Software development to help individuals with communication limitations or complete absence of speech: a systematic review

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ARTICLE

DESENVOLVIMENTO DE SOFTWARE PARA AUXILIAR INDIVÍDUOS COM LIMITAÇÕES NA COMUNICAÇÃO OU AUSÊNCIA TOTAL DE FALA: UMA REVISÃO SISTEMÁTICA

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RESUMO: Este estudo tem como objetivo apresentar o estado da arte atual no desenvolvimento de softwares para computadores, dispositivos móveis e dispositivos adicionais de comunicação, projetados para facilitar a socialização de indivíduos com limitações na comunicação ou ausência total de fala. A pesquisa analisou estudos realizados nos últimos anos, com foco na aplicação de diferentes dispositivos, nos tipos de comprometimentos da fala e na eficácia dos processos comunicativos. Foi realizada uma revisão sistemática utilizando o método PRISMA (Moher et al., 2015), abrangendo a última década (2010–2020), por meio da análise de artigos científicos publicados em periódicos. A análise do estado da arte revelou avanços na área, identificou lacunas de pesquisa e apontou áreas que necessitam de aprimoramento. Inicialmente, foram identificados 3.308 artigos, dos quais 38 foram selecionados após análise criteriosa, sendo categorizados de acordo com o tipo de tecnologia desenvolvida, especialmente conteúdos computacionais para dispositivos móveis ou de baixa tecnologia. A análise dos 38 artigos selecionados evidenciou uma preferência pelo uso de dispositivos populares, como computadores, smartphones e tablets. Os artigos revisados concentraram-se predominantemente em indivíduos com condições como Paralisia Cerebral (PC), Transtorno do Espectro Autista (TEA) e Esclerose Lateral Amiotrófica (ELA), ressaltando a necessidade de democratização da ciência por meio do desenvolvimento de recursos gratuitos para pessoas com Necessidades Comunicativas Complexas (NCC).

Palavras-chave: software, limitações na comunicação, ausência de fala

SOFTWARE DEVELOPMENT TO HELP INDIVIDUALS WITH COMMUNICATION LIMITATIONS OR COMPLETE ABSENCE OF SPEECH: A SYSTEMATIC REVIEW

ABSTRACT: This study aims to present the current state of the art regarding software development for computers, mobile devices, and additional communication devices designed to facilitate socialization for individuals with communication limitations or complete absence of speech. The research analyzed studies conducted in recent years, focusing on the application of various devices, types of speech impairments, and the effectiveness of communication processes. A systematic review was conducted using the PRISMA Method (Moher et al., 2015) over the past decade (2010-2020), involving the examination of scientific papers published in journals. The analysis of the state of the art revealed advancements in the field, identified research gaps, and outlined areas for improvement. Initially, 3,308 papers were identified, of which 38 were selected after thorough analysis, categorizing them based on the type of technology developed, particularly computational content for mobile or low- tech devices. The examination of the 38 selected articles highlighted a preference for utilizing popular devices such as computers, smartphones, and tablets. The reviewed articles predominantly focused on individuals with conditions like Cerebral Palsy (CP), Autism Spectrum Disorder (ASD), and Amyotrophic Lateral Sclerosis (ALS), emphasizing the necessity for democratizing science through the development of free resources for individuals with Complex Communicative Needs (CCN).

KeyWords: software, communication limitations, absence of speech.

DESARROLLO DE SOFTWARE PARA AYUDAR A INDIVIDUOS CON LIMITACIONES EN LA COMUNICACIÓN O AUSENCIA TOTAL DEL HABLA: UNA REVISIÓN SISTEMÁTICA

RESUMEN: Este estudio tiene como objetivo presentar el estado del arte actual en el desarrollo de software para computadoras, dispositivos móviles y dispositivos adicionales de comunicación, diseñados para facilitar la socialización de individuos con limitaciones en la comunicación o ausencia total del habla. Métodos: La investigación analizó estudios realizados en los últimos años, con énfasis en la aplicación de diferentes dispositivos, en los tipos de alteraciones del habla y en la eficacia de los procesos comunicativos. Se realizó una revisión sistemática utilizando el método PRISMA (Moher et al., 2015), abarcando la última década (2010–2020), mediante el análisis de artículos científicos publicados en revistas académicas. Resultados: El análisis del estado del arte reveló avances en el área, identificó vacíos de investigación y señaló áreas que requieren mejora. Inicialmente, se identificaron 3.308 artículos, de los cuales 38 fueron seleccionados tras un análisis exhaustivo, siendo categorizados de acuerdo con el tipo de tecnología desarrollada, especialmente contenidos computacionales para dispositivos móviles o de baja tecnología. Conclusión: El análisis de los 38 artículos seleccionados evidenció una preferencia por el uso de dispositivos populares, como computadoras, teléfonos inteligentes y tabletas. Los artículos revisados se centraron predominantemente en individuos con condiciones como Parálisis Cerebral (PC), Trastorno del Espectro Autista (TEA) y Esclerosis Lateral Amiotrófica (ELA), destacando la necesidad de democratizar la ciencia mediante el desarrollo de recursos gratuitos para personas con Necesidades Comunicativas Complejas (NCC).

