Embodying Conversational Agents in Paediatric Speech Therapy: A systematic review

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Abstract

Language disorders in pediatric age affect not only linguistics, but also socio-educational dimensions. Despite its importance and advancements in using digital interventions to support speech therapy rehabilitation in its repetitive activities, there has been a knowledge gap in the systematization of the characteristics of Embodied Conversational Agents (ECAs) that make rehabilitation sessions more enjoyable and engaging for children. A systematic literature review was, therefore, conducted across PubMed, Scopus and ACM Digital Library for papers published between 2010 and 2026, following the PRISMA 2020 guidelines. A total of 200 records were identified, with 24 studies meeting the inclusion criteria. This review addresses three research questions addressing three research questions: (RQ1) which language and communication disorders are primarily addressed; (RQ2) what embodiment configurations are adopted; and (RQ3) whether ECAs improve clinical outcomes compared to standard care. The analysis reveals a limited but increasing number of studies, suggesting that ECAs are an emerging tool not yet widely adopted in clinical practice, predominantly used in speech therapy for language rehabilitation, but also applicable to social skills development. Physically embodied ECAs appear predominant, with a distinction between custom-developed systems and commercially available platforms; in both cases, a non-threatening, toy-like appearance prevails. However, longitudinal evidence is lacking on whether ECAs, whose multimodal communicative repertoire, encompassing verbal, prosodic, gestural, and facial channels, fosters a sense of social presence that approximates human interaction, can sustain a therapeutic relationship with pediatric users that supports clinical goals and maintains engagement across repeated sessions.

CCS Concepts

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **HCI design and evaluation methods**;

Keywords

ECAs, Speech Therapy, Children, Review



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1 Introduction

Traditional speech-language therapy is structured around in-person rehabilitation sessions, during which the professional stimulates language production and provides targeted corrective feedback, with the aim of reducing or resolving the patient's communicative disorder [20]. Speech, Language and Communication Disorders (SLCD) constitute a heterogeneous set of conditions affecting speech, language, voice quality or swallowing. It is estimated that these affects approximately 1% of the world's population and 8% of children between the ages of 3 and 17 are affected [2]. Among the most common conditions in childhood are fluency disorders such as stuttering, phonological and articulatory disorders, language delays, social communication disorders, and difficulties associated with neurodevelopmental conditions such as Autism Spectrum Disorder (ASD) and dyslexia.

Early intervention in treating these disorders is very important, as these not only affect communication but also have repercussions on children's ability to understand and convey information, interact with others, and on difficulties in school learning, with a great impact on the child's overall development [26]. For this reason, a structured rehabilitation programme in diagnosis is necessary despite the following factors can limit its impact in clinical practice [27]: the low frequency of individual sessions; the repetitiveness and monotony of the proposed exercises; and the growing number of patients that professionals are required to manage. For therapy to be effective, rehabilitation exercises must be continuous and repeated beyond the clinical setting as well, becoming integrated into the child's daily life (at home or at school) between sessions with the specialist. To encourage adherence to treatment, the tools employed must be appropriate to the age and specific needs of paediatric patients, transforming the rehabilitation experience into a motivating and engaging context.

Indeed, assistive technologies provide an opportunity to complement and enhance traditional clinical practice. A wide range of solutions can be employed in digital rehabilitation, including home-based settings, such as: sensors, wearable or environmental

tools useful for monitoring physiological parameters and movement; robotic devices such as gloves and exoskeletons for motor support; gamification through serious games to improve patient adherence and motivation; virtual and augmented reality (VR/AR) for immersive therapeutic simulations; artificial intelligence and machine learning for the personalisation of care pathway; the Internet of Things (IoT) for the development of smart homes; and brain-computer interfaces (BCI) to assist with complex movements [1].

Among the available technologies, Embodied Conversational Agents (ECAs) have opened new perspectives in the field of paediatric rehabilitation, and their introduction could have a positive impact on the rehabilitation process, making sessions more enjoyable and engaging for children [38]. ECAs are artificial systems endowed with a bodily representation, physical or virtual, designed to sustain conversational interactions with the user through autonomously generated verbal and non-verbal behaviours. Unlike simple text-based chatbots, ECAs simultaneously integrate multiple communicative channels: these produce and recognise vocal input, manage turn-taking, generate facial expressions and gestures, and provide contingent feedback to the interlocutor [6]. These characteristics confer upon the agent a sense of presence that tends, in the user's perception, to bring it closer to a human interlocutor, thereby stimulating the patient's active participation in the clinical setting [25].

From the standpoint of embodiment modality, ECAs are distinguished into three main categories: disembodied agents (i.e., exclusively vocal or textual systems), on-screen virtual conversational agents, and social assistive robots. The embodied representation can take various forms: bio-inspired (human, humanoid, animal or plant-based), functional when it reflects the task performed by the agent, as in the case of animated objects, or artificial when it displays components of a mechanical nature [7].The development of these systems in the paediatric context requires a particularly careful design process, one that considers the specific needs of children and provides adequate training for the staff who will use them, so that they may genuinely support clinical work [11].

