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Augmented Reality-based Speech-Language Therapy for Individuals with Communication Disorders: Current Evidence, Limitations, and Benefits*

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ABSTRACT

This study aimed to review currently available research on augmented reality (AR) based speech-language therapy for individuals with communication disorders. AR is generally referred to as a system in which the user has a direct view of their environment and where a specially constructed device allows additional information or graphical elements to be blended with the real environment in the form of an overlay. AR-based speech-language therapy refers to speech-language therapy delivered via computer-simulation technology to improve speech and language abilities for children and adults with communication disorders. In addition, this paper addressed limitations of previous studies and benefits of AR-based speech-language therapy. Recent Findings Recent research reports suggest that AR-based speech-language therapy is a viable option for treating children and adults with speech-language disorders. However, most of the research studies were conducted without a rigorous experimental design. Additionally, the quality of technology is difficult to assess and application to real clinical practice is currently lacking. Future studies should be conducted with a rigorous experimental design and more advanced technology. Summary This paper has reviewed current evidence related to the effectiveness of AR-based speech-language intervention for children and adults with speech-language impairment. This paper discussed limitations of the current research and benefits of AR-based speech-language therapy.

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1. Introduction

Augmented reality (AR) generally refers to as a system in which a specially constructed device allows a 3D virtual image to be blended with the real-world image or background in the form of an overlay, combining the real world with a virtual world containing additional, real-time information and presenting them as one interface. Virtual reality (VR) is an human-computer interface that realizes a specific environment or situation on a computer as if the user is actually interacting with a real environment. AR and VR are also compatible with devices such as smart glasses, head-up displays, head-mounted displays (HMD), and handheld devices that combine the real and virtual worlds. Research and development on the core application areas of AR/VR technology is expanding to include gaming, entertainment, GPS, healthcare, engineering, design, architecture and interior design, commercial purposes, education, media, military, aerospace, and defense as well as other professional education (Kim & Kim, 2014).

In the healthcare sector, AR/VR products and services are being adopted for more efficient healthcare and to address such challenges as the increase in chronic diseases, aging population, limitations in infrastructure, and lack of skilled workers. Accordingly, the healthcare sector is expected to make up about 17% of the total AR/VR market as it positions itself as a major application area alongside aerospace and defense, consumer and commercial applications, and enterprise solutions (Ventura et al., 2018).

AR and VR are used in various areas in healthcare including surgery, stroke rehabilitation, and the treatment of autism, but VR may result in symptoms such as dizziness, nausea, headache, eye strain, and imbalance in the user response system depending on use, which can lead to health problems. Another issue is possible confusion during or after the exposure to an immersive VR environment; the US National Advisory Mental Health Council recommends fully understanding both the positive and negative effects of VR system on the user and establishing a protocol for patients and doctors exposed to the VR environment. In the case of VR HMD, most systems are bulky and not ergonomically designed, often causing discomfort during use due to low resolution and restricted visual field (Khor et al., 2016). In consideration of these side effects, this paper focuses on AR research in communication disorders.

This article aims to review the technologies available today and their application in the medical field, and in particular for speech language pathology. The review presents an overview of significant developments that have occurred in medicine and in the discipline of speech-language pathology using AR. Considering both the achievements and the remaining challenges, it aims to identify trends and possible future developments. Although a number of studies are available that report positive effects of augmented reality-based speech-language therapy for adults and children with communication disorders, some of the evidence from these studies was not included in the current review because they mainly focused on descriptions of technical developments, with the clinical application of augmented-reality-based speech-language therapy mainly qualitatively described without specific experimental procedures.

2. Current Findings on AR for Adults and Children with Communication Disorders

2.1 Neuro-Language Disorders

Antkowiak et al. (2016) introduced an AR-based treatment program that can be implemented at home to address the problem that repetitive, experienced-based treatment, which is essential in aphasia, is difficult to achieve in practice. AR was used to improve the reality of home-based treatment and an online platform was developed for feedback, but the results of applying this system to actual subjects were not reported.

An et al. (2017) developed a script-based AR content for the treatment of aphasia by creating categories of activities that can occur in the living area, rooms, bathrooms, and the kitchen. This program was applied to five patients with expressive aphasia over 24 sessions of an intervention program, and the results of the Korean Boston naming test (K-BNT) and communicative effectiveness index (CETI) were compared using nonparametric tests. The results of K-BNT showed that the score increased from 26 points to 38.4 points after the treatment, and remained at 36.6 points even during the retention phase, while CETI scores showed an increase from 33 points to 48.4 points after the treatment.

2.2 Hearing Impairment

Mirzaei et al. (2014) used an Automatic Speech Recognition (ASR) system that can automatically recognize the listener's speech with a speech-to-text converter to present video of the other person with subtitles in an AR environment to improve difficulties in understanding speech in those with impaired hearing (Fig. 1). When three subjects with severe hearing impairment were tested in a highly noisy environment, the error rate in speech understanding was improved from 40% to 2% after the application of the system.