Palabras clave: software, limitaciones en la comunicación, ausencia del habla

INTRODUCTION

According to the UN Disability and Development Report, an estimated one billion people worldwide live with some form of disability(United Nations 2018). Despite the significant number of individuals with disabilities, progress in public policies targeting them has been limited. Over the past 60 years, there have been only eighteen milestones related to the inclusion of people with disabilities, with the first being in 1961 with the establishment of Law No. 4.024 - Directives and Bases of National Education. The scarcity of recent achievements underscores the urgent need for discussions on disability inclusion. The UN (2020) notes that the lack of data and statistics on persons with disabilities contributes to their invisibility, hindering policy implementation.

In Brazil, according to the last census conducted in 2010 by the Brazilian Institute of Geography and Statistics (IBGE), 45,606,480 people reported experiencing some form of disability (IBGE 2010). However, due to the COVID-19 pandemic, the census for 2020 has been postponed, rendering the current data outdated. The limited historical milestones and insufficient data on people with disabilities underscore the pressing need for inclusive dialogue. It's important to note that this data does not specifically address individuals with communication limitations or complete absence of speech, who are the focus of this study. This research is part of a Ph.D. project titled "Development and Usability Analysis of a Multiplatform System for Augmentative and Alternative Communication."

The few events on the timeline history, the insufficient information concerning people with disabilities from the last census point to the growing need for debates about the inclusion of people with disabilities. It is worth mentioning that this information does not present specific data about people with communication limitations or a complete absence of speech, since they are the target individuals of this study. This research is part of the Ph.D. research entitled "Development and Usability Analysis of a Multiplatform System for Augmentative and Alternative Communication".

METHODS

To broaden understanding of research practices in Augmentative Alternative Communication (AAC), a Systematic Literature Review was conducted. Scientific papers on AAC were searched across key databases in health and engineering, including the Virtual Health Library (BIREME), Medical Literature Analysis and Retrieval System Online (Medline), Latin American and Caribbean Literature on Health Sciences (LILACS), Google Scholar, IEEE, PubMed, and Scielo.

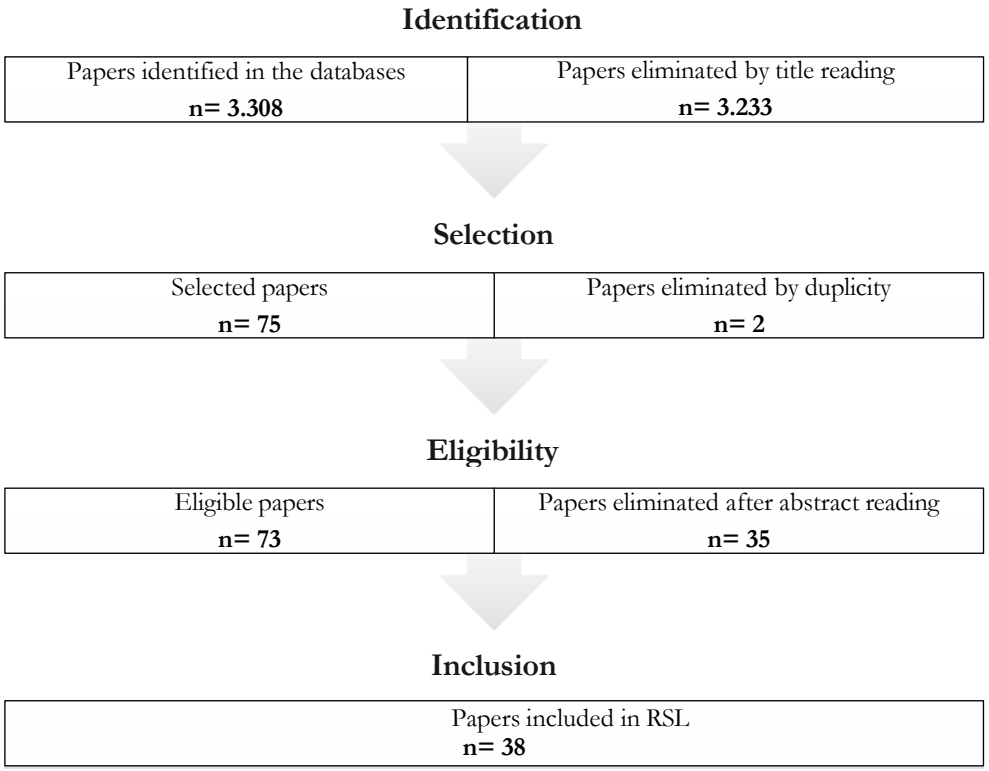
Various sets of keywords in English and Portuguese were employed, focusing on terms like: "assistive technology / tecnologia assistiva " OR "communication / comunicação" AND "alternative / alternativa" OR "supplemental / suplementar" OR "augmentative / aumentativa" AND "computer system / sistema de computador " OR "mobile application / aplicação móvel."

Inclusion criteria comprised selecting original papers with detailed methodology and data reporting published within the past decade (2010-2020). Papers with insufficiently detailed methods or inaccessible content were excluded. The inclusion process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Moher et al. 2015), encompassing identification, selection, eligibility, and inclusion stages.

RESULTS

The identification phase yielded 3,308 papers across all databases. After screening titles, 3,233 papers were eliminated. Subsequently, seventy-five papers underwent a duplicate analysis based on titles and authors, resulting in the removal of two papers. This left seventy-three papers for eligibility assessment, with thirty-five being excluded based on the theme. Ultimately, 38 papers were included in the final review.

