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Future technologies in alternative and augmented communication: a scoping review of innovations

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Introduction: This scoping review analyzes the convergence between augmentative and alternative communication (AAC) and new technologies, with emphasis on the role that artificial intelligence and mobile devices play in augmenting communication and social skills in individuals with complex communication needs. Technological advancements are revolutionizing AAC potential at a high velocity; thus, the aim of this study was to identify the latest technological applications and evaluate facilitators and barriers using the International Classification of Functioning, Disability and Health framework.

Methods: The review was performed according to PRISMA guidelines to identify peer-reviewed literature published between 2017 and 2025. The literature search was conducted in the four main databases: IEEE Xplore, PubMed, Web of Science, and Scopus, and found 47 eligible studies.

Results: Artificial intelligence and mobile applications are the dominant technologies that emerged. The application of artificial intelligence was categorized into four general research themes: optimization and interpretation of user input, generation of communicative content, prediction and adaptability, and communicative and technological intermediation. Mobile applications, in contrast, were categorized into: applications for integrating advanced functionalities based on intelligent systems, applications for video-based visual support strategies, applications for supporting caregivers, educators, and clinicians, and applications for multilingual and cultural support. The design of new hardware and extended reality was not extensively represented in the included literature.

Discussion: The study's findings can serve as a scientific reference for researchers and technology developers, enabling them to leverage identified strengths, learn from current limitations, and uncover new research opportunities also considering that evidence on the real-world effects of such technologies remains scarce, with only a minority of studies using rigorous experimental designs and reporting a quantitative impact on communication skills.

KEYWORDS

augmentative and alternative communication (AAC), complex communication needs (CCN), assistive technologies, artificial intelligence—AI, mobile applications, scoping review, international classification for functioning and disability, barriers & facilitative factors

1 Introduction

Communication is a fundamental process that permeates every aspect of our lives, enabling the construction of bridges between the self and the other to create a connection that consolidates human relationships, whether affective, professional, or social, to share ideas and information, to express ourselves, and to negotiate to achieve our goals. Communication is a right for all ([National Joint Committee for the Communication Needs of Persons with Severe Disabilities, 2024](#)), but not everyone communicates in the same way ([Beukelman and Light, 2020](#)). Some individuals have complex communication needs, which arise from the need to communicate with others to express desires, passions, and needs, and the difficulty of doing so, compromising language production or comprehension, communicative intentionality and relationships, spontaneous and structured play activity, from early childhood and in every life context ([Galdieri et al., 2022](#)). In agreement with the international literature, this review uses the term complex communication needs as an umbrella term that refers to all individuals who require alternative communication methods, while acknowledging that this often includes a significant language impairment.

One of the most widespread strategies for addressing complex communication needs is the use of Augmentative and Alternative Communication (AAC), which offers the possibility of building or supporting communicative skills, including both low-tech solutions (e.g., the ETRAN panel or sign language) and high-tech solutions (e.g., the use of software applications or brain-computer interfaces). AAC users represent a highly heterogeneous population. Age can vary considerably, but also the clinical conditions that determine communication difficulties, environments, and living conditions can be very diverse. Communicative difficulties can derive from congenital causes, such as intellectual disabilities, rare syndromes, infantile cerebral palsy, dyspraxia, and multisensory disabilities. They can also appear as a result of acquired causes, such as stroke, adult neurodegenerative diseases, traumatic brain injuries, and cerebrovascular diseases ([American Psychiatric Association, 2013](#)). Finally, communicative difficulties can also last for a limited period, for example, during oro/nasotracheal intubation in intensive care, or in pre- or post-operative care, which can cause a temporary inability to speak and write ([American Psychiatric Association, 2013](#); [Beukelman and Ray, 2010](#); [Light and McNaughton, 2012](#)).

In general, AAC interventions have proven very effective in improving both comprehension and expression in people with developmental disabilities and can be a valuable support for improving, for example, pragmatics, semantics, and morphosyntax ([Allen et al., 2017](#); [O'Neill et al., 2018](#)). These interventions are closely linked to technological evolution, which has progressively expanded their possibilities ([Crowe et al., 2022](#); [Farzana et al., 2021](#)). However, the accelerated technological evolution introduces new challenges and potential risks, for example, regarding personal data protection and ethical issues based which are meriting serious reflection and will be addressed in the discussion section of the article.

Technological advancement is significantly transforming the communication landscape, and this has major implications for the development of AAC. It is sufficient to consider that the trend in the diffusion of mobile devices in 2025 is still increasing ([IDC, 2025](#)), and that augmented reality and virtual reality solutions are expected to become widespread and cover a large market by 2031 ([Damani, 2024](#)). Furthermore, artificial intelligence has obtained increasing capabilities in performing tasks previously exclusive to human beings such as

image classification and natural language understanding. Consequently, artificial intelligence systems are rapidly being integrated into various aspects of daily life, from consumer products to scientific applications ([Maslej et al., 2024](#)).

In this context of rapid innovation, AAC support paradigms have evolved equally dynamically. For example, there has been a diffusion of research and tools based on mobile devices and tablets ([Alzrayer and Banda, 2017](#); [Moraiti et al., 2023](#); [Vlachou and Drigas, 2017](#)), brain-computer interfaces ([Luo et al., 2022](#)), artificial intelligence ([Ding et al., 2020](#); [Rehman et al., 2021](#); [Sennott et al., 2019](#)), and speech-generating devices ([Sigafos et al., 2014](#)).

Recent meta-analyses have highlighted that the introduction of innovative technologies can represent a promising perspective for enhancing the communicative abilities of people with complex communication needs. For example, in the context of autism spectrum disorders, tablet-mediated interventions have moderate to large effects ([Hong et al., 2017](#)), as well as moderate effects have been found on verbal abilities after the use of speech-generating devices ([Muharib and Alzrayer, 2018](#)) and virtual reality ([Karami et al., 2021](#)). The outcomes of these interventions can vary depending on both the type of technology used and the specific characteristics of the users involved. In a recent comparative study, for example, [Pak et al. \(2023\)](#) found no differences between the use of speech-generating devices and picture exchange for children learning to request, highlighting the importance of considering the individual preferences of children.

This scoping review aims to critically examine the application and effects of emerging technologies, including mobile applications, artificial intelligence, and extended reality, on the communicative and social skills of individuals with complex communication needs. Special consideration will be given to scientific studies wherein authors explicitly address human or artificial learning contexts. The analysis will specifically investigate, on the one hand, how employed advanced technologies may influence communication skills, and on the other hand, how the algorithmic training inherent in artificial intelligence systems could support the development of pedagogical tools or environments designed to facilitate human training, learning, and skill acquisition.

Furthermore, technologies will be analyzed as potential facilitators or barriers for individuals with complex communication needs, according to the theoretical framework of the International Classification of Functioning, Disability, and Health (ICF) ([Della Sanità, 2002](#)). This model, adopting a biopsychosocial perspective, conceives disability not as an exclusive characteristic of the individual, but as the result of the interaction between health conditions and environmental factors, paying particular attention to the quality and effectiveness of this interaction in determining levels of participation and functioning.

2 Background and rationale

Numerous systematic reviews have focused on identifying studies concerning the use of high-tech technologies to support AAC. In many cases, these reviews specifically target individuals with autism spectrum disorder, exploring a wide range of research areas. Technological advancement has been a central theme. Reviews like [Farzana et al. \(2021\)](#) have indicated a paradigm shift from the use of low-tech modalities, such as the Picture Exchange Communication System, and an increase in high-tech options, most notably mobile applications and, most recently, artificial intelligence and extended reality systems.

Several of these have addressed critical aspects of design and implementation. For instance, the review by [Liu et al. \(2023\)](#) on mobile apps for autism care emphasizes that usability is the deciding factor for success. Their key finding is that the majority of applications fail due to poor interface design, but those successful offer users with a broad possibilities for customization and robust support for caregivers, who are identified as key stakeholders in the adoption process. Such user-centered design is also implemented for specific features, such as synthetic speech quality. [Zeffate and Elhari \(2023\)](#), for example, noted that robot-like or incongruent voices can provoke rejection of AAC devices in public settings, suggesting that personalized voice generators would have a crucial role for social acceptance. Other reviews have adopted a broader technological scope, including technology-based interventions such as serious games, robotics, and eye-tracking ([Peng et al., 2021](#)), or have analyzed the types of tools used to improve social and communication skills ([de Lima Antão et al., 2018](#)). A recurring finding of these reviews is that, despite technology has advanced, high-tech AAC research has, in some cases, not yet fully explored more advanced communicative and social skills compared to low-tech systems ([Gilroy et al., 2017](#)). Evidence regarding the effectiveness of these systems has shown inconsistent results. For instance, the systematic review by [White et al. \(2021\)](#) showed that most studies did not find an increase in speech production outcomes through the use of AAC. Consequently, the authors suggest that “practitioners should provide parents or teachers with realistic expectations of the effects of AAC” (p. 4210). Similarly, [Syriopoulou-Delli and Eleni \(2022\)](#) found no superiority of high-tech AAC in increasing communicative abilities or vocabulary in individuals with autism spectrum disorder, highlighting that the effectiveness of tools is strongly linked to the unique characteristics of the end-users.

Beyond the technology itself, the latest literature has also emphasized the importance of the pedagogical context. The [Lorah et al. \(2024\)](#) systematic review, for instance, found that mobile AAC technology is intrinsically linked to evidence-based practices. Their findings suggest that teaching techniques involving prompting and modeling are essential for users to acquire the relevant skills, indicating that the mere provision of technology is insufficient without a structured training methodology.

However, some reviews adopt a broader perspective, focusing on specific aspects of interaction between individuals with complex communication needs and high-tech AAC, or proposing taxonomies of AAC devices and interventions ([Curtis et al., 2022](#)) to address the issue of high abandonment rates. An example of a cross-cutting approach is a mega-review that synthesizes systematic reviews, meta-analyses, and narrative reviews published between 2000 and mid-2020 ([Crowe et al., 2022](#)). This work reported significant effects of high-tech speech-generating devices on specific communication abilities of children with autism spectrum disorders and confirmed the increasing adoption of mobile technology in recent years. This latter aspect is further confirmed by a review focused on the use of iPads as AAC devices and their positive effects on communication skills and school participation ([Ok, 2018](#)).

In an even more technology-focused area, the research of [Elsahar et al. \(2019\)](#) provides an extensive characterization of signal acquisition methods used in AAC platforms, from touch-screen-based platforms to brain-computer interfaces, and provides an evaluation of these methods based on features of accessibility, cost, and conversational speed. They found that although traditional input methods are faster, they are often inaccessible to users with severe motor impairments. Conversely, advanced techniques like brain computer interfaces offer accessibility for these populations but

typically they have considerably slower communication velocities and increased complexity. This result highlights the importance that AAC systems should be highly individualized and that significant barriers, including cost and the need for extensive training, still limit the real-world use of even the most advanced technology.

A seminal piece of work is the systematic review conducted by [Baxter et al. \(2012\)](#). To the best of our knowledge, it was the first to apply the ICF to examine, systematically, barriers and facilitators to the use of high-tech AAC. Their main results, more than a decade ago, identified persistent barriers, including the high cost of devices, the lack of technical support and training for users and their families, and of adverse attitudes that could jeopardize adoption.

While this body of work provides important insights, there is an explicit research gap. Literature is, far too frequently, fragmented, emphasizing greatly a specific disability (mainly autism spectrum disorder) or an isolated type of technology (mostly mobile applications). Moreover, the technology landscape has, essentially, changed since the pioneering ICF-based study of [Baxter et al. \(2012\)](#), particularly given the latter advances of applied artificial intelligence.