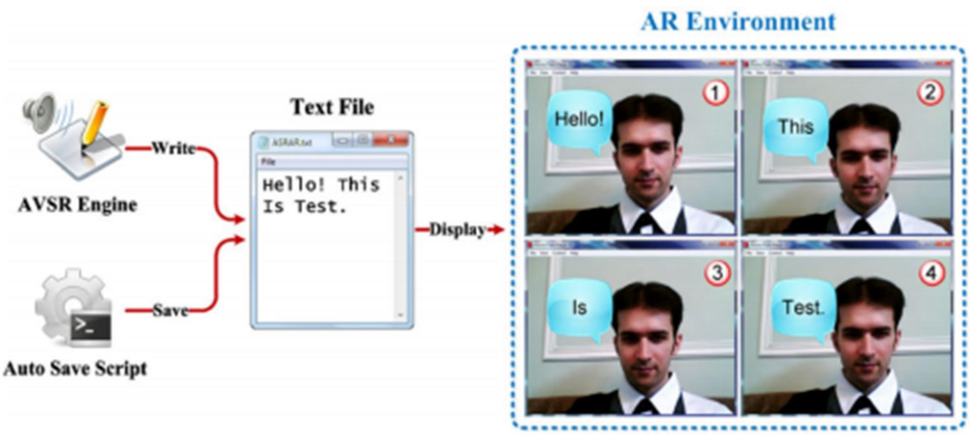

Fig. 1. AR subtitles output system based ASR system (Mirzaei et al., 2014)

Engwall (2011) developed an AR-based Talking Head and used a 3D visual feedback to present various phonemes that are difficult for the hearing impaired to perceive (Fig. 2). When 18 subjects with hearing impairment were assessed using approximately 280 sentences, an average 10% increase in phoneme recognition was reported.

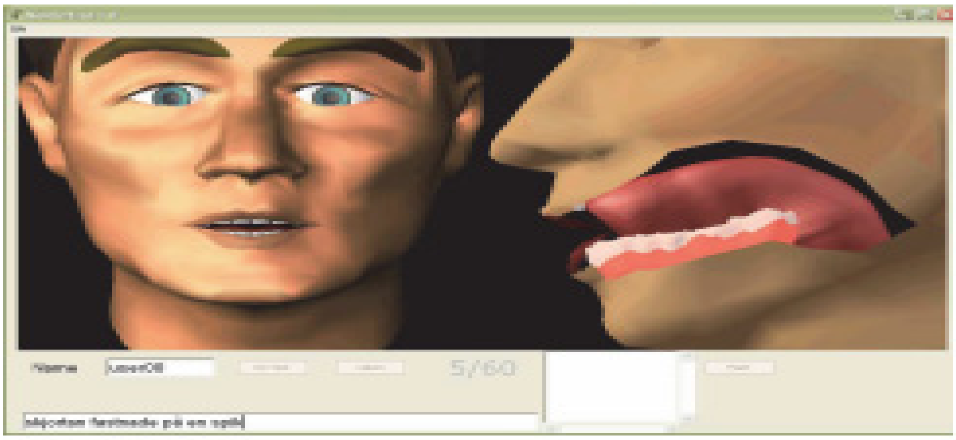

Fig. 2. The dual face display showing a normal front view and an AR side view simultaneously (Engwall, 2011).

Deb et al. (2018) developed hardware and an application that can recognize Sign Language (SL) for people with severe hearing impairment who are unable to communicate in spoken language, creating a system with which these individuals can learn SL easily using AR and others can easily understand their SL (Fig. 3). When 10 subjects with severe hearing impairment were tested, 4 subjects were able to quickly acquire and use SL after only one session of training. Using a similar method, Al-Megren and Almutairi (2019) and Dabran et al. (2017) have also reported a superior performance of AR in SL acquisition.

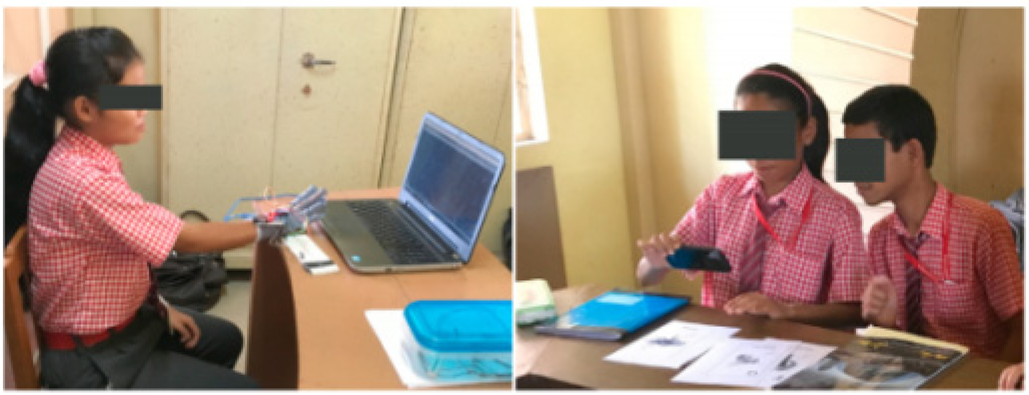

Fig. 3. Hearing impaired students are using the prototype AR contents (Deb et al., 2018).