Figure1. Information flow with the distinct phases of a Systematic Review



Source: Elaborated by the authors (2022).

Table 1 details the selected articles that will be discussed in the following section.

Authors	Papers	Disabilities
MIRANDA et al. (2004)	Contributions of low-tech Alternative Communication in cerebral palsy without oral communication: Case report	Cerebral Palsy
FERM et al. (2010)	Using talking mats to support communication in persons with huntington's disease	Doença de Huntington
WALLACE et al. (2014)	A multimodal communication program for Aphasia during inpatient rehabilitation: A case study	Aphasia
RODRIGUES et al. (2015)	Use of PeCs associated with video modeling in children with Down syndrome	Down syndrome
WOLFF-BARNABÉ et al. (2016)	Mitochondrial Disease and Supplemental and Alternative Communication: Clinical Case Study	Mitochondrial Disease

Authors	Papers	Disabilities
TÖNSING et al. (2019)	Multilingualism and Augmentative and Alternative Communication in South Africa – Exploring the views of persons with complex communication needs	Not specified
QUACH et al. (2010)	Facilitating children's learning of dynamic-display AAC devices: The effect of two instructional methods on the performance of 6- and 7-year-olds with typical development using a dual-screen prototype	Neurotypical
DELIBERATO (2011)	Supplemental and Alternative Communication Systems in the Expressive Abilities of a Student With Cerebral Palsy	Cerebral Palsy
RADTKE et al. (2011)	Listening to the voiceless patient: case reports in assisted communication in the intensive care unit	Tracheostomy
BEZ et al. (2012)	Scala 2.0: Alternative Communication software for web	Didn't present tests
HAWLEY et al. (2013)	A voice-input voice-output communication aid for people with severe speech impairment	Moderate dysarthria
GÓRAL-PÓŁROLA et al. (2016)	Augmentative and Alternative Communication (AAC) for a patient with a nonfluent/agrammatic variant of PPA in the mutism stage	Primary Progressive Aphasia
MANZINI et al. (2019)	Alternative Communication Program for a Child with Cerebral Palsy and Their Communication Partners: A Multiple Survey Design Study	Cerebral Palsy
MOHAN et al. (2019)	Capitalizing on technology for developing communication skills in autism spectrum disorder: a single case study	Autism Spectrum Disorder
HORNERO et al. (2015)	A wireless Augmentative and Alternative Communication system for people with speech disabilities	Severe motor impairments
DA SILVA et al. (2018)	AACVOX: mobile application for Augmentative Alternative Communication to help people with speech disorder and motor impairment	Cerebral Palsy, speech difficulties and motor impairment

Authors	Papers	Disabilities
THIEMANN-BOURQUE et al. (2018)	Incorporating a peer-mediated approach into speech-generating device intervention: Effects on communication of preschoolers with autism spectrum disorder	Autism Spectrum Disorder
CARNIEL et al. (2019)	Supporting the dialog of people with intellectual disabilities through Augmentative and Alternative Communication	Intellectual Disability, Cerebral Palsy, Apraxia, Psychomotor difficulty
D'AMICO et al. (2019)	Technology-aided leisure and communication support in extensive neuro-motor and communication impairments	Neonatal encephalopathy
MORAES et al. (2019)	Use of Alternative and Augmentative Communication Resources by Patients with Amyotrophic Lateral Sclerosis	Amyotrophic Lateral Sclerosis
WENDT et al. (2019)	Effects of an iPad-based speech-generating device infused into instruction with the picture exchange communication system for adolescents and young adults with severe autism spectrum disorder	Autism Spectrum Disorder
CHAN et al. (2020)	A context-aware Augmentative and Alternative Communication system for school children with intellectual disabilities	Intellectual Disability
SILVA et al. (2020)	Bela Tagarela: Mobile App for Augmentative and Alternative Communication	Autism Spectrum Disorder
FALK et al. (2010)	Augmentative communication based on realtime vocal cord vibration detection	Cerebral Palsy
LANCIONI et al. (2010)	Camera-based microswitch technology for eyelid and mouth responses of persons with profound multiple disabilities: Two case studies	Multiple disabilities
STONER et al. (2010)	Implementing Augmentative and Alternative Communication in inclusive educational settings: a case study	Cerebral Palsy
BLOCH (2011)	Anticipatory other completion of Augmentative and Alternative Communication talk: A conversation analysis study	Amyotrophic Lateral Sclerosis

Authors	Papers	Disabilities
GUIMARÃES et al. (2012)	Alternative Assistive Communication System triggered by electromyographic signals	Neurotípicas
LANCIONI et al. (2014)	Case studies of technology for adults with multiple disabilities to make telephone calls independently	Multiple disabilities
SELLERS et al. (2014)	Noninvasive brain-computer interface enables communication after brainstem stroke	Cerebral stroke
BACHER et al. (2015)	Neural point-and-click communication by a person with incomplete locked-in syndrome	Locked-in syndrome
LANCIONI et al. (2015)	Assistive Technology to help persons in a minimally conscious state develop responding and stimulation control: Performance assessment and social rating	Post coma
KOHLBERG et al. (2016)	Development of a low-cost, noninvasive, portable visual speech recognition program	Tracheostomy
VANSTEENSEL et al. (2016)	Fully implanted brain–computer interface in a locked-in patient with ALSs	Amyotrophic Lateral Sclerosis
MELTZNER et al. (2017)	Silent speech recognition as an Alternative Communication device for persons with laryngectomy	Tracheostomy
PATIÑO-CUERVO et al. (2017)	Technology applied to a particular case of multiple disability	Autism Spectrum Disorder
KIM et al. (2018)	Development of an electrooculogram-based human computer interface using involuntary eye movement by spatially rotating sound for communication of locked-in patients	Amyotrophic Lateral Sclerosis
SCHUDLO et al. (2018)	Development and testing an on-line near-infrared spectroscopy brain–computer interface tailored to an individual with severe congenital motor impairments	Severe motor impairment

Source: Elaborated by the authors (2022).