Weightman et al. (2010) hold the view that involving children in the co-design process is more complex than with adults: children have greater difficulty verbalising their thoughts, a more limited attention span, and participatory methodologies must contend with the traditional power asymmetry between adults and minors. The use of ECAs in the specific field of paediatric speech-language rehabilitation remains an area that has yet to be explored in a systematic manner. Existing reviews have examined the use of ECAs in rehabilitation broadly conceived or have focused on specific populations such as children with autism spectrum disorder, chronic illnesses, or eHealth in general, without offering an organically structured synthesis centred on language and communication disorders in childhood [17, 32; 41]. The present review therefore aims to fill this gap by identifying, selecting and synthesising studies that evaluate their effectiveness, with particular attention to the design characteristics of these systems, to summarise how these might meet the needs of children and inspire researchers in the development of new devices. Through the PICO framework, the review intends to address the following research questions:

RQ1: What types of language and communication disorders are primarily addressed with ECA support in the paediatric population? RQ2: What are the embodiments of ECAs used as therapeutic interventions to interact with patients in this field?; and RQ3: Does the use of ECAs improve clinical outcomes comparing interventions or standard care?

2 Methodology

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, a well-established approach that ensures methodological rigour, reproducibility, and transparency in data reporting [31]. To structure the research question, the PICO framework was adopted, given it is used in the healthcare field to break down complex clinical scenarios into research questions. It articulated in the following components: Problem/Population, describing the condition of interest and the target group; Intervention, referring to the treatment, assessment tool, or condition under study; Context, specifying the setting or environment in which the intervention takes place; and Outcome, indicating the measurable results expected from the intervention [4].

2.1 Eligibility criteria

Studies included in the review had to meet specific inclusion and exclusion criteria, defined on the basis of the PICO framework. Regarding the Population, only studies involving children and adolescents aged 0 to 18 years old with language, speech, or communication disorders were included. Studies focusing exclusively on adult or older adult populations, with no paediatric component, were excluded. Regarding the Intervention, studies were considered eligible if these involved the use of an Embodied Conversational Agent (ECA) or social robots capable of interacting autonomously, through a physical or virtual embodiment, which t were not avatars intended as direct projections of a player or human operator. Studies using non-conversational technologies were excluded, such as applications or games without an agent, software lacking an ECA, Internet of Things (IoT) or smart objects without a conversational component, databases and data collections, works focused exclusively on algorithmic implementation, video game avatars directly controlled by the user and lacking autonomy, as well as systems based solely on voice without any form of embodiment. The intervention had to be described in sufficient detail to allow the extraction of the system's technological and design characteristics. ECAs employed in non-therapeutic contexts, such as for educational or school purposes, were also excluded. Regarding the Outcomes, studies focusing on non-communicative conditions, such as diabetes or obesity, were excluded. In addition, primary empirical studies were included: Randomised Controlled Trials (RCTs), quasi-experimental studies, case studies, pilot studies, and usability studies. The accepted language is English. To avoid including excessively outdated technologies not representative of ECAs in their current form, articles published before 2010 were excluded. Furthermore, all non-primary data sources were excluded, including meta-analyses, editorials, opinion papers, study protocols, conference proceedings and proceedings collections, as well

Table 1: String and filters of the research

String	(child* OR pediatric* OR paediatric* OR preschool* OR ”pre-school*” OR adolescen* OR toddler* OR infant* OR youth OR ”school-age” OR ”school age” OR ”young people”) AND (”conversational agent*” OR ”embodied conversational agent*” OR chatbot* OR avatar* OR ”dialog* system*” OR ”virtual assistant*” OR ”virtual nurse*” OR ”virtual patient*” OR ”virtual coach*” OR ”intelligent assistant*” OR ”relational agent*” OR ”assistive technolog*” OR ”assistance technolog*” OR ”voice-based interface*” OR ”voice assistant*” OR ”social robot*” OR ”dialogue system*” OR ”intelligent tutoring system*” OR ”speech recognition software” OR ”voice recognition software” OR ”automatic speech recognition” OR ”natural language processing” OR robot* OR ”digital therap*” OR ”digital intervention*”) AND (”speech therapy” OR ”language therapy” OR ”speech-language patholog*” OR ”speech rehabilitation” OR ”language rehabilitation” OR ”language intervention” OR ”speech intervention” OR ”speech-language therapy” OR ”communication therapy” OR ”communication intervention”).
Filter	Title/abstract
Time range	2010-2026

as articles for which the full text was unavailable or that existed only as abstracts or posters.

2.2 Search methods

The bibliographic search was conducted on 16 March 2026 across three databases: PubMed, for include adequate representation of clinical and speech-language pathology research, which is systematically underrepresented in HCI-focused repositories; ACM Digital Library, which indexes the proceedings of CHI, ASSETS, and related HCI venues, to capture contributions on human-computer interaction, design, and usability; and Scopus, which additionally covers RO-MAN and HRI conference proceedings within its multidisciplinary scope, to ensure broad interdisciplinary coverage. The search string was constructed by combining three main thematic areas: terms related to the population (children, adolescents, pediatric age), terms related to the technology, drawing on the definition adopted by de Corck et al. (2020) in another systematic review on ECAs and terms related to the type of intervention (speech and language therapy). The string was applied to titles and abstracts, with a time filter ranging from 2010 to 2026 (cf.Table 1).

