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Efficacy and Implementation of Online Speech Therapy Systems for Childhood Speech Communication Disorders: A Systematic Review

Radhika Jain*

Department of Audiology and Speech Language Pathology, AWH Special College, Kerala University of Health Sciences, Calicut, India

Abstract

Currently, not all children in need of speech therapy have the opportunity to receive treatment from a therapist due to a shortage of speech-language pathologists (SLPs) worldwide. To address this issue, there is a growing demand for online tools that can assist SLPs in their daily work. The technical requirements and knowledge necessary to use these programs pose a challenge for SLPs. Furthermore, there has been a lack of systematic identification, analysis, and reporting of previous studies on this topic. We systematically reviewed OST systems that can be utilized either in clinical settings or at home as part of a comprehensive treatment program for children with speech communication disorders. We thoroughly examined the features of these programs and extracted and presented the main findings. Our analysis indicates that the majority of systems designed to support SLPs primarily utilize supervised machine learning approaches and are available as either desktop or mobile applications. The results of our review demonstrate that speech therapy systems can offer significant benefits for childhood speech disorders. To ensure the successful implementation of such systems, collaboration between computer programmers and SLPs is crucial, as it can lead to the development of effective automated programs and enable greater access to quality speech therapy for children in need.

Keywords: Speech-language pathologist; Communication; Disorders; Speech therapy; Learning; Speech disorders

Introduction

The communication skills of young children significantly influence how they perceive and judge each other, resulting in potential social consequences for those with communication disorders [1]. Research suggests that children who receive therapy before the age of five tend to experience more positive outcomes compared to those who begin therapy at a later age [2]. However, even when access to a speech-language pathologist (SLP) is available, SLPs often face challenges in effectively managing therapy plans for each client. Typically, SLPs work with clients on a weekly basis, conducting hour-long sessions that involve various exercises to assess performance and track progress [3]. Despite this, it can be difficult for SLPs to generate personalized therapy plans at the end of each session due to the demanding nature of their work, which involves managing multiple clients throughout the day [3]. It is important to note that the role of an SLP encompasses more than just conducting exercises with patients, as highlighted by the American Speech-Language-Hearing Association (ASHA), which states that SLPs are responsible for preventing, assessing, diagnosing, and treating various communication and swallowing disorders in both children and adults, including speech, language, social communication, and cognitive-communication disorders [4].

Previous studies have highlighted the positive effects of incorporating Information and Communication Technologies (ICT) in therapy [5]. Children in developed countries are increasingly exposed to digitalization and readily embrace online platforms [6]. As a result, the use of ICT in interventions for children with communication impairments is growing, leading to the emergence of various online speech therapy (OST) systems. The attractiveness of digital technology to children is considered advantageous, as it simplifies the process of connecting clients with appropriate clinical expertise, making therapy more accessible [6].

At present, there is a global shortage of speech-language pathologists (SLPs) [7]. Consequently, approximately 70% of SLPs have waiting lists, a situation that extends to developed countries like The Netherlands [7,8]. As a result, not all children requiring intervention for communication impairments have access to a therapist. However, the availability of software systems in developed nations has made it possible for speech therapy to be accessible without the need for physical contact. This paper aims to conduct a systematic literature review (SLR) to systematically identify, analyze, and describe the latest advancements in online speech therapy (OST) systems for communication disorders. The study assesses the current state-of-the-art in OST systems designed for children with communication disorders, which include assessment and/or intervention functions or provide tailored support to SLPs in other ways.

Communication disorders

As defined by the American Speech-Language-Hearing Association (ASHA), a communication disorder refers to a difficulty in receiving, sending, processing, or comprehending concepts through verbal, nonverbal, or graphic symbol systems. These disorders can manifest in hearing, language, and/or speech processes [4]. ASHA classifies communication disorders into four main variations: (a) speech disorders that affect the processing or production of language sounds, including phonology, motor planning, and executive functions; (b) language disorders that impact the comprehension or production of semantics, morpho-syntax, or discourse; (c) hearing disorders; and (d) central auditory processing disorders. Specifically, a speech disorder

*Corresponding author: Radhika Jain, Department of Audiology and Speech Language Pathology, AWH Special College, Kerala University of Health Sciences, Calicut, India, E-mail: radhika_jain@hotmail.com

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pertains to issues with fluency, voice, and the manner in which speech or sounds are produced. It is also referred to as a phonological disorder or a speech sound disorder (SSD). It is important to note that a speech sound disorder should not be confused with a broader communication disorder. While speech disorders are a form of communication disorder, they specifically disrupt the process of everyday speech [9]. ASHA explains that speech disorders can arise from impairments in articulation, fluency, and/or voice production [4].