DISCUSSION

The results of this Systematic Literature Review indicated thirty-eight papers suitable to the research criteria. The papers were gathered by category of developed or used technology:

(1) Low-tech resources: characterized by manual manufacture, developed by cutting out images and words for pasting them on cards or communication boards. These resources are usually developed by the professionals who use them with the users, such as: teachers, speech therapists, psychologists, or occupational therapists. It is essential to develop the material according to the its users' needs, as well as, new figures and expressions may be introduced as its use becomes natural and intuitive for both (Schirmer et al. 2007).

(2) High-tech resources: defined as such because they require more complex equipment, for instance: widespread mechanisms like computers, tablets, and cell phones, or resources specifically developed for AAC as eye trackers and voice devices (Schirmer et al. 2007).

The paper written by Miranda et al. (Miranda & Gomes 2004), titled Contributions of Low Technology Alternative Communication in Cerebral Palsy Without Oral Communication, is a case report which counted on paper boards as a communicative resource. The intervention was done by comparing the communication of a subject with cerebral palsy (CP) without conditions of verbal expression before and after the implementation of the system. The patient had been deprived of communication during childhood and adolescence. The authors of the study believe that the introduction of an AAC system should be done as early as possible in order to provide the patients better social and school opportunities.

The system permitted the individuals meaningfully express themselves expanding their repertoire of responses. Earlier, these answers were limited to affirmative and negative head movements. The "sweeping" technique was used. This specific case, it was carried out with the partner passing his index finger from the left to the right, selecting the column where the symbol appears, and then vertically until the symbol could be found.

Ferm et al. (2010), in their paper titled: Using talking mats to support communication in persons with Huntington's disease, used a mat with augmentative communication figures for individuals in advanced stages of Huntington's disease. Huntington's disease (HD) is a neurodegenerative, inherited disease characterized by the presence of movement disorders, psychiatric disorders, and dementia (Graziani 2007). Five subjects participated in the study. Communication was examined under the following conditions: (1) unstructured communication; (2) structured communication; and (3) with Talking Mats (TM). Talking Mats Limited is a social enterprise whose vision is to improve the lives of people with communication difficulties and those close to them. The TM is a kind of mat where the figures are classified. Access is available at: https://www.talkingmats.com/. The authors provided evidence of increased communicative efficacy, and verbally structured conversation resulted in higher efficacy than the unstructured counterpart. The efficacy varied depending on the topic of conversation was also observed.

In spite of that, four factors were observed and statistically analysed: (1) the participant's comprehension of the options presented. (2) The participant's commitment to the interviewer and the task. (3) The participant's ability to maintain self-control. (4) The interviewer's comprehension of the participant's opinions.

The authors Wallace et al. (2014), in a research titled A multimodal communication program for aphasia during inpatient rehabilitation: a case study, use a multimodal communication program for drill aphasia. Drill aphasia is when the ability to produce words is impaired, but comprehension and the ability to form a concept are preserved. Two adults with this impairment participated in this study. The researchers analysed their performance, observing greater accuracy in the production of various alternative communication modalities. Further investigation during inpatient rehabilitation has been shown to be necessary. Comparisons between multimodal and standard treatments would help to determine appropriate interventions in this setting.

The paper written by Rodrigues et al. (2015), The Use of the Picture Exchange Communication System (PECS) associated with Video Modeling in Children with Down Syndrome, a

plastic communication folder and contact closures were used to attach the PECS system pictures. The participants were a 9-year-old child with Complex Communication Needs (CCN) and a 12-year-old peer with no communicative difficulties who acted as a communication partner. Before beginning each session, the participant watched 20–30 second videos depicting diverse activities, environments, and communication partners. The results indicated an increase in communicative initiations and vocabulary, as well as autonomy to communicate with different people.

Wolff-Barnabé et al. (2016), in their paper Mitochondrial Disease and Supplemental and Alternative Communication: A Clinical Case Study, used a notebook format communication board. They described the results of an 11-year-old child with a medical diagnosis of Mitochondrial Disease. Mitochondrial genetic diseases account for the most common inborn errors of metabolism, caused by mutations in both nuclear and mitochondrial DNA genes (Bianco & Montagna 2016). The activities were chosen according to the child's interests; games, storybooks, and amusement were explored. The figures were used in a spontaneous way, usually by pointing, but any act such as looking or picking up was accepted. The results indicated an increase in the subject's oral language functionality, especially regarding communicative intention in the interactional context.