The present study draws theoretical insights by the biopsychosocial, systematic approach of [Baxter et al. \(2012\)](#) but is not a formal update. This scoping study, however, aims to fill the noted gap by providing an expansive, contemporary map of the modern landscape of emerging technologies (with special reference to artificial intelligence) for the entire spectrum of complex communication needs, without being limited to an isolated diagnosis. By systematically applying the ICF framework to this new era of technology, the study intends to uncover the contemporary barriers as well as facilitators that characterize the user-system interaction with these emerging systems.

Specifically, the present work aims to address the following research questions:

RQ1: What are the most recent technologies used to support complex communication needs through AAC?

RQ2: What are the main facilitators and barriers to the use of emerging AAC technologies, when categorized according to the ICF framework?

Given the broad nature of the research questions, the increasingly rapid technological evolution, and the multiplicity of methodologies and populations present in the existing literature, the authors determined that conducting a scoping review was the most appropriate method to survey the most recent research, identify technologies and methodologies, and highlight existing gaps. This scoping review was therefore conducted to address these exploratory needs.

3 Methods

The review was conducted adhering to the guidelines delineated in the Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) statement ([Tricco et al., 2018](#)).

3.1 Eligibility criteria

The inclusion criteria for this review encompassed articles published in peer-reviewed scientific journals or conference

proceedings relevant to the fields of education, communication sciences, technology, and cognate disciplines. Articles were required to describe, evaluate, or detail the development of advanced technologies—including, but not limited to, augmented, virtual, or mixed reality, mobile applications, artificial intelligence, and machine learning aimed at supporting communicative and/or learning processes for individuals with complex communication needs. Furthermore, studies focusing on the technical underpinnings of these technologies, such as algorithm design, development, or training and optimization, were included, when they connected these technical aspects to create effective learning situations or tools for improving communicative competence.

Ideally, included studies also reported on specific technological features, underlying theoretical frameworks, educational or communicative objectives, inherent limitations, and the measured quantitative or qualitative impact of the technologies on the communicative, social, or learning skills of individuals with complex communication needs. Only articles written in English and Spanish were considered for inclusion.

Studies were excluded from the review if they met one or more of the following criteria: insufficient detail regarding methodology, results, or the implications of the assistive technology, or the presence of significant methodological weaknesses, unresolved ethical concerns, or evident conflicts of interest.

3.2 Search strategy

The following databases were queried: IEEE Xplore, PubMed, Web of Science, and Scopus.

The search strategy aimed to explore three primary concepts: (1) emerging technologies, (2) learning and education, and (3) AAC. The query strings were adapted to the syntax of each database, using different field tags (e.g., title, abstract, keywords) specific to each search portal. The entire, unmodified search strategy for all databases is presented in [Annex 1](#). The search was limited to these electronic databases, and no other sources were used to identify studies.

The main search focused on articles that were published between 2017 and 2025. The first search, for the years 2017–2023, was conducted on 19 December 2023. The updated search, covering publications up to July 2025, was conducted on 16 July 2025.

The decision to commence the search in 2017 was driven by the publication of “Attention is All You Need” ([Vaswani et al., 2017](#)). This seminal paper introduced the Transformer architecture, which underpins most current large language models and marked a turning point in the development of modern artificial intelligence. Given that this review also focuses on these types of technologies, choosing 2017 as the starting year allows us, first, to avoid redundancy with other works by not analyzing now-obsolete technologies. Second, this choice enables us to map the literature on technologies supporting AAC in the “post-Transformer” era.

3.3 Selection process

In the scoping review presented here, initial data from the scientific articles were pulled from the search engines in CSV format. The datasets were merged with a custom R script with the aim to systematically eliminate duplicate entries and retrieve missing abstracts from online sources using the DOI of each article via the “rcrossref” package ([Chamberlain et al., 2022](#)). The selection

process was conducted by two independent reviewers who screened the articles initially based on the titles and abstracts before proceeding to a full-text assessment. The review team consisted of a senior researcher with a specialization in psychotherapy and second reviewer holding a Master’s degree, both with specific expertise in assistive technologies and developmental psychology. At each stage of evaluation, the reviewers engaged in discussions to resolve any discrepancies and ensure consensus regarding the eligibility of the studies. [Figure 1](#) depicts the flow diagram of the article identification and screening process in accordance with the PRISMA model.

Based on the previously defined inclusion and exclusion criteria, 47 studies were identified ([Table 1](#)).

3.4 Data charting

An author-developed data-charting form was used to systematically extract information from the selected articles. The form, saved as an Excel file, included the following variables: (1) authors, (2) year of publication, (3) research design, (4) type of technology, (5) technological features, (6) type of complex communication need, (7) sample size, (8) statistical analyses, and (9) quantitative results, (10) ICF-based facilitators, and (11) ICF-based barriers. Data entry into the form was conducted independently by the two reviewers. At the beginning of the process, the form was tested on three studies in order to evaluate its suitability. Discrepancies identified during the data charting phase were discussed until a consensus was reached. No authors of the included studies were contacted for additional information.

During the charting process, some data (research designs, complex communication needs, technologies) were grouped into broader categories. For instance, technologies were categorized as artificial intelligence, extended reality, mobile apps, and new hardware design. Similarly, complex communication needs were grouped into communication disorders, neurodevelopmental disorders, motor impairments, and acquired conditions. In the categorization of research designs, the term “Design-Based Research” was frequently used when an iterative process was found that included conceptualization, prototyping, evidence-based testing, and the refinement of the solution based on the real-world use of prototypes or actual use contexts.

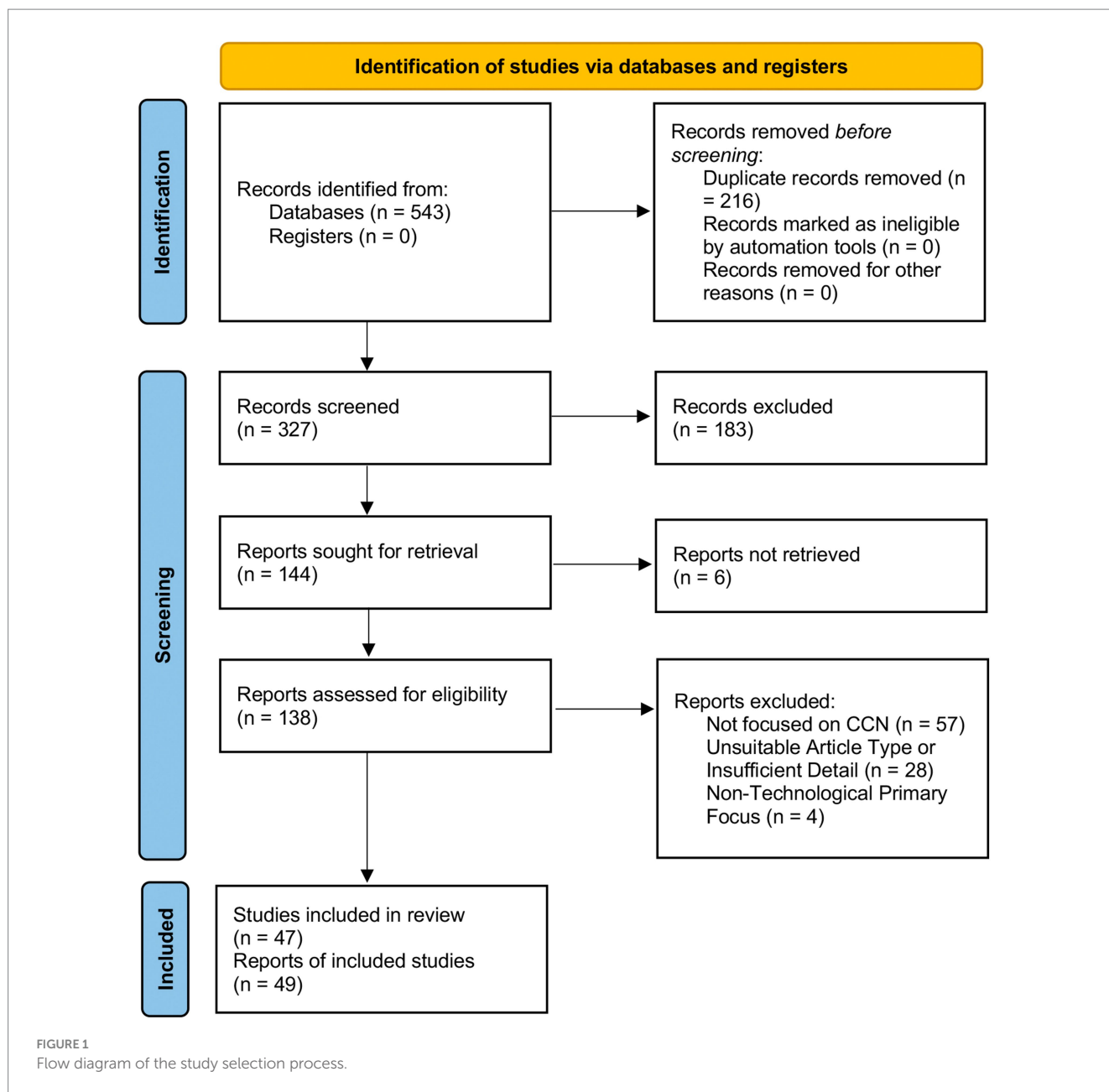
With regard to quantitative results, the main evidence-based findings from the studies were reported, along with the effect size, where available.

3.5 Critical appraisal

In line with the objectives of a scoping review, a formal assessment of the methodological quality or risk of bias of the included studies wasn’t conducted.

3.6 Data synthesis

In order to address RQ1, the technologies identified in the studies were categorized and presented using descriptive statistics (frequencies and percentages) in relation to the year of publication and the target



population. Similarly, for RQ2, a thematic analysis of the textual data was conducted to identify recurring themes based on the components of the ICF. We identified facilitators and barriers mapped to the following domains: activities and participation, environmental factors, and personal factors.

4 Results

The analysis of the annual distribution of scientific publications on the use of technologies AAC reveals significant variability in academic output. Figure 2 presents the quantity of articles published in each year. The data indicate a general increase starting in 2019 ($N = 6$, 12.8%), which is interrupted in 2021 ($N = 2$, 4.26%) and 2022 ($N = 3$, 6.38%), before resuming a positive trend in 2024 ($N = 10$, 21.3%) and the first half of 2025 ($N = 9$, 19.1%).

From the standpoint of rigorous evidence-based data, a prevalence of studies reporting metrics for the accuracy and efficiency of machine learning algorithms ($N = 16$, 34.04%) and data related to single-case designs ($N = 5$, 10.63%) are observed. The presence of statistical tests ($N = 2$, 4.25%) and reported effect size indices ($N = 1$, 2.12%) is rarer. Other studies present numerical data, but these are primarily descriptive.

4.1 What are the latest technologies to support complex communication needs through AAC?

Figure 3 presents absolute and relative frequencies of the main technologies found in the review. Most of the studies focus on the emergence of artificial intelligence ($N = 26$, 49.1%), followed by studies on the use of mobile applications ($N = 20$, 37.7%). Further

TABLE 1 List of articles included in the review.