2.3 Study selection and Data Collection

The selection process was articulated in four phases, as illustrated in the PRISMA diagram. The process began with the identification of relevant articles across multiple databases. Duplicate records were then removed, and the remaining articles proceeded to a screening phase, during which titles and abstracts were carefully reviewed. Any records deemed irrelevant according to the predefined inclusion criteria were excluded at this stage. The articles that passed screening then moved on to a full eligibility assessment, where these were read in their entirety (see Figure 1). Only those meeting all inclusion and exclusion criteria and directly relevant to the aims of the review were ultimately selected and included in the final sample.

In the identification phase, 200 articles were retrieved, of which 43 were removed as duplicates. In the screening phase, the remaining 157 articles were evaluated on the basis of title and abstract, with 84 excluded for not meeting the inclusion criteria. In the eligibility phase, the remaining 73 articles underwent full-text reading. At the end of this assessment, 24 studies were deemed eligible and included in the systematic review, as shown in Table 2. A detailed analysis of the included studies, structured according to the PICO framework, is provided in Appendix A.

3 Discussion

In response to the research question RQ1: What types of language and communication disorders are primarily addressed with ECA support in the paediatric population?, the findings emerging from the present systematic review highlight how ECA-based technologies find application across a broad and heterogeneous spectrum of clinical conditions in the paediatric population. For instance, Table 3 shows that the most represented category is language disorder in a broad sense, accounting for 28% of the included studies (n=7), followed by autism spectrum disorder, which represents the most frequently addressed specific condition, representing 20% of cases (n=5). This latter finding is consistent with what has already been documented in the literature: children with autism spectrum disorder may particularly benefit from interaction with technological agents, which do not elicit the anxiety response typically associated with social interaction with human figures [5]. Among the specific conditions addressed, dyslalia (n=2) and disorders arising from organic deficits, such as hearing impairment (n=2) and cleft lip and palate (n=1) are also represented. When considering the distinction between studies adopting a broad diagnostic perspective, encompassing heterogeneous populations such as children with general disabilities (n=3), learning disabilities (n=1), language disorders (n=7), multiple disorders with complex communication and sensory needs (n=1), hearing impairment (n=2), these collectively accounted for 58% of the total studies. By contrast, studies focused

