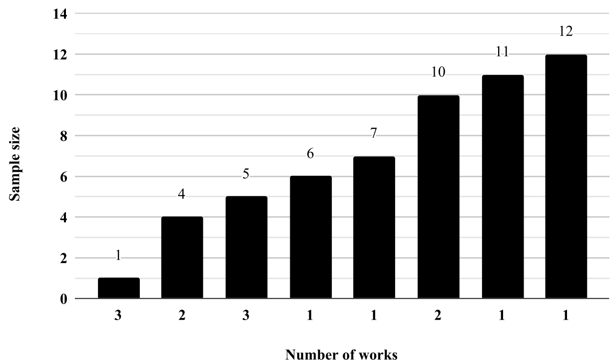

FIGURE 7. Number of children included in the experiments.

Approximately 61% (see Table 5) of the tools were developed for the direct use by a child with ASD during the intervention process. The children in these studies ranged from 2 to 15 years old. Most studies were conducted at schools, homes, or clinics (typically controlled environments).

As mentioned above, the technological tools developed for direct implementation with children with ASD focused on skill acquisition **(RQ2 - What behavior(s) did the technology seek to optimize for individuals with ASD?)**. Figure 6. shows that approximately 87% of the proposed technologies sought improvements in communication, attention, or social behavior. The heightened focus on these behaviors may be related to their significant impact on a child's physical, social, emotional, and intellectual functioning.

We identified some points in the proposed tools that may compromise their quality, replicability, and use. Among them, factors such as sample size and participant demographics such as the participant's skill deficits and IQ levels. Once there were not single-subject design surveys, Figure 7 denotes that number of articles under each sample size. Approximately 87.5% of works whose experiments were performed directly with children cited the sample size. A significant portion of the articles (71.5%) cited for the review had a sample size under seven participants. Only 28.5% of the studies contained a sample size of ten to twelve participants.

According to the APA (2013), the DSM-V classifies the ASD in three levels: mild, moderate, and severe. This classification is related to how much support a child with ASD may need. Children diagnosed as mild need little support to perform basic tasks; those diagnosed as moderate need some support; those diagnosed as severe need high levels of support.

In regards to the child's current functioning **(RQ3 - Did the studies seek to identify the Intelligence Quotient (IQ) and ASD level of the investigated people?)**, studies were evaluated based on their inclusion of intelligence quotient information or validation of ASD level determined by DSM-V. Only 25% of studies described information about the ASD level or current level of functioning of the children involved. Not all studies followed the standards defined in the DSM-V. Reference [40] did not use a particular diagnostic tool; however, they described with the children they worked with as having moderate to severe levels of ASD. Reference [46] used diagnostic data drawn from the Social Communication Questionnaire (SCQ) [53]. Their diagnostic scored children from 18 to 32 points, on a scale from 0 to 39. Reference [43] reported that their participants scored greater or equal to the cutoff point in the Autism Diagnostic Observation Schedule-Generic (ADOS-G) [54]. [49] did not use any specific tool. The children involved in their study were previously evaluated and demonstrated concerning levels of speech, extremely passive behavior, and reduced involvement in spontaneous interaction and communication. The lack of ASD-related information in most studies (75%), together with the lack of a standard to describe this

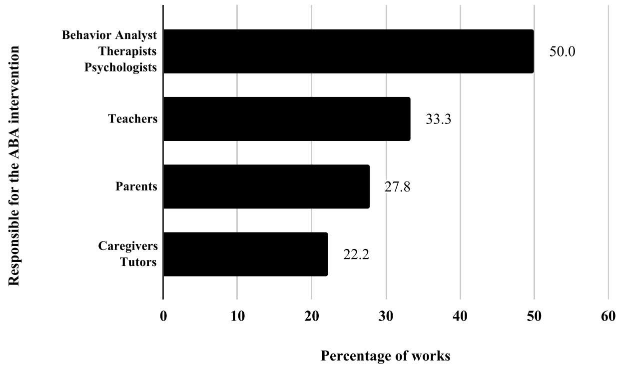

FIGURE 8. ABA professionals supported by the proposed tools.