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Kultsova, M., Matyushechkin, D., and Anikin, A.	2018	Design based research	Artificial intelligence	Implementation of a web-service for translating pictograms into coherent Russian text	Communication disorders (speech impairment), motor impairments (motor deficit)	Qualitative analysis	NA	8 children with autism spectrum disorders, together with their parents and therapists	Flexibility and interoperability	Inherent technical limitations
de Oliveira Schultz Ascari, R. E., Pereira, R., and Silva, L.	2018	Design based research	Artificial intelligence	Personalized gesture interaction, utilizing computer vision and machine learning techniques	Communication disorders (speech impairment), motor impairments (motor deficit)	NA	NA	9 human-computer interaction specialists	Expansion of participation and autonomy; customization and adaptability; positive technical features; availability of low-cost solutions	Inherent technical limitations; technology-user alignment
Zilak, M., Car, Z., and Jezic, G.	2018	Descriptive research	Extended reality	Development of a prototype elementary math virtual classroom based on Oculus Rift and Leap Motion devices	Neurodevelopmental disorders (developmental disabilities)	Descriptive statistics	Average playing time 2.5 times longer than an expert user	30 students with typical development	Positive technical features	Lack of familiarity with technology; inherent technical limitations
Babb, S., Gormley, J., McNaughton, D., and Light, J.	2019	Single case design	Mobile app	Use of videos with visual scene displays, presented via a tablet app, as support for adolescents with autism spectrum disorder and complex communication needs	Neurodevelopmental disorders (autism spectrum disorder)	Visual analyses	TAU-U = 1.0, $p = 0.000$, CI [0.56, 1.0]	1 subject with autism spectrum disorder	Positive technical features; high user motivation	Difficulty participating in specific contexts
Carniel, A., Berkenbrock, C. D. M., Berkenbrock, G. R., Costa, S. E. da, and Cordeiro, A. F. M.	2019	Design science research; participatory design; single-case design	Mobile app	Development of a collaborative system that uses augmentative and alternative communication on tablets to support dialogue for people with intellectual disabilities	Communication disorders (speech impairment)	Comparison of the mother's and patient's responses and calculation of the success rate	NA	1 subject with intellectual deficiency, cerebral palsy, apraxia, high psychomotor difficulty	Customization and adaptability; effective support (caregivers/therapists); positive technical features; high user motivation	Acquired habits (resistance to change); inherent technical limitations; difficulty participating in specific contexts

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Chuckun, V., Coonjan, G., and Nagowah, L.	2019	Qualitative study	Artificial intelligence, mobile app	Development of a mobile application called “HandyApps” designed to facilitate the lives of individuals with visual, auditory, or language disabilities	Communication disorders (speech impairment)	Qualitative analysis	NA	12 students with hearing or speech disabilities or both	Positive technical features; high user motivation	Technology-user alignment; inherent technical limitations
Heo, Y., and Kang, S.	2019	Design based research	Artificial intelligence	Augmentative and alternative communication system designed to minimize manual input and errors, suggesting candidate symbols to the user	Communication disorders (speech impairment, hearing impairment)	Machine learning and probabilistic modeling	Reduction of the number of key presses by 87.6% (12.4 times less than a traditional input method)	Annotated corpus in Korean language consisting of 3,415 sentences	Positive technical features	Inherent technical limitations
Liegel, L., Nogueira, G., and Nohama, P.	2019	Prototype validation study with pre-test/post-test design	New hardware design	Portable computerized system designed for people with cerebral palsy and preserved cognitive abilities that offers alternative computer access via a special keyboard activatable manually or via infrared signals generated by head movements	Communication disorders (speech impairment), neurodevelopmental disorders (Rett syndrome)	Descriptive statistics	Percentage reduction in the time required to complete communicative activities	5 healthy volunteers with intact cognitive abilities, control of head movement and literacy	Positive technical features; availability of low-cost solutions	Inherent technical limitations; technology-user alignment

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Neamtu, R., Camara, A., Pereira, C., and Ferreira, R.	2019	Descriptive research	Artificial intelligence	Development of LIVOX, an Android-based mobile application that uses machine learning algorithms to provide context-based recommendations, designed for people with motor and verbal communication difficulties	Communication disorders (speech impairment)	NA	NA	NA	Customization and adaptability; effective support (caregivers/therapists); positive technical features	Technology-user alignment
Babb, S., McNaughton, D., Light, J., Caron, J., Wydner, K., and Jung, S.	2020	Single case design	Mobile app	Use of videos with visual scene displays, presented via a tablet app, as support for adolescents with autism spectrum disorder and complex communication needs	Neurodevelopmental disorders (Down syndrome)	Visual analyses; interobserver agreement	TAU-U = 1.0, $p = 0.000$, CI [0.56, 1.0]	4 adolescents with complex communication needs and 6 education professionals	Expansion of participation and autonomy; positive technical features; real and meaningful context of use	Technology-user alignment
Kodirov, K., Kodirov, K., and Lee, Y. S.	2020	Initial phase of a design based research	Artificial intelligence	Development of ConWis, a web application designed to help people with hearing and speech problems communicate more easily	Communication disorders (speech impairment), neurodevelopmental disorders (intellectual disabilities)	NA	NA	NA	Positive technical features; customization and adaptability	Limited linguistic availability; inherent technical limitations
Liu, Y.-K., Huang, T.-Y., and Luong, M. H. N.	2020	Action research	Mobile app	Development of the "Listen & Talk" software for children with complex communication needs	Communication disorders (speech impairment, disartry)	Descriptive statistics and qualitative analysis	NA	5 teaching professionals (needs analysis and usability test), 1 subject with Rett syndrome and complex communication needs (case study)	Customization and adaptability; positive technical features; effective support (caregivers/therapists)	Technology-user alignment

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
de Oliveira Schultz Ascari, R. E., Pereira, R., and Silva, L.	2020	Mixed design	Artificial intelligence	Personalized gesture interaction, utilizing computer vision and machine learning techniques	Communication disorders (speech impairment), motor impairments (motor deficit)	Descriptive statistics and inter-agreement Kappa	High accuracy with custom datasets (> 0.94) and on a public dataset (up to 90%); the SVM-based classifier with OF-MHI motion representation demonstrated an efficiency of 0.92 with the target user group	5 volunteers with no motor or speech-language disabilities and 6 students with motor and speech-language disabilities	Flexibility and interoperability; availability of low-cost solutions; customization and adaptability; effective support (caregivers/therapists)	Low user motivation; inherent technical limitations; technology-user alignment
Samonte, M. J. C., Guelos, C. M. C., Madarang, D. K. L., and Mercado, M. A. P.	2020	Design based research	Mobile app	Development of Tap-to-Talk, an Android application designed for children with autism who have communication difficulties	Neurodevelopmental disorders (autism spectrum disorder)	NA	NA	NA	Customization and adaptability; effective support (caregivers/therapists); positive technical features; multilingual support	Difficulty participating in specific contexts; inherent technical limitations
Elsahar, Y., Hu, S., Bouazza-Marouf, K., Kerr, D., Wade, W., Hewett, P., Gaur, A., and Kaushik, V.	2021	Design based research	Artificial intelligence	System to decode a user's breathing patterns and transform them into synthesized messages for conversation	Communication disorders (speech impairment)	Supervised machine learning	The piecewise dynamic time warping algorithm achieved a classification accuracy of 91.05% with a processing time of just 0.65 s	25 volunteers without speech disabilities	Positive technical features; customization and adaptability	Inherent technical limitations; technology-user alignment
Laxmidas, K., Avra, C., Wilcoxon, C., Wallace, M., Spivey, R., Ray, S., Polsley, S., Kohli, P., Thompson, J., and Hammond, T.	2021	Design based research	Artificial intelligence	Development of CommBo, a web-based and speech-generating picture communication board that uses machine learning to provide intelligent suggestions	Neurodevelopmental disorders (autism spectrum disorder), acquired conditions (cranial trauma)	T-test	NASA TLX scores significantly lower using CommBo in physical demand, performance limits, effort, and frustration metric ($p < 0.05$)	3 subjects with complex communication needs	Customization and adaptability; availability of low-cost solutions; flexibility and interoperability; positive technical features	Inherent technical limitations; technology-user alignment

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Li, W., Qiu, X., Li, Y., Ji, J., Liu, X., and Li, S.	2022	Design based research	Artificial intelligence	Development of machine learning augmentative and alternative communication, an image-based contact table with speech synthesis, designed to provide intelligent recommendations to users through a customizable framework and deep learning capabilities	Communication disorders (speech impairment), motor impairments (motor deficit)	Error metrics (mean absolute error and root mean square error), Pearson's correlation model	The model "machine learning augmentative and alternative communication" had the best performance in recognition rate (96%), information transfer rate (obtaining the lower value after 10 epochs), and reduced emotional load, effort, limitations, and frustration for the user	3 subjects with communication disorders in preliminary tests, 2 already using augmented and alternative communication in the final phase	Flexibility and interoperability; customization and adaptability; positive technical features	Technology-user alignment
Mulfari, D., Celesti, A., and Villari, M.	2022	Within-subjects experimental design	Artificial intelligence	CapisciAMe project which aims to study supervised machine learning approaches for dysarthric speech recognition	Communication disorders (speech impairment)	Accuracy level in keywords recognition expressed in percentage	Word recognition accuracy for subjects with dysarthria increased by 10% on average, using artificial intelligence trained on just 5 personal speech samples	Dataset including 21,184 speech recordings from 156 Italian users with neuromotor disabilities and dysarthria; 13 subjects with different levels of dysarthria severity	Positive technical features	Technology-user alignment; inherent technical limitations
Qian, R., Sengan, S., and Juneja, S.	2022	Development and evaluation research	Artificial intelligence	Development of BDIAl-AAC, a big data and artificial intelligence-based English language teaching system for people with neurological disorders	Communication disorders (speech impairment), neurodevelopmental disorders (Angelman syndrome, Phelan McDermid syndrome)	Machine Learning	Good metric performances: word recognition rate (98.01%), prediction rate (97.89%), high efficiency (95.34%), performance (96.45%), accuracy (95.14%), stimulus (94.2%), and disorder identification rate (91.12%) when compared to other methods	NA	Positive technical features	Inadequate or absent support; inherent technical limitations; technology-user alignment

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Athuljith, A., Raju, S., Sudheer, A., SR, A. B., Aswathy, T., and Sheela, P.	2023	Descriptive research	New hardware design	Design of a dedicated and economical device to assist children under 11 in communicating and acquiring basic knowledge	Communication disorders (speech impairment), neurodevelopmental disorders (intellectual disabilities)	NA	NA	NA	Positive technical features; availability of low-cost solutions; customization and adaptability	NA
Atyabi, A., Boccanfuso, L., Snider, J. C., Kim, M., Barney, E., Ahn, Y. A., Li, B., Dommer, K. J., and Shic, F.	2023	Predictive modeling study	Mobile app	Development of the FreeSpeech app, designed for individuals with learning disabilities and autism spectrum disorder	Neurodevelopmental disorders (autism spectrum disorder)	T-test; K-Means Clustering; Machine Learning	Deep learning classifiers pushed diagnosis classification accuracy as high as 82%, a significant step up from the 70% accuracy achieved by conventional machine learning methods	Data from 5,372 individuals with valid usage patterns from the FreeSpeech app; 214 participants who voluntarily filled out an online survey	Positive technical features; high user motivation; customization and adaptability; availability of low-cost solutions	NA
Costanzo, F., Fucà, E., Caciolo, C., Ruà, D., Smolley, S., Weissberg, D., and Vicari, S.	2023	Pre-experimental pilot intervention study with repeated measures	Artificial intelligence, mobile app	Use of Talkitt, a mobile application, which leverages speech recognition technology and artificial intelligence models to translate unintelligible sounds into clear words in real-time, allowing people with speech production problems to communicate verbally in real-time	Communication disorders (speech impairment)	Descriptive statistics, repeated measures ANOVA	Significant improvement in the ABAS II global composite score (global adaptive behavior), with a medium effect size ($\eta p^2 = 0.33$); statistically significant improvement was found in the Naming subtest of the BVL language assessment, with a medium effect size ($\eta p^2 = 0.48$, $p < 0.001$)	23 subjects with Down syndrome	Customization and adaptability; effective support (caregivers/therapists); positive technical features; high user motivation	Inherent technical limitations; difficulty participating in specific contexts