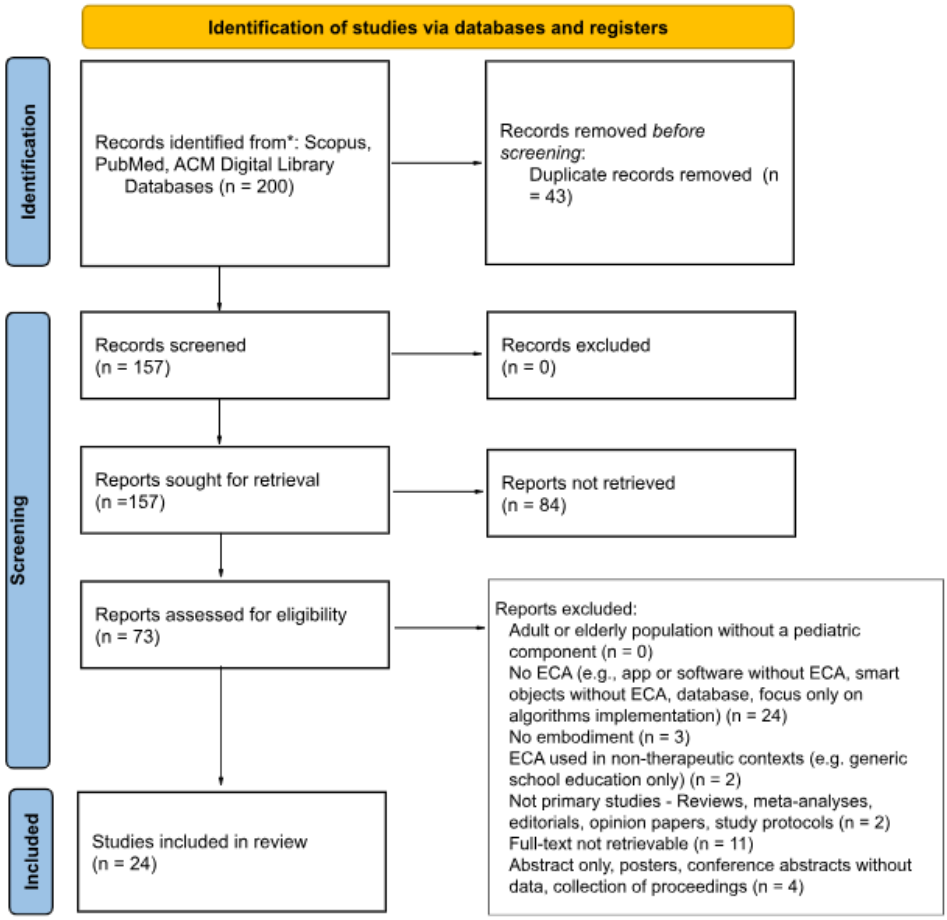


Figure 1: PRISMA flow diagram

on specific conditions, such as autism spectrum disorder (n=5), dyslalia (n=2), and cleft lip and palate (n=1), constituting 32% of the analysed corpus. With regard to therapeutic objectives, it emerges transversally that interventions target two main dimensions: language and social skills. Language skills refer to the abstract knowledge of grammatical, syntactic, lexical, phonological rules and the functional use of language in context, encompassing the ability to convey and interpret meaning effectively. Social skills refer to the broader interpersonal competencies involved in interaction, such as turn-taking, the management of conversational pragmatics, and adaptive behaviour in social exchanges. ECAs in the field of speech and language rehabilitation are primarily used to improve language skills only (n=15) 62.5%, but also language and social skills combined (n=7) 29.2%, and educational purposes (n=1) 4.2%. ECAs targeting both language and social skills are predominantly used with a population of children with Autism Spectrum Disorder (n=5 out of 7), followed by children with learning disabilities and disabilities in general (n=2), and in only one instance for language disorders [37], specifically to expand emotional vocabulary.

Regarding the embodiment of ECAs (RQ2: What are the embodiments of ECAs used as therapeutic interventions to interact with patients in this field?), the studies analyzed are divided between those that developed custom solutions for the project (37.5%, n=9) and those that adopted platforms already available on the market (58.3%, n=14), while one study does not specify the robot used.

This distribution reflects two distinct design orientations, each with relevant methodological implications. Commercial systems including: NAO (n=6), QT Robot (n=2), iRobiQ (n=2), Pepper, RASA, Kaspar, and Pleo, were selected primarily for their immediate availability, well-established technical documentation, and the reproducibility they afford across studies. For instance, the prevalence of NAO suggests that platform selection is often driven by accessibility and familiarity within the research community, rather than by a systematic match between the robot's characteristics and the needs of the target population. A notable exception, however, is Kaspar, designed specifically for interaction with children with ASD through its intentionally reduced expressivity, inspired by the Japanese Noh theatre mask, which limits the cognitive load associated with decoding facial emotions.

Table 2: Records included in the review

Authors	Title	Publication year
Boccanfuso L. et al.	A low-cost SAR and robot-assisted intervention for children with ASD	2017
Di Cara M. et al.	Enhancing Communication in Minimally Verbal Autistic Children: A Study on NAO-Assisted Therapy	2025
Egido-García V. et al.	Integration of a social robot in a pedagogical and logopedic intervention with children: a case study	2020
Esfandbod A. et al.	Utilizing an emotional robot capable of lip-syncing in robot-assisted speech therapy sessions for children with language disorders.	2023
Estévez D. et al.	A case study of a robot-assisted speech therapy for children with language disorders	2021
Ioannou A., Andreva A.	Play and learn with an intelligent robot: Enhancing therapy of hearing-impaired children	2019
Jeong M. et al.	Lexical representation of emotions for high functioning autism (HFA) via emotional story intervention using smart media	2015
Kim E.S. et al.	Social robots as embedded reinforcers of social behavior in children with autism	2013
Lakatos G. et al.	A feasibility study of using Kaspar, a humanoid robot for speech and language therapy for children with learning disabilities	2022
Lee H., Hyun E.	The intelligent robot contents for children with speech-language disorder	2015
Lekova A. et al.	Toward robot-assisted psychosocial techniques for sound stimulation of children born with hearing loss	2021
Lekova A. et al.	A system for speech and language therapy with a potential to work in the IoT	2022
Ochoa-Guaraca M. et al.	A robotic assistant to support the development of communication skills of children with disabilities	2016
Oliva D. et al.	Designing socially assistive robots for clinical practice: insights from an asynchronous remote community of speech-language pathologists	2025
Origlia A. et al.	Evaluating a multi-avatar game for speech therapy applications	2018
Ramamurthy P., Li T.	Buddy: a speech therapy robot companion for children with cleft lip and palate (cl/p) disorder	2018
Robles-Bykbaev V. et al.	SPELTRA: a robotic assistant for speech-and-language therapy	2015
Robles-Bykbaev V. et al.	RAMSES: a robotic assistant and a mobile support environment for speech and language therapy	2015
Robles-Bykbaev V. et al.	Robotic assistant for support in speech therapy for children with cerebral palsy	2016
Shin S. et al.	How Co-design and Personas can Inform Game Implementation for Robot-assisted Speech Therapy in Clinical Settings	2025
Spitale M. et al.	Design patterns of technology-based therapeutic activities for children with language impairments: a psycholinguistic-driven approach	2021
Spitale M. et al.	Using socially assistive robots in speech-language therapy for children with language impairments	2023
Tenesaca-Tenezaca Ó. et al.	FonAPP: An interactive application for the therapeutic intervention of children with dyslalia from embedded devices and robotic assistants	2021
Velásquez-Angamarca V. et al.	Robotic assistants for the rehabilitation of communication disorders in children: A proposal based on MTO manufacturing for developing countries	2024