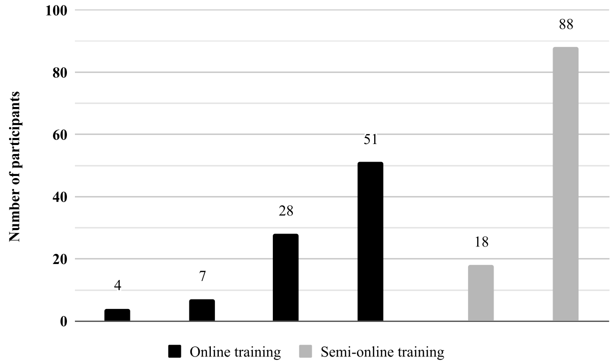

FIGURE 9. Attendance in training programs ([5] proposed an online training program but did not inform the attendance).

information, makes it difficult to properly analyze the target audience for each tool, as well as a general analysis of them.

The cognitive profile of ASD children is distinct from those with typical development, as well as other developmental anomalies with similar cognitive ability [55]. Thus, we attempted to identify if the researchers were concerned about determining the IQ level of the children selected to participate in their researcher. Just 25% of the studies gave attention to IQ identification. References [46] and [47] described that children had High IQ levels. References [43] and [39] described that their participants had low IQ levels.

Adult participants were included in studies whose programs were focused on training applicators of ABA techniques. About 78% of the overall studies included in our corpus were intended for use by adults to be trained in ABA techniques. Figure 8 shows the distribution of intended participants supported by the proposed tools. Approximately 50% of these tools were proposed for parents or caregivers, critical subjects in the ABA intervention process. The vast majority of the tools, about 83%, were intended for behavior analysts, therapists, psychologists, or teachers.

Considering works providing training programs, the attendance (sample sizes) was vastly different. Figure 9 shows that almost 67% of the studies involved less than 30 participants, although approximately 71% of these works used only distance learning resources. This small number of participants indicates a problem of scale, as one of the purposes of online courses is to conduct training involving a more significant number of participants.

We attempted to assess the effectiveness of the technological tools through the seven dimensions of ABA (**RQ4 - Did the intervention process implemented by the technology follow the principles of ABA?**). The seven dimensions were used to evaluate ten studies that involved direct behavioral intervention with children with ASD. We evaluated all works to determine if their intervention processes were in accordance with the primary objective proposed by each dimension of ABA. Table 6 shows our analysis of the adequacy of such works concerning each dimension.

All of the studies met the dimensions of *applied* and *behavioral*. The eleven studies targeted observable and measurable behavior for children with autism. While no data is present to ascertain whether the behaviors targeted were deemed socially significant by the participants, caregivers, or teachers. The behaviors selected for treatment are pivotal behaviors in the development of communication [33], [40], [44], [49], [50], social participation [39], [46], [47], and academic skills [40], [42], [44], [49], [50]. The other five dimensions were not followed entirely, with 91%, 45%, 18% and 9% of the works complying with the *conceptually systematic*, *technological*, *analytical*, and *effective* dimension, respectively. All works performed their experimental procedures mostly in controlled environments, not being possible to analyze their adequacy to the *generalized* dimension.

The primary focus of the studies evaluated were pilot studies or initial evaluations of technological behavioral interventions. Often the measures used to evaluate the technological interventions were qualitative measures on the ease of implementation or acceptability of the technology by children or adults. A single study [46] measured the behavior targeted by the intervention. This study reported an increase in self-initiated questions for participants who interacted with their robots. Reference [34] also recorded data on participant target behavior; however, their intervention was not effective in increasing emotional discrimination. Due to the limited data on the targeted behavior, combined with the already mentioned sample sizes, it is difficult to confirm the authors' analysis of effectiveness for the remaining studies.

TABLE 6. Analysis of works in relation to ABA dimensions.

Author(s)	*Ap	°Be	⊗CS	△Te	◊An	•Ef	▽Ge
[46]	Yes	Yes	Yes	Yes	Yes	Yes	No
[34]	Yes	Yes	Yes	Yes	Yes	No	No
[49]	Yes	Yes	Yes	Yes	No	No	No
[6]	Yes	Yes	Yes	Yes	No	No	No
[39]	Yes	Yes	Yes	Yes	No	No	No
[40]	Yes	Yes	Yes	No	No	No	No
[42]	Yes	Yes	Yes	No	No	No	No
[44]	Yes	Yes	Yes	No	No	No	No
[47]	Yes	Yes	Yes	No	No	No	No
[50]	Yes	Yes	Yes	No	No	No	No
[33]	Yes	Yes	No	No	No	No	No

**Applied, °Behavioral, ⊗Conceptually Systematic, △Technological, ▽Generalized, ◊Analytical, •Effective*

Limited data on targeted behavior also limits the analysis of the *analytical* dimension. In order for an intervention to be considered *analytical* there must be an analysis between the behavior and the environment. With the exception of [46] and [34], it is impossible to assess whether these interventions meet the *analytical* domain without any data on the targeted behavior. It was difficult to assess what measures of the behaviors were being collected by the technological system to assess if analysis beyond the pilot phase would be possible.