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Draffan, E., Wald, M., Ding, C., and Yin, Y.	2023	Design based research	Artificial intelligence	Use of generative artificial intelligence to adapt the pictographic symbols of augmentative and alternative communication	Communication disorders (speech impairment), motor impairments (motor deficit)	NA	NA	5 experts in the field of augmented and alternative communication	NA	Inherent technical limitations
Kumar, P. V., Balamurugan, D., Suriya, K., and Reshma, R.	2023	Design based research	Artificial intelligence	Integrated Big Data Analytics framework to improve English language learning for people with neurological disorders. This system uses eye tracking for data input and speech synthesis for output	Communication disorders (speech impairment)	Comparison of average ratio of performance metrics using traditional machine learning algorithms with deep learning algorithms	Convolutional Neural Network had the best performances in terms of accuracy (98.63%), precision (97.12%), recall (97.93%), F1-score (97.53%)	NA	Positive technical features	Inherent technical limitations
Pereira, J., Nogueira, R., Zanchettin, C., and Fidalgo, R.	2023	Development and evaluation research	Artificial intelligence	Definition of a method for generating synthetic textual data through the use of Large Language Models to expand an existing corpus for augmented and alternative communication in Brazilian Portuguese	Communication disorders (speech impairment), neurodevelopmental disorders (intellectual disabilities)	Descriptive statistics and unsupervised machine learning algorithm	High semantic similarity of generated sentences to human ones, with a coverage ratio of 0.7 (training) and 0.5 (test)	18 professionals	NA	Inherent technical limitations

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Radici, E., Heboyan, V., and De Leo, G.	2023	Comparative and counterbalanced research design	Mobile app	Development of an iPad app designed to assist communication partners in programming augmented and alternative communication devices through speech-to-text technology	Neurodevelopmental disorders (autism spectrum disorder)	Descriptive statistics and interrater reliability	NA	4 experts in augmented and alternative communication, 2 subjects with complex communication needs (Angelman syndrome and Phelan-McDermid syndrome)	Positive technical features	Inherent technical limitations
Wang, C.-P.	2023	Single case design	Artificial intelligence	Use of artificial intelligence applied to robot and mobile application (OSM) to improve the operant interaction for auditory understanding and the autonomy in making requests and asking for help through automatic organization of the components of a sentence	Neurodevelopmental disorders (autism spectrum disorder)	Kendall's W test, Friedman's related samples test	Accuracy in help requests for children with ASD increased on average from 29% (baseline) to 70% (intervention), a statistically significant improvement for two of the four participants ($p = 0.016$ and $p = 0.014$)	4 children with autism spectrum disorder (experimental group) and 2 children with typical development (control group)	Positive technical features	Technology-user alignment
Zagrouba, R., Alroqaya, L., Aldraiweesh, L., Almegdad, Z., Alotaibi, H., and Alsomaly, Y.	2023	Descriptive research	Mobile app	Development of Aabbir, an open-source application developed for iOS or Android mobile devices to help children with speech disorders and intellectual disabilities	NA	NA	NA	NA	Multilingual support; customization and adaptability; effective support (caregivers/therapists)	NA

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Ayoka, G., Barbareschi, G., Cave, R., and Holloway, C.	2024	Qualitative study	Mobile app	Use of Google Project Relate in Ghana to support speech recognition models in English for non-standard speech	Communication disorders (dysarthria, stutter, dysphonia)	Reflexive thematic analysis	NA	10 speech language therapists and 20 adults with a range of communication difficulties (13 with dysarthria, 4 with dysphonia post-laryngectomy, 2 with aphasia and dysarthria, and 1 with a stutter)	High user motivation; expansion of participation and autonomy; customization and adaptability	Limited linguistic availability; inherent technical limitations; technology-user alignment; difficulty participating in specific contexts; inadequate or absent support
Bandara, T. W. M. I. P. S., Deshan, M. A. D., Prasanth, P., Nadeera, M. S., Krishara, J., and Samaraweera, M.	2024	Development and evaluation research	Mobile app	Development of SIPNENA, a mobile app integrating features like a chatbot, emotion recognition, an augmentative alternative communication keyboard, and activities to learn English and Math	Neurodevelopmental disorders (autism spectrum disorder)	Machine learning model development (CNN, Keras sequential model) evaluated with accuracy metrics, descriptive statistics, and qualitative comparative analysis of system features	NA	100 developmentally normotypic subjects (chatbot training); 1,000 s and third grade students (creation of an audio dataset)	Multilingual support; customization and adaptability; effective support (caregivers/ therapists); high user motivation; positive technical features	Limited linguistic availability; inherent technical limitations
Curtis, H., Jenkins, A., Ibrahim, S., and Neate, T.	2024	Design science research; participatory design	Extended reality, mobile app	Development of complementary prototypes for augmentative and alternative communication through mixed-reality, projection, and audio-based approaches	Language impairments (aphasia)	Thematic analysis, descriptive statistics	NA	14 subject with aphasia, 7 speech and language therapists	Expansion of participation and autonomy; positive technical features; customization and adaptability	Technology-user alignment; inherent technical limitations; difficulty participating in specific contexts; lack of familiarity with technology

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Farhan, M. A., Myassar, H., Kadhim, H., Hussain, F. H. T., and Hussain, F. H. T.	2024	Development and evaluation research	Artificial intelligence	Development of a machine learning-enhanced gesture-based motion-detection technique (GMDA-ML)	Neurodevelopmental disorders (autism spectrum disorder)	Classification and prediction models (linear regression, logistic method), probability functions (prior and posterior probability), and system evaluation metrics (entropy calculation, gesture detection efficiency)	The GMDA-ML model achieves an understanding and accuracy level of 97.92%, outperforming the other algorithms in the comparison	Autistic Disorder DataSet	Customization and adaptability; flexibility and interoperability; effective support (caregivers/therapists)	Inherent technical limitations
Fontana De Vargas, M., Yu, C., Shane, H. C., and Moffatt, K.	2024	Design based research, participatory design, within-subjects experimental design	Artificial intelligence, mobile app	Development of QuickPic, a mobile augmented and alternative communication application aimed at enhancing language learning for non-speaking individuals	Communication disorders (speech impairment)	Descriptive statistics	NA	1 researcher, 4 Speech-Language Pathologists, 9 special education teachers (Co-design); 8 Speech-Language Pathologists (User study)	Customization and adaptability	Inherent technical limitations
Hervás, R., Francisco, V., Concepción, E., Sevilla, A. F. G., and Méndez, G.	2024	Development and evaluation research	Artificial intelligence	Development of an API ecosystem based on natural language processing to create customized assistive technologies aimed at people with cognitive disabilities	Neurodevelopmental disorders (autism spectrum disorder, learning disorder), communication disorder (speech impairment)	NA	NA	NA	Flexibility and interoperability; customization and adaptability; availability of low-cost solutions; expansion of participation and autonomy	Inherent technical limitations

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Mukherjee, S., Chatterjee, A., Chandrakar, K., and Saxena, S.	2024	Predictive modeling study	Artificial intelligence	Development of a chatbot designed to apprehend and process speech inputs	Communication disorder (speech impairment, hearing impairment)	Classification models and performance evaluation (feedforward neural network, categorical cross-entropy loss function), and system evaluation metrics (training and validation accuracy, comparative model analysis)	The model achieved a validation accuracy of 96.30%, outperforming other architecture, such as RNN (93.2%), SVM (92.3%), Naive Bayes (81%), and KNN (87.6%)	NA	Multilingual support; customization and adaptability	Inherent technical limitations
Sánchez-Álvarez, J. F., Jaramillo-Álvarez, G. P., and Jiménez-Builes, J. A.	2024	Single case design	Artificial intelligence	Development of an adaptive alternative and augmented communication system with multiple interaction modalities	Neuromuscular diseases (amyotrophic lateral sclerosis, muscular dystrophy, and spinal cord injury)	Quantitative (calculation of error rate) and qualitative evaluation	High usability scores: efficiency 90%; effectiveness 100%; learnability 90%; satisfaction 80%; overall usability 88%.	10 subjects, with 3 having diagnoses of amyotrophic lateral sclerosis, muscular dystrophy, and spinal cord injury, respectively	Customization and adaptability; flexibility and interoperability; real and meaningful context of use; expansion of participation and autonomy	Technology-user alignment
Zaharudin, R., Izhar, N. A., and Hwa, D. L.	2024	Qualitative study	Mobile app	Development of Smart-App, a mobile app to support personal care, physical function, and communication needs	Neurodevelopmental disorders (intellectual disability, attention deficit hyperactivity disorder, autism spectrum disorder, specific learning disorders)	NA	NA	4 students with learning impairments	Effective support (caregivers/therapists); positive technical features	Acquired habits (resistance to change); technology-user alignment
Zisman, A., Katz, D., Bennasar, M., Alrimawi, F., Price, B., and Johnston, A.	2024	Initial phase of a design based research	Artificial intelligence	Development of a framework to use machine learning algorithms and sensors to create a personalized mobile communication system	Communication disorders (cerebral palsy)	NA	NA	NA	Customization and adaptability; effective support (caregivers/therapists); positive technical features	Technology-user alignment

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Agius, M. M., Stansfield, J., and Murray, J.	2025	Single case design	Mobile app	Comparison of differing organizational formats for teaching requesting skills using an app on a tablet	Neurodevelopmental disorders (autism spectrum disorder)	Visual analysis, Tau-U	Effect size analysis by Tau-U indicated a moderate treatment effect for one participant and a very large treatment effect for the other three, with no differences emerging between the two display conditions (visual scene display and grid display) for any participant	4 with autism spectrum disorder	Customization and adaptability	Inherent technical limitations; technology-user alignment
Goo, M., Nishida, M., Gonzalez, R., and Hines, B.	2025	Single case design	Mobile app	Use of mobile apps for video modeling	Neurodevelopmental disorders (autism spectrum disorder)	Descriptive statistics	75% mean percentage of correct responses	3 with autism spectrum disorder	Positive technical features	Difficulty participating in specific contexts; inherent technical limitations
Kitukale, D., Patidar, G., Kate, V., Bansal, C., Solanki, M., and Jain, D.	2025	Development and evaluation research	New hardware design	Design of new device integrating a camera, Raspberry Pi, and Google's Text-to-Speech technology to translate personalized sign language gestures into speech	Communication disorders (speech impairment)	Use of convolutional neural network and random forest	Random forest algorithm resulted more efficient in training (127 s) with a smaller dataset and an accuracy between 84 and 99%	NA	Effective support (caregivers/therapists); multilingual support; customization and adaptability; positive technical features	Inherent technical limitations
Macedo, A. A., Gonçalves, V. de S., Mandrá, P. P., Motti, V., Bulcão-Neto, R. F., and Rodrigues, K. R. da H.	2025	Development and evaluation research	Mobile app	Development of SofiaFala, a mobile app supporting online speech therapy	Communication disorders (phonological disorder)	Chi-square test, multiple correspondence analysis	The type of phonological disorder influences app evaluation; 100% recognition kiss/verbal praxis, 80% blow (non-verbal sounds)	34 patients with phonological disorders, 15 speech language pathologists	Customization and adaptability; availability of low-cost solutions; multilingual support; real and meaningful context of use	Inherent technical limitations; lack of familiarity with technology; technology-user alignment