Custom-developed systems, while heterogeneous in their technical implementation, are united by a shared design rationale: reducing costs to make therapeutic technology economically accessible, while maintaining the functional and aesthetic requirements demanded by paediatric clinical contexts. This orientation toward low-cost, accessible solutions shapes several recurring technical choices. A number of systems leverage Android smartphones or tablets as both facial interface and central processor, enabling dynamic expressive animations at minimal hardware cost, a strategy adopted by SPELTRA [34, 35] and Buddy [33]. Similarly, 3D printing is employed to produce the robot body at low cost while retaining the possibility of customization, as in FONA [40, 42]. Beyond cost considerations, custom systems also allow for targeted functional extensions tailored to specific therapeutic needs. RAMSES [34], for instance, integrates hand gesture recognition via a coloured

Table 3: Population and Problem of the records

Authors	Popolation	Problem
Boccanfuso L. et al. (2017)	Autistic Spectrum Disorders (ASD)	Language and social skills
Di Cara M. et al. (2025)	Autistic Spectrum Disorders (ASD)	Language and social skills
Egido-García V. et al.(2020)	Autistic Spectrum Disorders (ASD)	Language and educational
Esfandbod A. et al. (2023)	Language disorders	Language
Estévez D. et al. (2021)	Language and learning disorders	Language
Ioannou A., Andreva A. (2019)	Hearing impaired	Language
Jeong M. et al. (2015)	Autistic Spectrum Disorders (ASD)	Language and social skills
Kim E.S. et al. (2013)	Autistic Spectrum Disorders (ASD)	Language and social skills
Lakatos G. et al.(2022)	Learning disabilities	Language and social skills
Lee H., Hyun E.(2015)	Language disorders	Language
Lekova A. et al. (2021)	Hearing impaired	Language
Lekova A. et al. (2022)	Language disorders	Language
Ochoa-Guaraca M. et al. (2016)	Children with disabilities	Language
Oliva D. et al. (2025)	Multiple pediatric disorders including complex communication and sensory needs	Informed design requirements for Social Assistive Robots
Origlia A. et al. (2018)	Language disorders	Language
Ramamurthy P., Li T. (2018)	Cleft lip and palate disorder	Language
Robles-Bykbaev V. et al. (2015)	Children with disabilities	Language
Robles-Bykbaev V. et al. (2015)	Children with disabilities	Language
Robles-Bykbaev V. et al. (2016)	Children with disabilities	Language and social skills
Shin S. et al. (2025)	Language disorders	Language and social skills
Spitale M. et al. (2021)	Language disorders	Language
Spitale M. et al. (2023)	Language disorders	Language
Tenesaca-Tenezaca Ó. et al. (2021)	Dyslalia	Language
Velásquez-Angamarca V. et al. (2024)	Dyslalia	Language

glove and personalization extends further to the robot's appearance through interchangeable costume systems, adapted to the child's preferences or diagnostic profile. Furthermore, Spitale M. et al. (2021) proposes a design framework based on levels of abstraction that allows the same therapeutic activities to be deployed across different platforms: tablet, robot, or combined modality, regardless of the specific ECA used. Finally, Oliva D. et al. (2025) defines the characteristics that ECAs should possess to be clinically effective, identifying as fundamental requirements: multimodal communication, personalization based on the patient's capabilities, adaptability in following the therapeutic flow, and longitudinal data tracking.

Lastly, the analysis of the collected data suggests that the use of ECAs produces favourable clinical outcomes compared to control conditions, whether traditional therapy or therapy conducted without robotic support (RQ3: Does the use of ECAs improve clinical outcomes comparing interventions or standard care?). Several studies report statistically relevant or clinically significant improvements in domains such as spontaneous verbal production [42], social interaction and joint attention [3], syntactic construction and vocalization [12, 14], as well as overall language comprehension and production [10, 19, 34]. Notably, the latter author highlights the superiority of the robot over conventional therapy in the phonological and morphosyntactic domains, with equivalent performance at the semantic level. Additional recurring benefits include increased motivation, attention, and self-esteem among participants, at times accompanied by skill generalization [18, 21]. However, the interpretation of these findings warrants caution: some studies present significant methodological limitations, including the absence of a clinical control group [28], the lack of measurement of primary clinical outcomes [22, 29], or inconclusive results [38]. Overall, the available evidence points to a promising therapeutic potential of ECAs, but underscores the need for randomized controlled trials with larger samples to consolidate these findings and more precisely determine for which populations and communicative domains ECA-mediated intervention demonstrates to be the most effective.