In Multilingualism and Augmentative and Alternative Communication in South Africa: Exploring the Views of Persons with Complex Communication Needs, a study by (Tönsing et al. 2019), picture frames and books based on picture symbols and alphabet signs were employed, as well as, typing on a phone or computer. Twenty-seven adults with some type of disability participated in the study. They presented levels of autonomy of expression which confirmed that their thoughts and opinions could be captured. The results of this exploratory study suggest that participants who use low-tech AAC can be better understood but facing limitations in their ability to express themselves in multiple languages. The current official account of multilingualism in South Africa since the democratic dispensation in 1996 delineates eleven official languages in a population of fifty-six million (Stroud & Richardson 2019). Thus, the majority of adults wanted to access the expressions in various languages.

The research titled Facilitating children's learning of dynamic-display AAC devices: The effect of two instructional methods on the performance of 6- and 7-year-olds with typical development using a dual-screen prototype (Quach & Beukelman 2010), carried out tests were to determine the effectiveness and efficiency of instruction on the operation and use of AAC devices aimed at improving overall communicative competence, reducing instructional time, and supporting educational activities. Twenty-one typically developing children between the ages of 6 and 7 participated in five sessions of the study, in which it was observed that the 7-year-olds were more accurate and faster than the 6-year-olds. For the learning sessions, the integrity of the instructions was 96%. In the generalization and maintenance sessions, the integrity of the instructions was 100%. The results of this research provided guidance in developing effective instructions to minimize learning demands and maximize communication for young children who need CAA.

In the study carried out by Deliberato (2011) entitled Supplementary and Alternative Communication Systems in the expressive skills of a student with cerebral palsy, low tech resources were used, such as objects, pictures, figures of the pictographic system, and high-tech resources, such as ImagoAnaVox (Multimedia systems that enable iconic-vocalic communication for patients with language loss or delayed language development, and more serious motor difficulties (Capovilla et al. 1994)) software and Boardmaker (It is a computer program that was developed specifically for creating alternative communication boards using the PCS symbols and several tools that allow the construction of personalized communication re-sources. Access is available at: https://www.clik.com.br/). The research volunteer was a 10-year-old boy with CP who underwent evaluation, implementation, and follow-up care for two years. The use of supplementary and alternative communication systems provided the student with the expansion of effective dialogic situations during activities performed in the speech therapy intervention. Augmentative and Alternative Communication (AAC) is also defined as Facilitative Alternative Communication (GONÇALVES et al. 1997), Enlarged Alternative Communication (NUNES 2003), or even Supplementary and Alternative Communication (DELIBERATO et al. 2006).

Radtke et al. (2011) in their study titled: Listening to the Voiceless Patient: Case Reports in Assisted Communication in the Intensive Care Unit employed high-tech devices and low-tech options

according to the motor and cognitive abilities of the researched subjects. They were three women admitted to the ICU who underwent tracheostomies, aged 28, 32, and 39 years. The medical staff attributed greater communication efficiency, better breathing during ventilator withdrawal tests, and greater patient involvement. Although the procedure has not currently part of routine in ICU practice, the provision of communication devices and materials may offer additional support, as well as improve the outcomes of socialization.

In the paper by Bez & Passerino (2012) titled Scala 2.0: Alternative Communication Software for the Web, a computer system was developed, with versions for mobile devices and a web version, for AAC board modules and story creation, relatively close to a comic book format, as well as, a research plan involving teacher formation and intervention in students with communication deficits. The authors hope to contribute to the communication acquisition of subjects with communicative deficits by making it available on the web for use by teachers and the community. However, this paper did not present tests with users but, only the development history.

In the paper A voice-input, voice-output communication aid for people with severe speech impairment carried out by (Hawley et al. 2013), the CAA system called VIVOCA (A CAA device that recognizes the user's disordered speech and constructs messages, which are converted into synthetic speech (Hawley et al. 2013)), a system that interprets the speech of the user with dysarthria, which is the loss of the ability to articulate words in a standard way, and reproduces it in the appropriate form with synthesized speech. The participant of the study was recorded speaking about twenty repetitions of the words, which were used to train the initial speech recognition system. The trial highlighted some issues that limit the performance and usability of the device when applied in real life situations, with about 67% recognition in these circumstances. Experiments have shown that this method is successful in generating recognition in disordered speech, even when recognition perplexity is increased.

In the paper titled: Augmentative and Alternative Communication (AAC) for a patient with a nonfluent/agrammatic variant of PPA in the mutism stage (Góral-Półrola et al. 2016), the study volunteer was a 73-year-old patient with a clinical diagnosis of Primary Progressive Aphasia (PPA), with whom twenty sessions covering communication exercises were carried out. As a result of this training, the patient started to communicate with her son and with the medical team, noting that the best solution is to combine diagnosis with therapeutic interaction, as it creates the possibility of familiarization with the patient and his problems, including both the disorders that occur and the possibilities that the patient retains.

In the research called Alternative Communication Program for a Child with Cerebral Palsy and His Communication Partners: A Multiple Probe Design Study (Manzini et al. 2019), the effects of an individualized AAC method for a 12-year-old boy with CP were observed in three contexts: at school with his teacher, at home with his mother, and in clinical settings with an occupational therapy trainee. The research findings contributed to confirm the importance of training communication partners to use CAA. The results also point out that the strategies adopted in the three settings were effective and provided learning opportunities about the use of CAA for the child and his communication partners.