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Prete, A. L., Andreini, P., Bonechi, S., and Bianchini, M.	2025	Predictive modeling study	Artificial intelligence	Use of artificial intelligence to predict user intent while using a smart virtual keyboard with the Brain Control Interface	Severe motor disabilities (locked-in syndrome)	Descriptive statistics	2.66 times less interaction than the solution not based on artificial intelligence	NA	Availability of low-cost solutions; positive technical features; customization and adaptability	Technology-user alignment; inherent technical limitations
Regondi, S., Donvito, G., Frontoni, E., Kostovic, M., Minazzi, F., Bratières, S., Filosto, M., and Pugliese, R.	2025	Development and evaluation research	Artificial intelligence	Development of a system based on voice banking and artificial intelligence, enabling individuals to preserve their voice for use with augmented and alternative communication devices	Neurodegenerative diseases (amyotrophic lateral sclerosis)	Two-way ANOVA, evaluation metrics such as pitch, intensity, formants, mel frequency cepstral coefficients, mel cepstral distance, and mean opinion score.	The model produced very natural voices (MOS of 6.013 ± 0.77) by faithfully replicating pitch and formants (no significant difference) and significantly increasing intensity ($p < 0.01$), achieving a competitive objective similarity score (mean MCD of 16.23)	10 amyotrophic lateral sclerosis patients	Expansion of participation and autonomy	Difficulty participating in specific contexts
Rocha, A. P., Guimarães, A., C. Oliveira, I., Fernandes, J. M., Oliveira e Silva, M., Silva, S., and Teixeira, A.	2025	Predictive modeling study	Artificial intelligence	Development of a system using smartwatch sensors and machine learning to recognise arm gestures executed while lying	Language impairments (aphasia)	Generalized mixed-effects models, Wilcoxon signed-rank test	High efficacy in recognizing in-bed arm gestures (macro F1-score $\geq 94\%$), with top configurations using accelerometer and gyroscope yielding a high accuracy of 94.9% and a mean F1-score of 95.1%, while maintaining a low False Positive Rate (1–5%)	10 healthy volunteers	Positive technical features; expansion of participation and autonomy	Inherent technical limitations

(Continued)

TABLE 1 (Continued)

Authors	Publication year	Research design	Technology	Features	Complex communication needs	Statistical analyses	Quantitative results	Participants	Facilitators	Barriers
Savaldi-Harussi, G., Amster, I., Stolar, O., and Ben-Itzhak, E.	2025	Single case design	New hardware design, mobile app	Development of “Smart-Glove” system combining radiofrequency identification technology, a video scene display on a tablet, and printed cards	Neurodevelopmental disorders (autism spectrum disorder)	Visual analysis, Tau-U	Tau-U Picture Exchange Communication System condition: 0.93; Tau-U Picture Exchange Communication System + Smart-Glove: 0.96; the mean reaction time decreased and the percentage of independent requests increased over time in the Smart-Glove condition	4 with autism spectrum disorder	High user motivation; positive technical features	Technology-user alignment; difficulty participating in specific contexts
Sweidan, S. Z., Abdel-Qader, A. A., and Darabkh, K.	2025	Development and evaluation research	Mobile app	Development of My Voice, an Android app including three different modes of communication	Communication disorders (apraxia of speech)	Descriptive statistics	NA	200 (46 parents of children with apraxia of speech and specialists; 39 computer engineering students; 77 medical schools students; 38 other)	Flexibility and interoperability; customization and adaptability; availability of low-cost solutions; multilingual support	Inherent technical limitations; limited linguistic availability

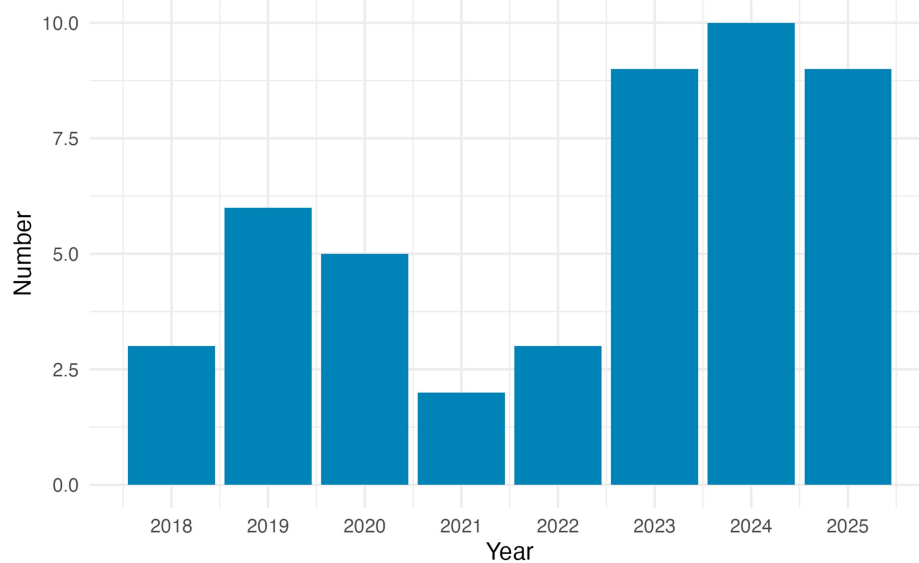


FIGURE 2
Distribution of articles by year of publication.

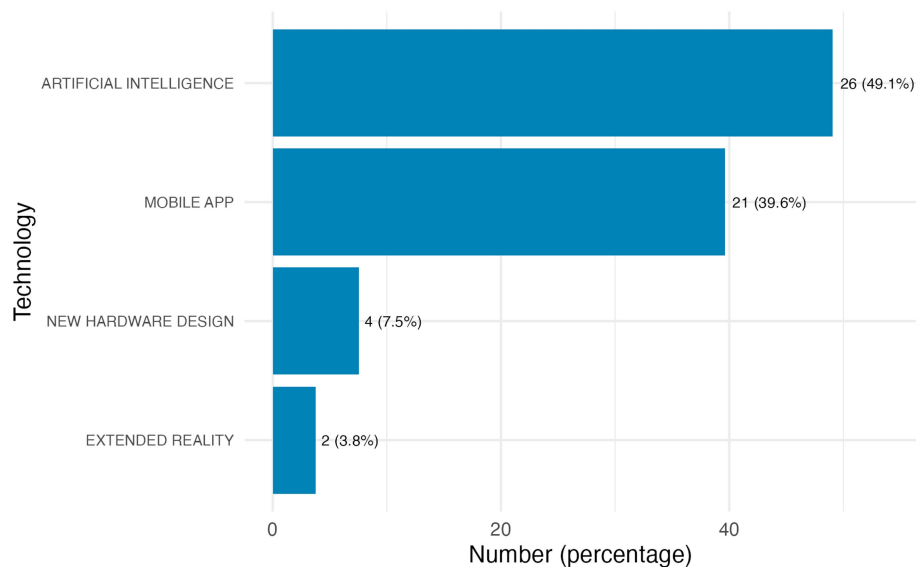


FIGURE 3
Distribution of articles by applied technology.

studies proposed the design and implementation of new hardware ($N = 4$, 7.55%), while extended reality was utilized only in two studies ($N = 2$, 3.77%).

Table 2 presents the distribution of the included studies by technological category and the diagnostic groups associated with complex communication needs. The data highlight a significant concentration of research, with two areas being clearly predominant. The first is the use of artificial intelligence, as mentioned, which is the most studied technological category ($N = 45$). Its application is broad but with a marked focus on communication disorders ($N = 19$) and

motor disorders ($N = 7$). The second area involves mobile applications ($N = 25$), whose use is concentrated on neurodevelopmental ($N = 14$) and communication ($N = 11$) disorders.

Simultaneously, the table highlights significant research gaps and potential future directions. Technologies such as extended reality ($N = 2$) and new hardware design ($N = 6$) remain marginal and underexplored. Furthermore, entire disability categories are almost entirely neglected by recent technological research; these include acquired conditions ($N = 3$), neurodegenerative diseases ($N = 2$), neurological conditions ($N = 2$), and sensory impairments ($N = 3$).

TABLE 2 Distribution of studies by technology type and diagnostic categories associated with complex communication needs.

Technology category	Acquired conditions	Communication disorders	Motor disorders	Neurodegenerative diseases	Neurodevelopmental disorders	Neurological conditions	Sensory impairments	Total
Artificial intelligence	3	19	7	2	9	2	3	45
Desktop and mobile apps	0	11	0	0	14	0	0	25
Mobile app	0	3	0	0	3	0	0	6
New hardware design	0	1	0	0	1	0	0	2
Extended reality	3	34	7	2	27	2	3	78
Total	3	19	7	2	9	2	3	45

Figure 4 displays the absolute and relative frequencies of the diagnostic categories associated with the complex communication needs addressed by the reviewed technologies, highlighting the prevalence of communication ($N = 31$, 43.7%) and neurodevelopmental disorders ($N = 26$, 36.6%).

4.1.1 Artificial intelligence

Most studies in this review ($N = 26$) utilize artificial intelligence to support the communicative processes of individuals with complex communication needs. These studies address heterogeneous problems and can be synthesized into four main research themes: optimization and interpretation of user input, generation of communicative content, prediction and adaptability, and communicative and technological intermediation.

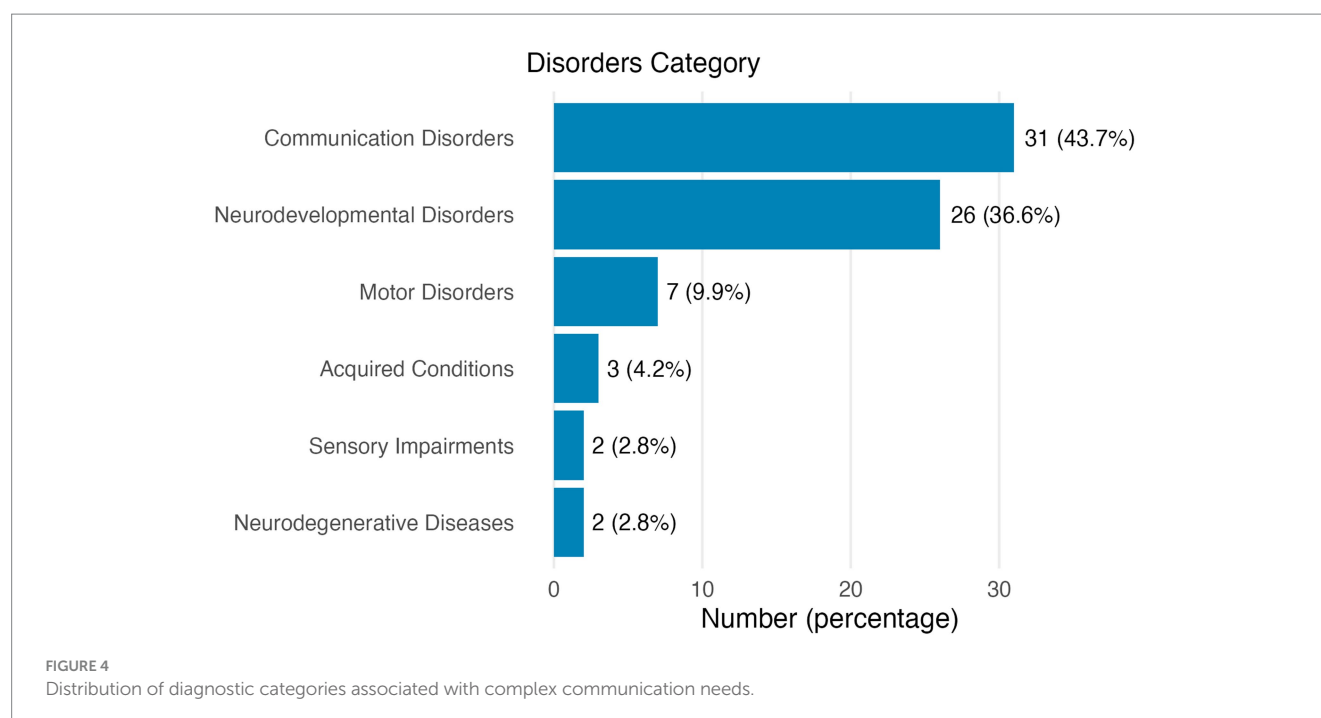
4.1.1.1 Optimization and interpretation of user input

One research area emerging in the review is the use of artificial intelligence algorithms to enhance user input, which can be imprecise due to symptomatic conditions. A type of input of great interest is the interpretation of movement and gestures. Studies by [de Oliveira Schultz Ascari et al. \(2018b, 2020\)](#) report very high accuracy (94%) in recognizing personalized gestures of individuals with motor deficits via computer vision. Similar high accuracy rates were found in other studies focusing on movement recognition. For instance, the work by [Farhan et al. \(2024\)](#) achieved 97.92% accuracy, while [Rocha et al. \(2025\)](#) reached 94.9% using advanced sensors and smartwatches. A different application of artificial intelligence for input interpretation was explored by [Costanzo et al. \(2023\)](#), whose system provides real-time translation of unintelligible sounds into clear words.