Table 4: Population and Problem of the records

Authors	Eca characteristics
Boccanfuso L. et al. (2017)	Custom
Di Cara M. et al. (2025)	NAO (SoftBank Robotics)
Egido-García V. et al.(2020)	NAO (SoftBank Robotics)
Esfandbod A. et al. (2023)	RASA (CEDRA, Sharif University)
Estévez D. et al. (2021)	NAO (SoftBank Robotics)
Ioannou A., Andreva A. (2019)	NAO (SoftBank Robotics)
Jeong M. et al. (2015)	iRobiQ (Yujin Robot)
Kim E.S. et al. (2013)	Pleo (Ugobe)
Lakatos G. et al.(2022)	Kaspar (University of Hertfordshire)
Lee H., Hyun E.(2015)	iRobiQ (Yujin Robot)
Lekova A. et al. (2021)	Pepper (SoftBank)
Lekova A. et al. (2022)	NAO + EmoSan (IoT multi-device)
Ochoa-Guaraca M. et al. (2016)	Custom
Oliva D. et al. (2025)	SAR (design study, no specific robot)
Origlia A. et al. (2018)	NAO + 3D avatar (Ellie)
Ramamurthy P., Li T. (2018)	Custom
Robles-Bykbaev V. et al. (2015)	Custom
Robles-Bykbaev V. et al. (2015)	Custom
Robles-Bykbaev V. et al. (2016)	Custom
Shin S. et al. (2025)	QT Robot (LuxAI)
Spitale M. et al. (2021)	Custom
Spitale M. et al. (2023)	QT Robot (LuxAI)
Tenesaca-Tenezaca Ó. et al. (2021)	Custom
Velásquez-Angamarca V. et al. (2024)	Custom

4 Conclusion

Paediatric language disorders represent a significant clinical challenge, structurally characterized by a therapeutic demand that exceeds available resources: the recommended intervention frequency rarely matches what is actually delivered, and the transfer of skills acquired in session to everyday life remains an unresolved problem. It is within this context that the present review situates itself, systematically examining the use of ECAs as support tools in paediatric speech-language therapy.

The present literature review analysed the target population, the issue addressed, the type of intervention, the embodiment characteristics of the ECAs used, and the clinical outcomes reported. The limited number of eligible studies (24 out of 200 records), which also includes early-stage projects, prototypes reporting no clinical outcomes, and single-case studies whose findings cannot be generalized, reflects the early-stage nature of ECA integration in paediatric speech therapy, suggesting that their use remains largely confined to experimental or research settings rather than established clinical practice.

The fact that 69% of the included studies (n=17) were published after 2020 further supports the notion that this is an emerging field, though the extent to which these findings can be generalised to broader clinical contexts remains to be determined.

The analysis revealed that the most represented category is that of language disorders, followed by autism spectrum disorder, which constitutes the most frequently treated specific condition. ECAs in the field of language rehabilitation are primarily used to improve linguistic skills alone, but in some cases also for a combined enhancement of linguistic and social abilities, the second approach is predominantly associated with populations with autism spectrum disorder.

Regarding embodiment, the studies analysed are divided between solutions developed specifically for the project and platforms already available on the market, the latter offering immediate availability, well-established technical documentation, and reproducibility across studies. Custom systems, although heterogeneous in the solutions proposed, share some recurring principles: reducing costs to make therapeutic technology economically accessible, a playful appearance and a physicality that considers the safety of the children with whom they will interact. Notwithstanding the predominance of physical embodiment across the included studies, the question of embodiment, physical versus virtual, remains open. Although based on preliminary findings, Spitale et al. (2023) directly compare physical and virtual SAR and identify differences in perceived engagement but not in linguistic performance, suggesting that the agent's form is not necessarily a determining factor for intervention efficacy. This finding is particularly relevant for the design of scalable and economically sustainable systems.

Ultimately, this review does not merely register a growing interest in ECAs within paediatric rehabilitation but aims to identify the conditions under which such interest can translate into effective support for clinical practice. Future research is called to address still open questions: at which stage of the therapeutic pathway and

Table 5: Comparison and outcome of the records

Authors	Comparison	Outcome
Boccanfuso L. et al. (2017)	Traditional therapy	Significant improvements in spontaneous utterances, social interaction, joint attention and requesting behaviors while overall communication scores, vocabulary and motor imitation did not reveal statistically significant increases
Di Cara M. et al. (2025)	Traditional therapy	Significant verbal improvement
Egido-García V. et al.(2020)	Therapy without robot	Improved vocalization, sentence construction and self-confidence
Esfandbod A. et al. (2023)	Robot without facial expression recognition/lip-syncing	Improved child-robot interaction quality with emotional and lip-sync features
Estévez D. et al. (2021)	Therapy without robot	Therapy with robot improved articulation, sentence structure, motivation, self-esteem and emotional bond formed between robot and patient
Ioannou A., Andreva A. (2019)	Therapy without robot	Improvement in sound response and instruction following
Jeong M. et al. (2015)	Traditional therapy	Robot intervention were effective at increasing the number and diversity of emotional words used by children
Kim E.S. et al. (2013)	Crossover study	Increased overall verbal output during robot interaction, with a successful generalization of social speech toward human adults
Lakatos G. et al.(2022)	Therapy without robot	Improvement in language production and comprehension
Lee H., Hyun E.(2015)	Therapy without robot	Increased social interactions and linguistic expressions
Lekova A. et al. (2021)	Traditional therapy	Positive evaluation from expert
Lekova A. et al. (2022)	Traditional therapy	Protocol technically implemented, clinical study pending
Ochoa-Guaraca M. et al. (2016)	Traditional therapy	Positive (no clinical control)
Oliva D. et al. (2025)	Traditional therapy	No clinical outcomes measured (design recommendations only)
Origlia A. et al. (2018)	Traditional AX test	>70% attention to system comparable to standard tests, emerge the potential beneficial effects on performance
Ramamurthy P., Li T. (2018)	Earlier prototype	Positive reactions, social engagement, interactive feedback appreciated
Robles-Bykbaev V. et al. (2015)	Implicit(pre-post relaxation time)	Relaxation time from 40 to 25 min, highest engagement in ADHD/Down, lower in severe ASD
Robles-Bykbaev V. et al. (2015)	Traditional therapy	The Likert-scale engagement assessment, not a clinical outcome measure, provides useful data on differential engagement across diagnostic groups
Robles-Bykbaev V. et al. (2016)	Traditional therapy	Robot superior in phonological and morphosyntax, similar output in semantics
Shin S. et al. (2025)	Traditional therapy	Positive (prototype stage)
Spitale M. et al. (2021)	Tablet vs. tablet+robot	Inconclusive
Spitale M. et al. (2023)	Physical vs. virtual SAR	Linguistic skill improvement in both conditions, greater engagement and speech occurrences with physical robot; therapists skeptical but acknowledged physical SAR benefits for child motivation and engagement
Tenesaca-Tenezaca Ó. et al. (2021)	Traditional therapy	Correct phoneme /r/ articulation achieved and increased motivation
Velásquez-Angamarca V. et al. (2024)	Traditional therapy	Faster phoneme learning, use more words, +17 min attention span