There was no formal standard in the development of these technologies, which limits our ability to assess if the technology is grounded in the principles of behavior analysis. If a study claimed to implement an established behavior analytic technique, such as discrete trial instruction [39], [40], [44], Picture Communication Exchange System [42], or Pivotal Response Training [47], then the study met the dimension of *conceptually systematic*. A study could also be considered *conceptually systematic* if the creators based their technology on the three-term contingency (antecedents, behaviors, and consequences) [56]. The existence of a contingency for the target behavior could be explicitly described by the authors [6], [39] or identified through the procedures described in the study [34], [46], [50].

As mentioned previously, analysis of the behavioral interventions was very difficult due to the limited information within the majority of the studies. The limited descriptions of the development and procedural aspects of the behavioral elements, excluded many studies from meeting the criteria under the *technological* dimension. However, a few studies did provide significant detail of the behavioral aspects of the intervention, as well as their method of implementation [6], [34], [39], [46], [49]. Thus, these works may be considered *technological* and may be replicable by future scientists.

While all of the studies evaluated claimed to include ABA techniques and principles, it was often difficult to assess if the interventions developed in these studies abided by the dimensions of ABA delineated by [10], since none of them explicitly cited such dimensions.

Regarding other factors, 95% of the papers presented user tests. The proposal validation is indispensable as it helps to verify user acceptance and whether the intervention had positive results. The study that did not present test with the user were in the prototype stage. User testing includes, in most cases, child observations, video recording, and interviewing. When the test was applied to education professionals, health professionals, and caregivers, they included observations, interviews, and questionnaires. All the technological tools tested showed positive results, according to the evaluations of their authors. Regarding the involvement of stakeholders in the development stage, only 16% had direct participation. The rest did not show any stakeholder involvement. The therapists, doctors, and educators providing direct services to the target population have valuable knowledge and experience with the needs of this population. It is critical to involve these stakeholders in all development stages, such as behavior selection, requirements, interface design, testing, and evaluation.

IV. CONCLUSION

In this work, we mapped the main proposals for ABA-based assistive technologies for the treatment of ASD. We aimed to identify their technological basis, the behavior domains addressed, and the target audience, as well as to describe their main characteristics. Several types of research in robotics are being performed. The use of robots allows the execution of specific, repetitive, and motivating tasks. Such technologies can be tailored according to the particular needs of the individuals.

Gamification is being employed to increase the learning rate in computer-mediated environments, ensuring effective monitoring and improvements in the pedagogical, social, and behavioral sense. Technologies employed in eye tracking have been helpful to understand visual interests, supervise reading activities, and act as a communication device. Online platforms are being used as a method to teach ABA to caregivers and health professionals. Finally, computational technologies to assist the application and monitoring of ABA interventions aim to provide robust management of information, which can guide better decision making regarding the treatment.

It has been observed that research should investigate which design resources are critical for the production of therapeutic effects and how these resources create their impact (that is, an understanding of the mechanisms of change). Although the existing literature offers some suggestions, additional research is needed to establish guidelines for the development and use of technology to provide behavioral interventions to children with ASD. The use of technology in interventions generally requires technical or programming knowledge that many clinicians lack, making it necessary to promote multidisciplinary research and clinical teams. In the same manner, development of technology-based behavioral interventions should adhere to the science of ABA. Board Certified Behavior Analysts (BCBAs) should be consulted in the development of the behavioral interventions to ensure adherence to the principles and dimensions of ABA. It is imperative that other key stakeholders, such as caregivers, clinicians, and educators, be consulted in determining what target behaviors should be the primary focus of an intervention and how technology can be individualized for a child with ASD. We hope that this study can contribute to the state of the art research involving technology and ABA. By synthesizing the current literature, future researchers may be able to identify innovative research opportunities and provide ABA professionals with a summary of current and future behavioral technologies. As future work, we intend to develop a protocol to guide and validate the adequacy of technological tools with regard to ABA principles. Consequently, tools developed following this protocol may ensure the correct execution of behavior analysis practices and would be appropriate to identify a profile of the target audience (age, ASD level, IQ, etc.).