Other studies achieve similar results but use different communication channels. For example, [Kumar et al. \(2023\)](#) obtains very high performance in the recognition of eye movements via a convolutional neural network (F1-score > 97%) to support English language learning in individuals with neurological disorders. Similarly, [Elsahar et al. \(2021\)](#) uses artificial intelligence to identify user breathing patterns to translate them into synthesized messages for conversation, with a piecewise dynamic time warping algorithm accuracy of 91%. In this area, the study by [Prete et al. \(2025\)](#), aimed at individuals with locked-in syndrome, should also be mentioned. Through the detection of brain activity via an electroencephalogram helmet and the use of large language models and recurrent neural networks, the authors managed to reduce the interactions needed to use a virtual keyboard by 2.66 times compared to solutions not based on artificial intelligence. A similar result is obtained by [Heo and Kang \(2019\)](#) who, through the use of artificial intelligence, achieves a 12.4-fold reduction in the number of keystrokes and errors in a communicative act via a digital interface.

4.1.1.2 Generation of communicative content

A second theme concerns studies where artificial intelligence is used to generate communicative content. A relevant study is that by [Regondi et al. \(2025\)](#), which focuses on individuals with amyotrophic lateral sclerosis. Their system, based on voice samples from the patient, is capable of generating highly natural voices that closely resemble the original in terms of pitch and formants, as observed through objective evaluations (mean MCD = 16.2) and subjective assessments (MOS = 6.013 ± 0.77).



Other studies concentrate on the generation of visual, textual, or video content. In this area, [Pereira et al. \(2023\)](#) developed a system to expand an existing corpus for AAC in Brazilian Portuguese by utilizing large language models, achieving high semantic similarity with natural phrases. Meanwhile, [Kultsova et al. \(2018\)](#) developed a web service that translates pictographic messages in English into Russian alphabetic text, reporting qualitative linguistic, cognitive, and behavioral improvements in the individuals who benefited from it. Generative artificial intelligence has also been used to produce stylistically consistent symbols to address the difficulty in finding suitable symbols for all needs ([Draffan et al., 2023](#)). In the video domain, the solution proposed by [Qian et al. \(2022\)](#) processes the speech of individuals with complex communication disorders and pairs it with a corresponding video or animation. The system achieved excellent performance with all key metrics, including word recognition, prediction rate, and accuracy, exceeding 91%.

4.1.1.3 Prediction and adaptability

A third research area utilizes artificial intelligence to predict user needs and adapt in accordance with their residual abilities and requirements. Although these studies are still in a preliminary stage, involving initial testing with end-users, the prototypes exhibit interesting functionalities. For example, [Sánchez-Álvarez et al. \(2024\)](#) employs fuzzy logic to identify the user's disease stage and propose the most suitable interaction modality, achieving overall usability scores of 88% with 100% effectiveness.

Other systems are primarily oriented towards content prediction. Through machine learning and contextual data (such as time or GPS coordinates), some systems can predict users' communicative habits and provide communication options appropriate to the time of day and context ([Neamtu et al., 2019](#)). In this domain, the machine learning augmentative and alternative communication model proposed by [Li et al. \(2022\)](#) achieved excellent performance in

recognition rate (96%) and reduced emotional load, effort, limitations, and frustration for users with whom a small test was conducted. A significant reduction ($p < 0.05$) in perceived workload, effort, and frustration, as measured by the NASA-TLX scale, is also observed in the web application Coombo, which is based on intelligent suggestions, as proposed by [Laxmidas et al. \(2021\)](#).

This area also includes the conceptual contribution of [Zisman et al. \(2024\)](#) for the creation of multimodal systems that continuously adapt to users' communicative needs based on sounds, gestures, and movements unique to each individual.

4.1.1.4 Communicative and technological intermediation

Finally, one research area explores the possibility of artificial intelligence acting as an intermediary for either human-to-human communication or communication between technological systems. In the first instance, [Wang \(2023\)](#)'s study employed an artificial intelligence-based robot is used as an intermediary between an operator and children with autism spectrum disorder to stimulate their desire to communicate. The researchers observed an increase in requests for help (from 29% at baseline to 70% in the intervention phase), and this improvement was statistically significant in two out of four subjects in the experimental group. In [Mukherjee et al. \(2024\)](#)'s study, on the other hand, the intermediary between a neurotypical individual and the user with a disability is a chatbot that converts speech to text and suggests three most probable textual responses to the user, which, once selected, are converted back into speech. The chatbot achieved a validation accuracy of 96.30%.

In the second instance, [Hervás et al. \(2024\)](#) proposes the use of natural language processing for the development of an ecosystem of application programming interfaces aimed at creating assistive technologies. This ecosystem offers a set of services for new technological solutions that facilitate interoperability between systems, increasing development speed and source code maintainability.

4.1.2 Mobile applications

Mobile applications represent the second most frequently encountered technology category in this review ($N = 19$). In general, the review identified five main, non-exclusive themes: apps integrating advanced functionalities based on intelligent systems, apps for video-based visual support strategies, apps for caregiver, educator, and clinician support, apps for multilingual and cultural support, and app for extended reality.

4.1.2.1 Apps integrating advanced functionalities based on intelligent systems

An emerging research area involves mobile applications equipped with “intelligent” functionalities based on artificial intelligence. While most studies provide descriptive accounts of the prototypes developed, a limited number of studies present objective evaluations related to the effectiveness and impact of these technologies.

For example, [Atyabi et al. \(2023\)](#) utilized deep learning classifiers to predict autism spectrum disorder diagnoses based on usage patterns of the mobile app FreeSpeech. The task was performed with an accuracy of 82%, a result significantly higher than the 70% achieved with traditional machine learning methods. Similarly, [Costanzo et al. \(2023\)](#) experimented with the Talkitt app among individuals with Down syndrome, aiming to translate unintelligible sounds into clear words in real-time. The application employs machine learning and automatic speech recognition technologies and researchers found improvements in both adaptive behavior and linguistic naming among users, achieving a medium effect size in both cases (respectively $\eta^2 = 0.33$ and $\eta^2 = 0.48$). Another example of real-time application is HandyApps which provides conversion from speech to text for individuals with hearing impairments and from text to speech for those with speech impairments ([Chuckun et al., 2019](#)).

Beyond these more rigorous studies, recent literature also features other prototypes with intelligent functionalities. For instance, QuickPic uses computer vision models and large language models like GPT to automatically generate symbol grids from an image ([De Fontana Vargas et al., 2024](#)). [Bandara et al. \(2024\)](#), conversely, applies deep learning, convolutional neural networks, and natural language processing in an app with integrated functionalities such as a chatbot, emotion recognition, an augmentative alternative communication keyboard, and activities to learn English and Math. Finally, [Curtis et al. \(2024\)](#) leverages iOS17 artificial intelligence to vocally reproduce phrases using the user’s replicated voice.

4.1.2.2 Apps for video-based visual support strategies

A notable technology identified in this review concerns the evolution of tools that primarily use video to support communication.

The most commonly found technology is that of visual scene display apps. Traditionally, visual scene displays employ static images of real-life scenarios with “hot spots” that, upon selection, trigger an audio output of a word or phrase. In an evolution proposed by [Savaldi-Harussi et al. \(2025\)](#), video activation occurs through radio frequency identification technology. [Babb et al. \(2019, 2020\)](#) have augmented visual scene displays with videos that capture dynamic events, allowing for pauses at critical junctures to create visual scene displays with hot spots programmed with relevant vocabulary. For instance, [Babb et al. \(2019\)](#) utilized video visual scene displays to instruct an adolescent with autism spectrum disorder in completing vocational tasks in a school library, while in [Babb et al. \(2020\)](#), subjects were

engaged in volunteer activities. In both cases, very large positive effects were found ($\text{Tau-U} = 1.0$, $p = 0.000$, CI [0.56, 1.0]). The effectiveness of visual scene displays was further analyzed by [Agius et al. \(2025\)](#), who, in another single-case design study, compared it with a traditional grid format for teaching requesting skills. The authors identified moderate to very large effects but found no significant differences between the two conditions.

Finally, [Goo et al. \(2025\)](#) provides an example of iPad-based video modeling aimed at facilitating the use of the Proloquo2Go™ app by individuals with autism spectrum disorder, finding an average of 75% correct responses in formulating requests via the app.

4.1.2.3 Apps for supporting caregivers, educators, and clinicians

An interesting area of research is where technology not only supports individuals with complex communication disorders but also targets caregivers, educators, and clinicians. These individuals can facilitate a deeper understanding of user needs and play a crucial role in the effectiveness of an AAC system, which presupposes a collaborative network around the individual.

Some studies show encouraging data on the involvement of these secondary users. [Radici et al. \(2023\)](#)’s study describes the Speech-to-Symbols app, aimed at reducing the programming time for AAC devices, which can be a barrier to their use, by leveraging speech-to-text features in a “just-in-time” mode. The app’s use shows a substantial reduction in steps (1–3) to program a new symbol compared to a traditional app (10–11), accompanied by a very high perception of the app usability. Similarly, [Macedo et al. \(2025\)](#) present the SofiaFala application, where speech therapists can manage and monitor online exercises. The software showed high accuracy rates in recognizing non-verbal and verbal sounds within a range of 80 to 100%. The study by [Carniel et al. \(2019\)](#) also demonstrated that technology-mediated communication support, grounded in collaborative efforts with key individuals in the relational networks of those with intellectual disabilities, achieved a high success rate in test responses. A unique aspect of their study is that they provided educators with a desktop application to record, modify, and organize images that would later be synchronized with the mobile app for the end-users.

Other studies report similar functionalities, for example, [De Fontana Vargas et al. \(2024\)](#) presents a solution for speech therapists and educators to rapidly generate communication boards from photographs, while [Zaharudin et al. \(2024\)](#) provides teachers with a platform to manage various support modules for their students.

4.1.2.4 Apps for multilingual and cultural support

A further research theme identified in the review is the necessity for cultural and linguistic adaptation, which is considered something more than mere interface translation. AAC systems are mostly designed in Western contexts and thus become a barrier to accessibility due to the fact that they usually include symbols and sets of images that cannot be universally used in other cultural worlds. Two research studies indicate apps with typical pictogram and text-to-speech features for the Arabic world ([Sweidan et al., 2025](#); [Zagrouba et al., 2023](#)), while Sinhalese ([Bandara et al., 2024](#)), and Filipino ([Samonte et al., 2020](#)) solutions are also present. Conversely, [Ayoka et al. \(2024\)](#) does not propose a new technological solution but evaluates the introduction of Google’s Project Relate, an app for the automatic recognition of people with non-standard speech, within the Ghanaian

context, aiming to leverage the pervasive spread of mobile devices and the severe shortage of speech therapy services.