The study titled Capitalizing on technology for developing communication skills in autism spectrum disorder: a particular case study (Mohan et al. 2019), a computer system was used by a 4-year-old child with Autism Spectrum Disorder (ASD). Over the course of a little months, the patient learned to use the system, resulting in a marked improvement in socialization skills which allowed better intentional communication of his thoughts and needs. This study highlights the importance of tailoring rehabilitation strategies for communicative deficits according to the patient's needs and preferences.

In the research titled A wireless Augmentative and Alternative Communication system for people with speech disabilities (Hornero et al. 2015), a solution consisting of vocabulary communication boards and the symbol player, both wirelessly connected. The prototype was evaluated in two special education schools, and the test were carried out with eight volunteers aged 7 to 17 years and four supervisors during three weeks. Positive evaluations from subjects who use the CAA system has opened the possibility of using the system in home and at the educational settings.

In the paper entitled AACVOX: mobile application for Augmentative Alternative Communication to help people with speech disorder and motor impairment (D. P. da Silva et al. 2018),

a total of twenty volunteers with CP, speech difficulties, and motor impairment participated in the tests. They used the app on a tablet connected to their wheelchairs. The results showed an above-average System Usability Scale (SUS) score for each of the quality components evaluated by the volunteers. According to the authors the developed software represents a new CAA option being customized to the communication needs of people with speech disorders and motor disabilities.

The research titled: In Incorporating a peer-mediated approach into speech-generating device intervention: Effects on Communication of Preschoolers with Autism Spectrum Disorder (Thiemann-Bourque et al. 2018), the authors used mobile technology on iPads devices with forty-five nonverbal or minimally verbal volunteers with ASD and ninety-five peers without disabilities. The children who used the device demonstrated significant increases in communication rates and more balanced responses and initiations than the children of the comparison group. They were able to generalize the improvements and maintain communication gains.

The study titled: Supporting the Dialogue of People with Intellectual Disabilities through Augmentative and Alternative Communication (Carniel et al. 2019), a tablet and computer software were used to identify the educational potential for teaching the meaning of pictures. The research was carried out by means of a questionnaire applied to a patient with intellectual disability (ID), CP, apraxia, psychomotor difficulty, and no oral communication skills. The research instrument consisted of ten questions about current and past situations, being answered first by the patient and then by his mother. The results showed that the system allows communication takes place and may be used in classrooms to improve the educational dynamics of people with ID.

The study titled: Technology-aided leisure and communication support for extensive neuromotor and communication impairments (D'Amico et al. 2019), six adults who had no speech or active functional communication were selected. The use of the cell phones, cards, and caregiver response worked as follows: if the participant used a card referring to a leisure option, the cell phone played, for example, a song or video. The evaluation of the program also involved social validation, with sixty rehabilitation and care professionals assessing the possible benefits of the program. Cases such as those presented in this study may achieve independent and functional engagement if supported by specific technology-assisted intervention programs.

The paper titled: Use of Alternative and Augmentative Communication Resources by Patients with Amyotrophic Lateral Sclerosis (Moraes et al. 2019), a tablet, notepad, and voice recorder were used, as well as, a whiteboard, paintbrush, and eraser. Five participants with ALS followed by the Rehabilitation and Readaptation Center were selected. They were submitted to the use of a CAA resource acquired by the site. The qualitative analysis was based on the investigative method, conducted from the spontaneous comments. It was concluded that, even with the use of CAA, ALS generates negative impacts on socialization.

Wendt et al. (2019), in the article: Effects of an iPad-based speech-generating device infused into instruction with the picture exchange communication system for adolescents and young adults with severe autism spectrum disorder, used an iPad with the app SPEAKall! set up. SPEAKall! It is a CAA application with a distinctive feature set for children with ASD and developmental disorders. Access is available at: http://www.speakmod.com/speakall/. The proponents evaluated increases in functional communication in adolescents and adults with ASD and little or no speech through sessions held twice a week for 30 to 40 minutes. Results indicated increases in application use requests for all participants during the intervention. Based on the current findings, the use of an iPad-based CAA system may be effective in increasing socialization skills.

Chan et al. (2020) described in their paper titled: A context-aware Augmentative and Alternative Communication system for schoolchildren with intellectual disabilities in the use of a tablet with an application that uses Bluetooth, in English "Bluetooth Low Energy" (BLE). Six students with moderate ID, all diagnosed as non-verbal, participated in the experiment, and were divided into experimental and control groups, performing the experiment repeatedly for three days in four sessions per day. The participants' performance was measured by two dependent variables: response time and accuracy rate. The results confirm that CAA can improve communication among school-aged children with ID.

In Bela Tagarela: Mobile Application for Augmentative and Alternative Communication, written by (F. de P. Silva et al. 2020), (Access is available at: https://play.google.com/store/apps/details?id=belatagarela.ta.caa) describes the development of an Assistive Technology (AT) for mobile devices that use the Android Operating System (OS), which is low-cost and free to the population, in order to reduce the limitations of children and adolescents with disabilities. This application focuses on ease of use, attractiveness, and customization through the inclusion of new images, called stickers, according to the user's wishes and the choice of voice for female and male genders. However, this paper describes only the development of this technology, it has not presented tests with volunteers.