Telepractice and online speech therapy (OST)

It allows clinicians to connect with clients for assessment, intervention, and consultation purposes. Over the years, various interactive tools have been developed to reduce the time and effort required from speech-language pathologists (SLPs) [10]. However, the term "telecommunications technology" is broad and lacks clear boundaries. The use of computers in speech therapy is often referred to as computer-based speech therapy (CBST). Furlong et al. provide a definition of CBST, stating that it encompasses software programs that offer predefined therapy tasks, instructional features (such as animated talking tutors or synthesized speech for modeling and instructions), motivational features (including animations and game-based activities), and quantitative features (tracking performance within and across therapy sessions) on personal computers. It's worth noting that this definition does not include mobile applications or wireless devices like tablets. However, due to the accessibility advantages mentioned earlier, some OST systems have been specifically designed for mobile phones and tablets, leveraging mobile connectivity to provide quick access. Therefore, this review also takes these systems into consideration. Chen et al. use the term "virtual speech therapist" (VST) to describe an interactive speech therapy computer program. It is important to distinguish VST programs from those designed to teach non-native languages or assist individuals with normal speech abilities, as they do not fall under the category of VST programs according to Chen et al. [11].

Speech recognition

Over the past 50 years, automatic speech recognition (ASR) has remained a prominent area of research [12]. ASR involves converting the acoustic microstructure of a speech signal into its implicit phonetic macro-structure, essentially performing speech-to-text conversion to generate digital text corresponding to the recognized speech [13]. Padmanabhan and Premkumar [14] outlined the general architecture of a speech recognition system. In this architecture, the input signal is pre-processed at the front end, extracting spectral-like features that are then passed to the decoder. The decoder includes a phone likelihood estimator, which assigns scores to each phone unit based on their likelihood. Ghai and Singh [13] identified four distinct approaches to ASR. The first approach is the acoustic-phonetic approach, which originated from the work of Hemdal and Hughes in 1967. This approach assumes a fixed number of phonetic units in each language, with each unit characterized by specific properties such as nasality. The second approach is the connectionist approach, which focuses on patterns of units rather than individual units. The dominant approach in ASR is the pattern recognition approach, which employs mathematical frameworks for execution [15]. The final approach, known as the knowledge-based approach, combines elements of the acoustic-phonetic and pattern recognition approaches. Generally, an ASR system consists of two phases: the training phase and the recognition phase [16].

Machine learning

Machine learning (ML) refers to the field of study focused on computer algorithms that improve automatically by leveraging experience and data. ML can be categorized into three main types: supervised learning, unsupervised learning, and reinforcement learning. In supervised learning, the ML algorithm is trained using a labeled dataset where each input data vector is associated with a corresponding output response or class. Unsupervised learning, on the other hand, involves the ML algorithm learning patterns from an unlabeled input dataset without any explicit feedback, such as guidance from a speech-language pathologist (SLP) [17]. Lastly, reinforcement learning involves an agent learning the optimal actions to achieve predefined goals within an interactive environment.

Methodology

In this study, we performed a systematic literature review (SLR), a rigorous approach that involves identifying, evaluating, and interpreting all pertinent studies pertaining to a specific topic [18-25]. By employing this method, we aimed to summarize the existing evidence related to technology, specifically focusing on the currently available or proposed online speech therapy (OST) systems. The review protocol was developed to outline the research questions, search strategy for identifying relevant literature, criteria for selecting studies, assessment of study quality, and the methodology for extracting and synthesizing information from the identified papers.

Discussion

The review encompassed studies examining a range of disorders, outcome measures, and levels of evidence. There appears to be a demand for authors who possess expertise in both the field of communication disorders and software engineering. However, no publications were found that effectively addressed both of these concerns. Although a certified speech-language pathologist (SLP) reviewed the papers and definitions, the presence of different categorization systems and a wide array of disorders posed challenges in establishing a universally agreed-upon grouping for all the systems. Consequently, one of the primary difficulties encountered in this review was the significant heterogeneity among the discussed papers, as seen in the study conducted by Chen et al. [11], making it arduous to draw definitive conclusions. The studies exhibited considerable variations in study designs and methodological quality [26-30]. Several experimental studies had small sample sizes, such as only five participants, which poses risks in drawing comprehensive conclusions regarding the systems, particularly considering their applicability to various communication disorders.

Conclusion

Speech therapy plays a crucial role in assisting children with communication disorders. However, due to the limited availability of speech-language pathologists (SLPs), not all children with communication disorders have access to this essential treatment. Fortunately, there have been advancements in the development and proposal of online speech therapy (OST) systems. However, existing systematic reviews on OST systems for children with speech sound disorders (SSDs) are limited and cover a wide range of features. To address this gap, this paper conducted a systematic literature review to examine the currently available automated speech therapy programs discussed in prior research. Eight research questions were formulated to gather further insights into the existing OST systems and gain a deeper understanding of the challenges they face. Out of the 4481 papers identified through our search strategy, 35 papers primarily focused on OST systems for children with speech disorders.

Our analysis reveals a diverse range of developed OST systems,

with the majority aiming to support SLPs in their tasks. These systems cater to different languages and target specific disorders. However, understanding the setup of some OST systems proves challenging, as most studies did not provide a reference architecture (RA) description. Among the studies that did include an RA, a client-server approach was commonly used, enabling clients to access speech therapy services through a database.

Furthermore, our analysis indicates that the adoption and utilization of machine learning techniques in OST systems were relatively low compared to those that did not employ such techniques. This finding sheds light on the abundance of OST system designs that are developed but few that are ultimately implemented for practical use.

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Conflict of Interest

Author declares no known competing interests.

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