4.1.3 New hardware design

The creation of new hardware is uncommon in the identified literature ($N = 4$). A common thread across these studies is their focus on focusing on needs not typically met by existing solutions. For instance, [Athuljith et al. \(2023\)](#) introduces the Voice of the Xtreme system, which aims to enhance the accessibility of AAC devices for Indian children. This population is significantly underserved due to the high costs and limited market availability of such devices within India. The system, built upon a Raspberry Pi 4 and a touchscreen display, provides users with a customizable database featuring an extensive range of categories and vocabulary.

Another important issue addressed by the design of new devices is portability. This aspect is found in both [Liegel et al. \(2019\)](#) and [Kitukale et al. \(2025\)](#)'s studies. In the former, the focus is on individuals with cerebral palsy who maintain preserved cognitive abilities and thus require communication support in various life contexts. The creation of the Portable System for Alternative Communication demonstrated a percentage reduction in the time required to complete communicative activities more than 10%, highlighting its advantages related to portability, accessibility via head movements, and affordability. In the latter, the new hardware integrates a camera, Raspberry Pi, and Google's Text-to-Speech technology to translate personalized sign language gestures into speech. Here, users can train the device to recognize their personalized sign language, eliminating the need to learn standard languages. The use of a random forest algorithm to support gesture recognition and phrase prediction showed high levels of efficiency in training, starting from a small dataset and achieving very high accuracy between 84 and 99%.

Conversely, [Savaldi-Harussi et al. \(2025\)](#) developed a Smart-Glove to improve the performance of individuals with autism spectrum disorder in using the Picture Exchange Communication System. This was achieved by initiating videos on a tablet when the child brought the card near the glove. Results indicated a significant improvement in children's communicative behavior ($\text{Tau-U} = 0.96, p < 0.001$) and a decrease in mean reaction time, while the percentage of independent requests increased over time.

4.1.4 Extended reality

Extended reality is an umbrella term generally used to encapsulate augmented, virtual, and mixed reality ([Çöltekin et al., 2020](#)). Although these technologies hold potential for AAC through their capacity to create immersive and interactive environments, this review identified only two relevant studies. [Zilak et al. \(2018\)](#) describe the development of a prototype virtual elementary mathematics classroom that leverages Oculus Rift technology and LeapMotion interaction to enhance learning engagement and interactivity. The prototype is grounded in the principles of an established mobile AAC application, suggesting that virtual reality may serve as a novel modality for delivering concepts and methodologies already validated within the field of communication. The average time to complete the game was 2.5 times longer than that of an expert user, highlighting a steep learning curve to familiarize with the technology, even considering that tests were conducted with neurotypical subjects.

The second study also found that mixed reality can be perceived as less user-friendly, especially when head-mounted displays are

required. [Curtis et al. \(2024\)](#), in fact, propose two technological solutions for augmentative and alternative communication that overlay information onto the real world to provide users with contextually relevant linguistic support, via both Microsoft HoloLens 2 (Holo AAC) and a pico projector connected to a mobile device (Pico-project AAC). Focus groups with individuals with aphasia and speech and language therapists revealed that Holo AAC was perceived as the more problematic solution in terms of ease of use and potential for public use.

4.2 What are the main facilitators and barriers to the use of emerging AAC technologies, when categorized according to the ICF framework?

In the following paragraphs, the thematic analysis of the macro themes related to facilitators and barriers will be presented in accordance with the domains of the ICF framework and is summarized in [Tables 3, 4](#), respectively.

4.2.1 Environmental factors

4.2.1.1 Technology-user alignment

A key theme from the analysis of studies concerning environmental factors is the lack of alignment between technology design and user abilities ($N = 23$). Technology is often unable to adapt to the physical functioning of its users, who may present with motor characteristics such as specific postures, involuntary movements, physical and mental fatigue, and fluctuating emotional states.

Studies have shown that poor motor coordination can lead to imprecise interaction with a tablet due to touchscreen sensitivity. Similarly, spastic movements can cause unintended selections, or the

TABLE 3 Main themes identified as facilitators to the use of technology.

ICF domain	Theme	Frequency
Environmental factors	Positive technical features	33
Environmental factors	Customization and adaptability	29
Environmental factors	Effective support (caregivers/therapists)	14
Environmental factors	Availability of low-cost solutions	11
Activities and participation	Expansion of participation and autonomy	9
Personal factors	High user motivation	9
Environmental factors	Flexibility and interoperability	8
Environmental factors	Multilingual support	7
Environmental factors	Real and meaningful context of use	3

TABLE 4 Main themes identified as barriers to the use of technology.

ICF domain	Theme	Frequency
Environmental factors	Inherent technical limitations	33
Environmental factors	Technology-user alignment	23
Activities and participation	Difficulty participating in specific contexts	9
Environmental factors	Limited linguistic availability	4
Environmental factors	Inadequate or absent support	3
Personal factors	Lack of familiarity with technology	3
Personal factors	Acquired habits (resistance to change)	2
Personal factors	Low user motivation	1

inability to control breathing can prevent proper system configuration. Every device, no matter how advanced, risks unintentionally introducing barriers. For example, mixed reality headsets can be difficult for end-users to operate due to a lack of tangible feedback. Analogously, the requirement for a precise gesture to align a communication card with a sensor often necessitates technical support from a third party.

A further level of misalignment concerns cognitive and sensory functions. Technologies may impose an excessively high cognitive load on the user, for instance, by presenting too many options or complex textual prompts that can confuse the user. Another crucial element is memory, as some systems require users to remember motor or breathing patterns. Any sensory difficulties can also compromise the gestures needed to use a technology. For example, auditory feedback, ideally designed to be a facilitator, can become a barrier if the user dislikes certain sounds.

Finally, in general, a barrier in many systems is the need for recognizable and repeatable inputs over time, without accounting for the variability in users' conditions and their inevitable individual differences.

4.2.1.2 Customization and adaptability

A highly represented aspect in the studies examined is the customization and adaptability of technologies to user needs ($N = 29$). This aspect facilitates technology use because it allows the user or caregiver to smoothly adapt the functions of technological devices to residual abilities through quickly programmable or configurable systems. Customization can occur at the level of the interface, content, settings, and activation methods.

Another aspect relates to the personalization of the input method, for example, by creating custom signs, gestures, or patterns, ensuring that systems adapt to user needs rather than the other way around. This can also involve adapting the interface to the user's condition as their symptom profile changes over time.

One of the forms of adaptability discussed is also multimodality, which involves providing multiple interaction channels, such as adding images, sounds, and animated videos to the user's communicative message. This enables users with complex functional characteristics to find the most effective interaction channel for them.

4.2.1.3 Context of use and adoption

A theme emerging from the thematic analysis is the support provided by therapists and caregivers. The involvement of a reference person for individuals with complex communication needs can be a valuable addition to technology use, as it promotes a network approach to supporting communication difficulties ($N = 14$). Caregivers, therapists, and educators play a fundamental role, from the initial system configuration and content programming to the continuous monitoring of progress.

However, some studies highlight that the need for a mediator to use the technology can become problematic when this figure is absent or inadequate ($N = 3$). This dependence on a reference person can severely limit the adoption of innovative technological solutions outside of study and research contexts.

A second theme that emerged is the context in which the technology is used. Some studies highlight that the use of new technological solutions can be particularly relevant when used in a real community setting ($N = 3$). However, concurrently, it can present an initial barrier to adaptation and task execution ($N = 9$). An unfamiliar environment can, in fact, slow down natural adaptation to a new system, while complex contexts like schools, where there might be significant noise, can complicate its use. Additionally, some technologies, such as those based on mixed reality, can cause embarrassment for users, thus hindering their adoption.

4.2.1.4 Accessibility and inclusion

The theme of accessibility and inclusion is articulated through three fundamental aspects: economic accessibility, support for multiple languages and cultures, and system flexibility.

The most significant issue is cost, represented by the importance of maintaining affordable prices for devices or software ($N = 11$). To keep costs low, technological systems utilize commonly available hardware with very modest minimum requirements, or they offer free solutions.

A second significant theme is the linguistic accessibility of the software. The lack of available translations is referred to as a significant barrier, as it prevents a large number of users from benefiting from technological support ($N = 4$). Multilingual apps, or apps in underrepresented languages, on the other hand, increase their potential for inclusion ($N = 7$). This theme extends beyond mere translation to encompass adaptation to cultures other than Western ones, which are most frequently represented. Indeed, the review includes solutions tailored to, for example, Brazilian Portuguese, Filipino, Sinhalese, and Arabic.

Lastly, systems' Flexibility and interoperability emerge as significant facilitators due to the potential to integrate with other software ($N = 8$). The user is not confined to a single technological solution but can use different systems with the support provided by the assistive technology. This category also includes offering accessibility options and enabling use by users with diverse functionalities and needs. Technically, this can mean providing an ecosystem of application programming interfaces or multiple interaction modes within the same system.

4.2.1.5 Technical factors

The technical factors of a system can act as a facilitator ($N = 33$) when they possess characteristics that broaden the circumstances of their use. A crucial aspect is ease of use and "just-in-time" interaction,

which enables real-time augmented communicative exchanges and timely feedback to guide the user's interaction with the system. Another key element is the capacity for correcting user input inaccuracies, effectively reducing user effort. This includes algorithms that require very brief training or leverage existing datasets for training to optimize technical efficiency before engaging with end-users.

Independence from infrastructure (technological and internet networks) and portability are equally important for promoting use in diverse life contexts. From a purely technical standpoint, the most facilitating technological devices are those that are open to technical integration with other systems (e.g., via APIs).

However, the inherent limitations of technology can become barriers when they fail to adequately respond to the functional diversity of users ($N = 33$). Technological tools can be sensitive to environmental conditions (e.g., ambient light, colors, or the need for particularly static environments), present feedback that can be perceived as unclear or misleading, feature overly rigid designs, necessitate an internet connection for system functionality, exhibit software availability for only certain devices or operating systems, and demonstrate suboptimal system performance when faced with complex user demands.

4.2.2 Personal factors

The analysis identified three themes related to personal factors that can act as either barriers or facilitators.

The first theme is user motivation. This factor can be crucial for benefiting from technological support. High user motivation can be a facilitator ($N = 9$). User motivation can be stimulated, for instance, through gamification-based designs or by enriching the communicative experience with multimodal information. Circumstances of low motivation can pose a serious risk, manifesting as an insurmountable barrier to use ($N = 1$).

A second theme relates to a lack of familiarity with the target technology, which can introduce a possible barrier to technology acceptance by the end-user ($N = 3$). If end-users perceive the technology as overly complex, they are unlikely to adopt it.

Finally, other studies ($N = 2$) identified the theme of acquired habits, highlighting how the routine of new communicative processes supported by technology can become a barrier if they are then difficult to replace or update.

4.2.3 Activities and participation

The analysis highlighted how technologies can directly impact the activities and participation domain, primarily as facilitators.

The first theme is the expansion of participation and autonomy ($N = 9$). Firstly, technologies enable individuals to communicate their daily needs more effectively and participate more actively in conversations. Additionally, thanks to interoperable technologies, users are no longer limited to a single app and can use other applications such as web browsers or text editors, thereby expanding their participation in various areas of life and increasing their autonomy. Successfully completing a communicative task not only allows users to be more autonomous but also supports their sense of self-esteem and accomplishment.

Finally, a barrier-related theme also emerged concerning difficulty participating in specific contexts ($N = 9$). One study, in particular, highlighted how using a device in a school setting can encounter obstacles, indicating that the social context and its dynamics can

represent a barrier to the effective use of technology, even if it functions well on a technical level.