In the case of the paper Augmentative communication based on real-time vocal cord vibration detection (Falk et al. 2010), a binary key attached by a neckband in the vicinity of the vocal cords was developed based on periodic vibration detection. To validate the solution created, eight sessions were conducted with a participant with a PC who was asked to copy a sentence containing all the letters of the alphabet using the WiViK and the proposed system. System for people unable to use a physical keyboard, such as those with spinal cord injuries, ALS, muscular dystrophy, and PC. Access is available at: https://www.1q4all.com/wivik.php. The participant was asked to rate how much effort it took to complete the task and how tired he felt using a five-point linear scale. The experiments showed the proposed system outperforming a popular commercial system, WiViK.

Lancioni and authors (Lancioni et al. 2010) in the study Camera-based microswitch technology for eyelid and mouth responses of persons with profound multiple disabilities: Two case studies used a micro-camera for eyelid and mouth responses. Two people with multiple disabilities participated in the study: a 21-year-old girl and a 25-year-old boy. They received from 3 to 10 minutes sessions per day, where mouth and eyelid opening responses were observed and automatically recorded on computer counters. The results are discussed concerning to the role of the innovative technology in helping people with multiple disabilities and minimal motor behaviour, as both participants had large increases in responses during the intervention periods.

Authors Stoner et al. (2010) , Implementing Augmentative and Alter-native Communication in Inclusive Educational Settings: A Case Study, Dynawrite described a case of implementing CAA throughout the school year for a 16-year-old with a medical diagnosis of CP, with a reduction in his fine motor skills and oral motor movement. The researchers noted benefits that included the volunteer's willingness and desire to implement the use of the device, the youth's increased intelligibility, peer acceptance of the technology, and increased socialization.

In the article Anticipatory Other Completion of Augmentative and Alternative Communication Talk: A Conversation Analysis Study (Stoner et al. 2010), a computer accessed by two switches attached to the head of the subject, who is a 38-year-old volunteer computer programmer who has been diagnosed with a subtype of ALS, was employed to analyse the characteristics of this experiment during a conversation between a person using a CAA system and a family member. It was noted that difficulties can arise in relation to topic changes, understanding the intended action of a running word, and recognizing the possible ending of an utterance.

In the paper CAA system triggered by electromyography signals, written by Guimarães and authors (Guimarães et al. 2012), it was proposed a Human Computer Interface (HCI) which uses a computer system and electromyography signals controlled by real-time recordings. Initially, it was operated with the capture, analysis, and treatment of the electromyography signal (EMG), and then computational devices which were developed to allow communication between the software used and the commands to trigger it through the muscle contraction signals. The system created allows customizations such as changes in the colors and keys of the virtual keyboard, adding or removing books, songs, and movies, or creating options for commonly used phrases. Experiments were carried out with users without pathology, showing potential for testing people with severe dysfunctions.

The paper written by (Lancioni et al. 2014), titled Case Studies of Technology for Adults with Multiple Disabilities to Make Telephone Calls Independently, used a pro-gram with micro switch activation to enable subjects with multiple disabilities to make telephone calls with two volunteers with congenital encephalopathy aged 38 and 39. Sessions occurred once or twice a day and lasted 10 minutes.

When a research assistant recorded the total number of phone calls made by the participant without assistance, the present case study highlights the effectiveness of this technology solution in helping different subjects.

The paper titled: Non-invasive brain-computer interface enables communication after brainstem stroke (Sellers et al. 2014), a computer system with electroencephalography (EEG) sensors was evaluated on a 68-year-old subject with stroke. The 68-year-old subject in this study suffered an acute multifocal ischemic stroke over a 13-month period and was able to successfully operate the system during 40 of 62 sessions, in which spelling accuracy was above 70%; no additional calibration data was collected. He was able to accurately spell words provided by the experimenter and initiate dialogue with his family. The results amply suggest that the use of the system can be beneficial.

In Neural point-and-click communication by a person with incomplete locked-in syndrome (Bacher et al. 2015), a radial virtual keyboard was used for fast and reliable communication for subjects with paralysis and anarthria. A disease of degenerative origin that consists of progressive articulatory difficulty with the grammatical, semantic, and graphic aspects of speech (Valle de Juan et al. 2004). To evaluate typing performance with each of the keyboards: the radial virtual keyboard and a standard computer keyboard, the following metrics were used with the 58-year-old participant with over 14 years of diagnosis: percent correct, keystrokes per minute, and correct characters per minute. The radial keyboard provided a significant improvement in typing accuracy and speed, al-lowing for typing rates above 10 correct characters per minute.

In another research project developed by (Lancioni et al. 2015), called Assistive Technology to Help Persons in a Minimally Conscious State Develop Responding and Stimulation Control: Performance Assessment and Social Rating, optical, pressure, or touch micro switches were also used to monitor eyelid, hand, or finger responses. Eight post-coma volunteers with extensive motor and speech impairments participated and showed marked increases in their response frequencies. The students and health professionals involved in the social validation check rated the technology-assisted approach positively compared to a control condition in which stimulation was presented automatically to the participants.

Kohlberg et al. (2016), in Development of a low-cost, non-invasive, portable visual speech recognition program based on the Microsoft Kinect to capture the spatial coordinates of lip movements. Microsoft's motion sensor was initially created for use with the Xbox. Access is available at: https://developer.microsoft.com/pt-br/windows/kinect/. Five adult English speakers with no diagnosis of speech-related pathology participated in the study. It was concluded that despite the limitation of the study in not testing with aphonic subjects, the program has the potential to improve communication in these subjects, including those with tracheostomies and those with advanced laryngeal cancer unable to use a tracheoesophageal prosthesis.