with which design configuration ECAs prove most effective; questions that require controlled experimental designs and longitudinal studies on clearly defined populations, with measurable and shared outcome measures.

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A APPENDICES

Table 6: PICO

Authors	Population	Intervention	Comparison	Outcome
Boccanfuso L. et al. (2017)	Autistic Spectrum Disorders (ASD). 8 children between 3-6 years of age.	Custom toy-like robot prototype. Pre- and post-intervention measures: VABS-II, MLSUD, MIS, UIA, EVT-2. 12 × 30-min sessions	Traditional therapy	VABS-II Communication: +9,84% within; between (r=0,57); Socialization+18–31%; trend between (r=0,51–0,56). MLSUD +35,3% e UIA +57–140% ; EVT2 n.s.
Di Cara M. et al. (2025)	Autistic Spectrum Disorders (ASD). 37 children 4-12 years old.	NAO robot. Single-blind, randomized, controlled study. 12 weekly 45-min sessions	Traditional therapy	TVL (12 subscale): NAO group: +159% more children improved compared to the control group (range 107–284%); p<0.001.Mand requests: increase over the 12 sessions: from 6.8 to 16.7 mands/session (p<0.001).
Egido-García V. et al.(2020)	Autistic Spectrum Disorders (ASD). 5 children between 1-10 years old.	NAO robot. Qualitative exploratory case study approach. 30 × 30 min sessions	Therapy without robot	Qualitative (therapist interviews, diaries, video): Improved sentence construction, voice volume, sustained attention, and willingness to engage; children developed emotional bonds with EBA and showed increased self-confidence.
Esfandbod A. et al. (2023)	Language disorders. 6 children with average 6 years.	RASA custom robot.Two-group experimental design. 10 40 min session	Robot without facial expression recognition/lip-syncing	Video coding: Intervention group significantly higher engagement (p=0.025; Cohen's d=1.66); +11.7s mean gaze time. TOLD: Intervention group showed significantly greater progress in word discrimination (p<0.005) and overall language ability vs. control.
Estévez D. et al. (2021)	Language and learning disorders. 5 children 9-12 years old.	NAO robot. Descriptive and explorative case study design. 30 × 30 min weeks.	Therapy without robot	Qualitative (therapist interviews, diaries, video): Therapy with robot improved articulation, sentence structure, motivation, self-esteem and emotional bond formed between robot and patient.
Ioannou A., Andreva A. (2019)	Hearing impaired. 6 children 3-4 years old.	NAO robot. Mixed-method study. 6 weeks, daily 45-min sessions (16–22 sessions per child).	Therapy without robot	Qualitative (therapist/teacher feedback): Improvement in sound response and instruction following.
Jeong M. et al. (2015)	Autistic Spectrum Disorders (ASD). 14 children 6-12 years old.	iRobiQ. Pre-, post-test (ANOVA). 21 sessions.	Traditional therapy	The total number of emotional words in the post- and maintenance phases (p >0,05) was significantly higher than in the pre-test phase (p < .05).
Kim E.S. et al. (2013)	Autistic Spectrum Disorders (ASD). 24 children 4-12 years old.	Pleo robot, human adult and touchscreen game. Three 6-min interactional conditions in random order	Crossover study	ANOVA + t-test (total utterances produced): Robot: M=43.0 (SD=19.4) > Adult: M=36.8 (SD=19.2) > Touchscreen: M=25.2 (SD=13.4); all differences significant (p<0.05 to p<0.001).