5 Discussion

The present study reports a scoping review conducted in accordance with the PRISMA guidelines to identify the latest technologies in the AAC field, evaluated using the conceptual framework of the ICF in order to identify aspects that may facilitate or hinder their adoption, and concurrently assess their potential impact on communication skills.

Compared to previous reviews in this field, which until recently highlighted a prevalence of mobile device-based technologies (Crowe et al., 2022; Ok, 2018), the present study observed a growing interest in artificial intelligence. Although artificial intelligence is a technology that originated several decades ago, it has recently seen widespread adoption thanks to advancements driven by the increased availability of data, models, and computational power. For example, large language models and related chatbots like ChatGPT are now considered emerging and general-purpose technologies (Filippo et al., 2024; Khan et al., 2024) due to their ability to achieve human-comparable performance in various tasks using natural language, despite the persistence of biases requiring attention (Makridakis et al., 2023).

Renewed interest in artificial intelligence has also been observed in the AAC field, as it offers potential avenues for addressing some of the most long-standing issues related to high-tech AAC technologies. These include improving the real-time adaptation to a user's characteristics, habits, and requests (Mulfari et al., 2022; Kodirov et al., 2020; Neamtu et al., 2019) and enhancing the ability to personalize communicative outputs, particularly for underrepresented cultural contexts (Ding et al., 2020; Kitukale et al., 2025; Mukherjee et al., 2024; Pereira et al., 2023). Furthermore, artificial intelligence is being applied to the recognition of various alternative input triggers, ranging from gestures (Farhan et al., 2024; de Oliveira Schultz Ascari et al., 2018b, 2020, 2023) and brain activity (Prete et al., 2025) to breathing patterns (Kumar et al., 2023). In all these applications, the analytical capabilities of artificial intelligence are leveraged to decipher complex communicative situations (Zdravkova et al., 2022).

A key finding of this review is the identification of studies reporting impressive performance in the accuracy and efficiency metrics of artificial intelligence algorithms (Farhan et al., 2024; de Oliveira Schultz Ascari et al., 2018b; Rocha et al., 2025) for classifying and identifying user inputs. These algorithms significantly reduce errors in interacting with technological systems and decrease the effort required for individuals to communicate. They are often capable of recognizing words, gestures, breathing patterns, eye movements, disease stages, effectively predicting the communicative intent of individuals with complex communication disorders and sometimes adapting to user needs based on their functional levels (e.g., Sánchez-Álvarez et al., 2024).

Despite these promising results, research on artificial intelligence in AAC does not yet appear entirely mature. Firstly, most of the studies reported in this review are still at a prototypical stage, and many innovations are not yet ready for integration into daily life. Furthermore, there is a degree of fragmentation among the proposed solutions, often with overlapping functionalities, and no mention of open-source releases. Unlike machine learning

algorithms, whose classification performance is well-established, the use of large language models in this review is not only rarer but also less mature when employed for content generation. For example, Draffan et al. (2023) found largely unacceptable results in symbol generation unless the symbol represented a very simple object and replicated a specific and consistent style. However, the rapid evolution of this technology is outlining promising scenarios for future advancements.

Nonetheless, numerous mobile technologies were identified in the review, and this aligns with many other studies (Farzana et al., 2021; González-González et al., 2024; Moffatt et al., 2015; de Oliveira Schultz Ascari et al., 2018a) that have highlighted a growing trend of use in recent years due to their ease of use (Moraiti et al., 2023), improvement of communication skills (Alzrayer and Banda, 2017), and the provision of interaction opportunities with caregivers and other key individuals in the individual with complex communication needs support network (Vlachou and Drigas, 2017). This latter aspect also emerged in the present review (Carniel et al., 2019; Liu et al., 2020; Costanzo et al., 2023; Costanzo et al., 2023; Kitukale et al., 2025; Radici et al., 2023; Zisman et al., 2024), where caregiver involvement in technology use was found to be fundamental to ensure that AAC systems are appropriately selected, used, and integrated into users' daily lives, consistent, for example, with findings by Uthoff et al. (2021).

Only two study (Curtis et al., 2024; Zilak et al., 2018) classified as an immersive technology was identified in the review. As stated by the study's author, the potential of these technologies is recognized but has not been fully exploited for AAC. This finding contrasts with a general trend showing positive uptake of these technologies, for example, in education (Avila-Garzon et al., 2021; Karakus et al., 2019; Soto et al., 2019), but is consistent with the assessment by Jesionkowska et al. (2020), according to whom augmented reality might not be an educational tool capable of reaching disadvantaged individuals, those at risk of exclusion, or those with special educational needs. Moreover, immersive technologies can be very costly (van Dinther et al., 2023; Koparan et al., 2023; Voštinár and Ferienc, 2023), cause visual fatigue (Hmoud et al., 2023), or require a very high level of technical skill for their use (Cetintav and Yilmaz, 2023).

5.1 Facilitators and barriers from a biopsychosocial perspective

The thematic analysis of the articles, conducted following the ICF theoretical framework, consistently with the review's aim, showed a prevalence of themes related to the environmental factors domain. Technology, being an external element to the person, can both positively influence an individual's functioning and hinder it. In this sense, aspects such as technology design, the socio-economic and cultural context, and the quality of support from reference persons can become crucial.

The most frequently cited barrier is the lack of alignment between technology and user abilities. Despite recent technology, especially artificial intelligence-based solutions, achieving very high technical performance, technologies can still struggle to fully align with the variability of human beings, whose cognitive, sensory, and motor performances can be highly diversified, inconsistent over time, and constantly changing (Ayoka et al., 2024; Mulfari et al., 2022). The

contrast between performance achieved in research settings and use in real-world contexts is a topic that scientific debate must certainly address.

In response to this challenge, the theme of customization and adaptability emerged from the thematic analysis. Recent years have witnessed a paradigm shift: while in the past, as highlighted by Baxter et al. (2012), efforts focused on removing barriers to technology use by reducing device programming complexity and facilitating interface personalization and vocabulary adaptation, some modern systems propose functionalities that progressively and dynamically adapt to a subject's changing symptomatic profile (Sánchez-Álvarez et al., 2024) or their communicative style (Zisman et al., 2024). While it can be a barrier if the process is unintuitive or time-consuming (de Oliveira Schultz Ascari et al., 2023; Radici et al., 2023), it primarily acts as a facilitator, enabling better adaptation to the user's specific motor, linguistic, and pictographic needs (Atyabi et al., 2023; Draffan et al., 2023; de Oliveira Schultz Ascari et al., 2023). Modern solutions are also more technically flexible, for instance through the utilization of application programming interfaces which facilitate connections between different applications, reducing workload and enhancing integration (Hervás et al., 2024; Li et al., 2022).

Another crucial element is the support from caregivers and reference persons. The analysis reveals that technology cannot be isolated from its context; instead, it needs to be integrated into a network where reference persons can play an educational role, contribute to system configuration, and provide guidance and monitoring that can support the subjects' autonomy. A good practice would, therefore, be to consider caregivers and therapists not as secondary to the individual with complex communication needs, but rather as fundamental components of the process that can positively influence the adoption of the technology itself, as recently highlighted by De Leon et al. (2024).

Finally, concerning accessibility and inclusion, conflicting data are observed. On one hand, solutions designed to be economically sustainable (e.g., Athuljith et al., 2023; Atyabi et al., 2023; Prete et al., 2025), portable (Liegel et al., 2019), easy to use and program (Radici et al., 2023), and attentive to linguistic and cultural diversity (Samonte et al., 2020) are emerging. On the other hand, the necessity of possessing specific hardware or a high-performance device (Ayoka et al., 2024; Sweidan et al., 2025), an internet connection (Mukherjee et al., 2024), or the presence of intrinsic configuration difficulties or concerns about malfunctions (Atyabi et al., 2023), can accentuate barriers that exacerbate a new form of technological exclusion within the community of individuals with communication disorders and underscores the need to consider user diversity and involve users directly in the development process (Carniel et al., 2019).

In general, continuous monitoring of the technology-user match is essential. As powerfully stated by Jin (2025), an AAC user, "similar to regular health checkups, periodic reassessments of AAC setups are vital to ensure they meet our changing requirements. Through advocacy and having an open dialogue with researchers, manufacturers, and clinicians, we can enhance inclusivity and accessibility for all AAC users" (p. 2).

5.2 The state of evidence

While a quantitative evaluation of the impact of the technologies included in this review on communicative processes falls outside its

scope, we believe it is important to highlight a significant gap in data that could demonstrate how and to what extent technological innovation can support communication difficulties. Generally, many technological solutions remain at a prototypical stage, developed in research settings with limited testing in real-world contexts with end-users. Rigorous trials in the AAC field are understandably challenging to conduct, largely due to difficulties with recruitment and study implementation involving this specific population. As a result, the research landscape often features small sample sizes (de Lima Antão et al., 2018) and numerous single-case studies (Crowe et al., 2022). This prevalence of smaller-scale designs significantly limits the generation of robust empirical evidence. In fact, it is crucial that high-tech AAC interventions incorporate evidence-based practices (Lorah et al., 2024) and that specific attention be paid to the generalizability of findings (Peng et al., 2021).

5.3 Critical perspectives and ethical challenges

Technologies can open up positive scenarios in the field of AAC because they can significantly increase communication and participation opportunities for individuals with CCN. However, they are not a panacea. This work has highlighted some fundamental barriers, but a series of key ethical aspects must also be considered when using these technologies with disabled individuals (Lillywhite and Wolbring, 2019; Perry et al., 2009).

First, the data collection by these systems presents privacy risks. More advanced systems, for example those with cloud architectures, can raise concerns about how data is stored, who has access, and the potential for breaches or misuse (Klein et al., 2022; Wangmo et al., 2019). This is particularly sensitive given that the target population consists of vulnerable individuals (Perry et al., 2009). The potential of artificial intelligence and its emerging ethical challenges has been highlighted also by a recent review by Collazos et al. (2022).

A further issue is related to the long-term sustainability of cloud-dependent systems, for example, if services were to be disrupted or discontinued. Another source of concern is informed consent, as some types of individuals may not be able to understand how their data will be processed and for what purposes. In general, therefore, the use of technologies to support AAC, especially the more advanced ones, merits a thorough reflection on the ethical repercussions it can raise (Olawade et al., 2024).

6 Limitations

Although the scoping review thoroughly searched four databases (PubMed, Scopus, Web of Science, and IEEE), it is possible that some relevant articles were missed. The search query might not have adequately captured the research questions, or the authors may have erroneously excluded eligible articles during the initial screening phase, thereby introducing selection bias.

Furthermore, the research scope might not fully encompass the issues surrounding the use of modern technologies in assistance towards complex communication needs, thereby unknowingly

omitting vital information pertaining to successful integration of such tools in realistic scenarios of meaningful application.

Moreover, the authors were unable to independently verify validity and accuracy of data reported in this study. Therefore, research with considerable methodological flaws may have been incorporated in this review.

7 Conclusion

This scoping review provides evidence of a renewed enthusiasm among the research community for the use of artificial intelligence, which excels at categorization tasks and adapting to user inputs. However, there remain areas for improvement, such as content generation and addressing associated ethical concerns. Meanwhile, interest in mobile technologies remains relatively constant.

Despite recent significant advancements, new technologies still face issues that deter widespread adoption. For example, device costs can be excessive, software may be difficult to use, programming complex, and there can be a need for repeated support from caregivers and therapists. Moreover, a lack of alignment between technology and users' complex motor and cognitive abilities is still somewhat present, alongside a degree of fragmentation among existing solutions based on functionalities and disorders.

Finally, there is a clear weakness in the existing body of research. Studies often do not employ rigorous, evidence-based design principles with the potential to quantitatively account for the impact of implementing these technologies in people's lives.

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Supplementary material

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