A Fully implanted brain-computer interface in a locked-in patient with ALSs (Vansteense et al. 2016) used subdural electrodes placed over the cortex and a transmitter placed subcutaneously on the left side of the chest in a 58-year-old woman with ALS who had 67 sessions (2 per week) lasting 2 hours to test algorithms that translated cortical activity to actions on the computer, to investigate system performance temporally, and to practice spelling. It was noted that the patient accurately and independently controlled a computer typing program within 28 weeks of electrode placement, typing two letters per minute.

In Silent Speech Recognition as an Alternative Communication Device for Persons with Laminectomy (Meltzner et al. 2017), electromyography (EMG) sensors were employed to develop a mechanism for speech understanding and transcription. Eight subjects aged 57–75 years, with at least 6 months after a tracheostomy had been performed, participated in the study. A single set of sentences was used to train phoneme-based recognition models, and the remaining sentences were used to evaluate the word recognition of models based on identifying the running speech phoneme. This solution provides an attractive proof-of-concept for EMG-based laryngeal speech recognition with strong potential to further improve performance.

In a summary, (Patiño-Cuervo & Caro 2017) write in the article Technology applied to a particular case of multiple disabilities: the development of a communicator in the form of a bracelet

adapted to the characteristics of the volunteer. In the case study, a child with ASD and visual impairment with difficulties in oral communication was observed, and at the end of the intervention period, the child's mother and the speech therapist were interviewed to measure the advances generated using this technology. The results of the process are presented from a case study approach, which gave rise to the construction of a kind of CAA system that, together with a mediation process, al-lowed the validation of cognitive modifiability.

In a paper titled: Development of an electrooculogram-based human computer inter-face using involuntary eye movement by spatially rotating sound for communication of locked-in patients, by authors (Kim et al. 2018), an electrooculogram-based system was developed (EOG) for CAA that does not require voluntary eye movement. Proposed for patients with Locked-in syndrome (LIS), corresponding to ALS. The electro-oculogram is a diagnostic tool used in ophthalmology to study the movement of the eye muscles (Área Oftalmológica Avanzada 2020). Ten healthy subjects and two subjects with ALS (or LIS) participated in the study. All experiments used the same sound stimuli, with different presentation durations and different experimental protocols. The results showed 94% communication accuracy in healthy subjects and subjects with ALS, in cases where decisions were made every six seconds.

Later in Development and evaluating an online near-infrared spectroscopy brain-computer interface tailored to an individual with severe congenital motor impairments (Schudlo & Chau 2018), measurements of prefrontal cortex reactions were performed on a 26-year-old subject with severe motor impairments who had control over his eyes but no other fine motor control. The goal was to assess the achievable accuracies of cortical activity during the execution of the Variable Frequency Transformer (VFT). The participant could reliably click his tongue once to communicate "yes" and twice to indicate "no." Each session consisted of a series of trials during which a multiple-choice question was answered. The results suggest potential for the use of a VFT-controlled system in cases of severe congenital disabilities.

CONCLUSION

Observing the technologies used or developed in the thirty-eight selected articles, there is a tendency to use popular devices such as computers, smartphones, and tablets. Regarding the target audience of the reviewed articles, there was a greater occurrence in tests with volunteers with Cerebral Palsy (CP), Autism Spectrum Disorder (ASD), and Amyotrophic Lateral Sclerosis (ALS). Which leads to reflecting on the need for the democratization of science by developing free resources for the integration of people with Complex Communicative Needs (CCN).

After this Systematic Literature Review (SLR), it was observed that, despite the remarkable number of publications found in CAA, the creation of innovative solutions for the target audience is still scarce, both in Brazil and worldwide, being insufficient and of excessive cost for the end users. The costs of each reported study were not dis-closed, but considering the use of electronic devices, added to the development of the system or the purchase of the license of an existing system, it is possible to conclude the excessive cost of CAA resources that use high technology.

It is possible to list the low-tech AAC resources exposed here as an effective and quickly accessible alternative to assist people with low-income CHN and to introduce AAC to these people who have not yet used other means, such as children with ASD or CP or adults recently diagnosed with ALS. As for high-tech resources, those that are created for mobile devices and are free are a good option for introducing CAA, considering the popularity of smartphones and tablets today.

The high-tech devices that use computers, sensors, trackers, micro-switches, and others are more complex and therefore more expensive options. These are indicated for more complex cases of limitations, when, for instance, besides the communication limitation, the subject also has a motor limitation that prevents him from pointing or using a cell phone.

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All data supporting the findings of this study are included within the article.

AUTHOR CONTRIBUTIONS

Author 1 – Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Resources, Writing – Original Draft Preparation, Writing – Review & Editing
Author 2 – Data Curation, Formal Analysis, Methodology, Project Administration, Resources, Software, Supervision, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing
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Author 5 – Visualization, Writing – Original Draft Preparation, Writing – Review & Editing

CONFLICT OF INTEREST STATEMENT

authors declares that there is no conflict of interest.

This preprint was submitted under the following conditions:

- The authors declare that the necessary Terms of Free and Informed Consent of participants or patients in the research were obtained and are described in the manuscript, when applicable.
- The authors declare that the preparation of the manuscript followed the ethical norms of scientific communication.
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