Lakatos G. et al.(2022)	Learning disabilities. 20 children 6-10 years old.	Kaspar robot. Assess Feasibility study. 9 sessions over 3 weeks.	Therapy without robot	Video coding + Wilcoxon test: improvement from first to last sessions in all measures: comprehension p=.011/.018; production p<.001/p=.002.
Lee H., Hyun E.(2015)	Language disorders. Children 4-8 years old.	iRobiQ.4 Post-session questionnaire.	Therapy without robot	Expert survey (n=3): treatment effects: 3/3 positive; remote controller and loudness: 3/3 positive; motivation: 2 agree, 1 neutral; suitability and availability: mixed (neutral to agree). Size and image: 2/3 positive; humanoid factor: mixed (1 disagree, 1 neutral, 1 agree). Monitoring and recording: 2/3 positive.
Lekova A. et al. (2021)	Hearing impaired	Pepper. Sound stimulation. Children born with hearing loss. Number of sessions and duration not specified.	Traditional therapy	Protocol design only; no empirical data collected yet
Lekova A. et al. (2022)	Language disorders. 15 children 3-10 years old.	NAO + EmoSan (IoT multi-device). Interactive play-based scenario. Parent questionnaire at 1 and 6 months. 4-5 per session over 6 months.	Traditional therapy	Protocol technically implemented, clinical study pending
Ochoa-Guaraca M. et al. (2016)	Children with disabilities. 32 children of regular schools.	Custom robot. Pilot experiment.	Traditional therapy	Child survey (n=32, typical development): 28 rated functionalities ”very good”, 4 “Good”; preferred robot costumes: dog (10), cat (9), dinosaur (7), rabbit (2), Other (4).
Oliva D. et al. (2025)	Multiple pediatric disorders including complex communication and sensory needs	4-week Asynchronous Remote Community. 30 Speech-language pathologists.	Traditional therapy	No clinical outcomes measured (design recommendations only)
Origlia A. et al. (2018)	Language disorders. 8 children.	NAO + 3D avatar (Ellie).Two-group experimental design. 2 administrations 7 days apart	Traditional AX test	ELAN-video analysis (n=4): >70% attention children gaze to system comparable to standard tests.
Ramamurthy P., Li T. (2018)	Cleft lip and palate disorder	Custom Buddy robot (prototype). Public demonstration session. 15-20 participants.	Earlier prototype	Positive reactions, social engagement, interactive feedback appreciated
Robles-Bykbaev V. et al. (2015)	Children with disabilities. 26 children (23 between 5-17 and 3 average 24 years).	Custom SPELTRA robot.	Implicit (pre-post relaxation time)	Clinical observation:session duration reduced from 40 to 25 minutes. Expert-rated Likert scale (n=6): Down syndrome (4.75), ADHD and mild ID (4.5); in ASD and severe ID (3.0)

Robles-Bykbaev V. et al. (2015)	Children with disabilities. 65 children.	Custom RAMSES intelligent environment. Pilot experiment.	Traditional therapy	Expert-rated Likert scale (1–5): Mild ID (4.83, n=23); Moderate ID (4, n=4), Cerebral Palsy (5, N=4), Epilepsy (4, N=3); ASD (3.75, n=4); Down syndrome (3.55, n=11), Other disabilities (n=11).
Robles-Bykbaev V. et al. (2016)	Children with disabilities. 29 children average 7 years old.	Custom SPELTRA robot. Two-group experimental design.	Traditional therapy	Gaussian probability density plot: robot superior in phonological and morphosyntax, similar output in semantics.
Shin S. et al. (2025)	Language disorders	QT Robot. 2 hours of prototype testing and semi-structured interviews.	Traditional therapy	Positive (prototype stage)
Spitale M. et al. (2021)	Language disorders. 12 children 4-12 years old.	Custom robot/ tablet. 8-session protocol: 1 assessment + 6 training + 1 re-assessment	Tablet vs. tablet+robot	Ongoing, partial data only
Spitale M. et al. (2023)	Language disorders. 20 children.	QT Robot. Explorative study. 8 weeks (1 session/week).	Physical vs. virtual SAR	Wilcoxon test: improvement in both SAR and V-SAR conditions ($p<.05$).OpenFace + PCA/k-means: participants shifting gaze between robot and screen ($p<.05$) Pyannote: SAR ($M=67.11$ vs 42.00) and speaker changes ($M=128.17$ vs 80.25) than V-SAR ($p<.05$). SUS (n=6): 73 (SAR) vs 69 (V-SAR).
Tenesaca-Tenezaca Ó. et al. (2021)	Dyslalia. 1 children 5 years old.	FONA robot (custom). Preliminary evaluation. 5 weeks (1 session/week)	Traditional therapy	Primary assessment of acquisition of the articulation of the phoneme /r/ isolated
Velásquez-Angamarca V. et al. (2024)	Dyslalia. 10 children 3-6 years old.	FONA robot (custom). Pilot experiment. 2 months	Traditional therapy	ELCE + session logs (n=2, cochlear implant): Robot: /r/ isolated by session 2, 7/10 initial words (mean 2.5 sessions), 3/6 medial words - Traditional: /r/ isolated by session 3, 5/10 initial words (mean 5 sessions), 0/6 medial words. Radial graph + session logs (n=10, dyslalia): robot group superior in syllable production and medial/final position words. Therapist observation: robot sessions +17 min sustained attention over traditional therapy (40-min sessions).