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FÁBIO JUNIOR ALVES was born in Campo Belo, Brazil, in February 17, 1983. He received the B.S. degree in information systems from Pontifical Catholic University, Arcos, Brazil, in 2006, and the M.S. degree in education from the University of Vale do Sapucaí of Pouso Alegre, Pouso Alegre, Brazil, in 2016. He is currently pursuing the Ph.D. degree in electrical engineering with the Federal University of Itajubá, Itajubá, Brazil. Since 2007, he has been working in the academic area, and he is currently an Adjunct Professor with the Department of Computing, Federal Institute of Education, Science, and Technology of South of Minas Gerais (IFSULDEMINAS). He has authored ten conference papers/journal articles. His research focuses on automation systems. His awards and honors include the Best Undergraduate Student from the Brazilian Computer Society (SBC), in 2006.

EMERSON ASSIS DE CARVALHO was born in Campos Gerais, Brazil, in June 11, 1982. He received the B.S. degree in computer science from José do Rosário Vellano University, Alfenas, Brazil, in 2005, and the M.S. degree in computer science and technology from the Federal University of Itajubá, Itajubá, Brazil, in 2013, where he is currently pursuing the Ph.D. degree in electrical engineering. His researches focus on automation systems, distributed systems, and artificial intelligence. He is an expert on software development and programming with ten years of industrial experience, developing solutions in mining, Linux technologies, and mobile and web applications. Since 2014, he has been an Adjunct Professor with the Department of Computing, Federal Institute of Education, Science, and Technology of South of Minas Gerais (IFSULDEMINAS). He has authored eight conference papers/journal articles. His awards and honors include the Best Undergraduate Student from the Brazilian Computer Society (SBC), in 2005.

JULIANA AGUILAR was born in Cali, Colombia, in April 17, 1985. She received the B.A. degree in psychology and sociology and the M.Sc. degree in applied behavior analysis from the University of Missouri, Columbia, MO, USA. She is currently pursuing the Ph.D. degree in disability disciplines with an emphasis in applied behavior analysis with Utah State University (USU), under the mentorship of Dr. T. Higbee, BCBA-D, LBA. She has been providing behavior analytic services to young children with ASD, since 2006. She is currently a board-certified behavior analyst and a licensed behavior analyst in the state of Utah. She currently works as the Case Manager of Autism Support Services, Education, Research, and Training (ASSERT) Program with the USU. She is a Graduate Assistant with the USU and focuses her research on skill acquisition in young children with ASD, caregiving, and staff training, as well as the effects of culture on behavioral interventions.

LUCELMO LACERDA DE BRITO was born in Teófilo Otoni, Brazil, in 1982. He received the degree in history from UNIVAP, São José dos Campos, Brazil, in 2006, and the M.S. degree in social history and the Ph.D. degree in education from Pontifícia Universidade Católica (PUC), São Paulo, Brazil, in 2009. He is currently pursuing a postdoctoral training in special education with the Federal University of São Carlos (UFSCar), São Paulo. His research focuses on teacher training processes for evidence-based apractices for special education. He acts as a teacher of basic education and higher education. He coordinated and taught the Applied Behavior Analysis Postgraduate Course with the CBI of Miami. He has authored the book *Transtorno do Espectro Autista: uma brevíssima introdução* and several articles in magazines and periodicals on education and school inclusion of the person with autism.

GUILHERME SOUSA BASTOS (Member, IEEE) was born in Volta Redonda, Brazil, in December 22, 1977. He received the M.Sc. degree in electrical engineering from the Federal University of Itajubá (UNIFEI), Itajubá, Brazil, in 2004, and the D.Sc. degree in electronics and computer engineering from the Aeronautics Institute of Technology (ITA), São José dos Campos, Brazil. He is currently an Associate Professor with the UNIFEI. He has authored over 70 journal articles, book chapters, and conference papers. He is carrying out his research on machine learning, autonomous robotics, power systems, and technology for autism spectrum disorders.