2.3 Articulation and Phonological Disorders

Research on articulation and phonological disorders related to AR began with the development of the AR-based Articulation and Phonological Assessment System by Kang et al. (2015), which Lee et al. (2019) applied to conduct articulation therapy at the sentence level as opposed to existing word-level treatment using AR contents in 10 children with articulation and phonological disorders. The results of the treatment showed that AR contents helped the subjects to reach a consonant accuracy of 98% or higher approximately 1 month faster than when not using the contents.

Kim and Kwon (2019) studied AR-based spontaneous speech collection at the sentence level based on the findings of previous research that the speech data collected at the sentence level were more accurate than those collected at the word level in articulation disorder assessments. When spontaneous speech was examined using reading, free play, and AR in 22 typically developing children, more consonants and vowels were collected when AR was used and this difference was statistically significant.

2.4 Speech and Language Disorders

2.4.1 Specific Language Impairment

Bae et al. (2014) reported the results of converting the contents of existing textbook-based speech therapy into AR contents and applying them in 10 subjects with specific language impairment. When those receiving existing textbook-based therapy (5 subjects) were compared with those receiving therapy with marker-based AR contents (5 subjects), there was no difference due to intervention effects between the two groups in phonological encoding ability, but higher interest and immersion were reported for AR-content-based treatment.

Bae et al. (2018) developed an AR-based speech therapy platform, applied natural feature tracking algorithms, and compared the effects of AR and image cards for 24 action verbs using alternating treatment design (ATD) in three children with specific language development delay (Fig. 4). Although both the image cards and AR contents were effective in increasing the number of action verbs, AR contents showed higher vocabulary accuracy in the retention phase. In addition, AR contents were reported to be effective in learning immersion and situational interest.

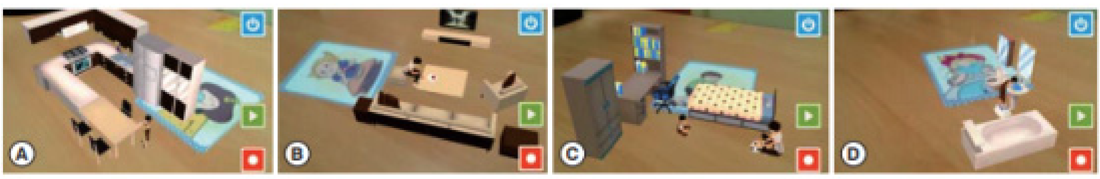

Fig. 4. Mixed reality therapy program based on augmented reality (Bae et al., 2018).

2.4.2 Autism

The use of AR for speech therapy in autism was first reported by da Silva et al. (2014). In their study, enhancement of functional communication ability was observed when AR contents were used in six scripted situations involving animals, household items, gender, behavior, sounds, yes/no, and story composition using nouns and verbs (Fig. 5). When four boys diagnosed with autism received 13 sessions of AR speech therapy, all participants showed a significant improvement in their functional communication abilities. Although the evaluation of communication skills was conducted subjectively and objective effects could not be demonstrated, the results suggested the possibility of using AR in the treatment of augmentative and alternative communication (AAC) and autism.

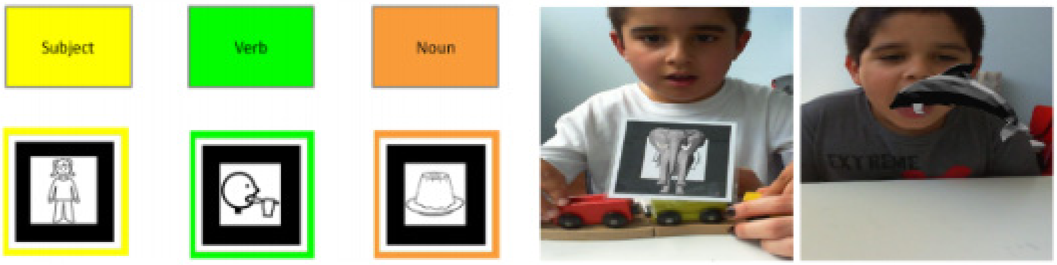

Fig. 5. AR-based AAC speech treatment program (da Silva et al., 2014)

Children with autism lack facial expressions and thus social communication abilities. To overcome this, a study was conducted using an AR-based video modelling system in which the children with autism could understand the facial expressions of others and express theirs in return (Chen et al., 2015; Chen et al., 2016). Chen et al. (2015) developed and applied an AR-based facial expression practice program to enable autistic children to communicate with different facial expressions (Fig. 6). A total of six facial expressions created with AR were designed to give feedback in AR when the subjects made various facial expressions by recognizing the changes in expression. Training of three subjects in the baseline, intervention, and retention phases resulted in an increased intention to communicate through facial expression, rising from an initial 40% to 80% during the retention phase.

Kim et al. (2018) examined the effects of using 68 verbs created with AR contents for three autistic children to increase verb vocabulary at the baseline, intervention, and retention phases and compared their attention using a pre-post design. The results showed that AR contents were more effective in increasing attention and verb vocabulary accuracy than existing treatment methods.

Fig. 6. AR-based facial expression training

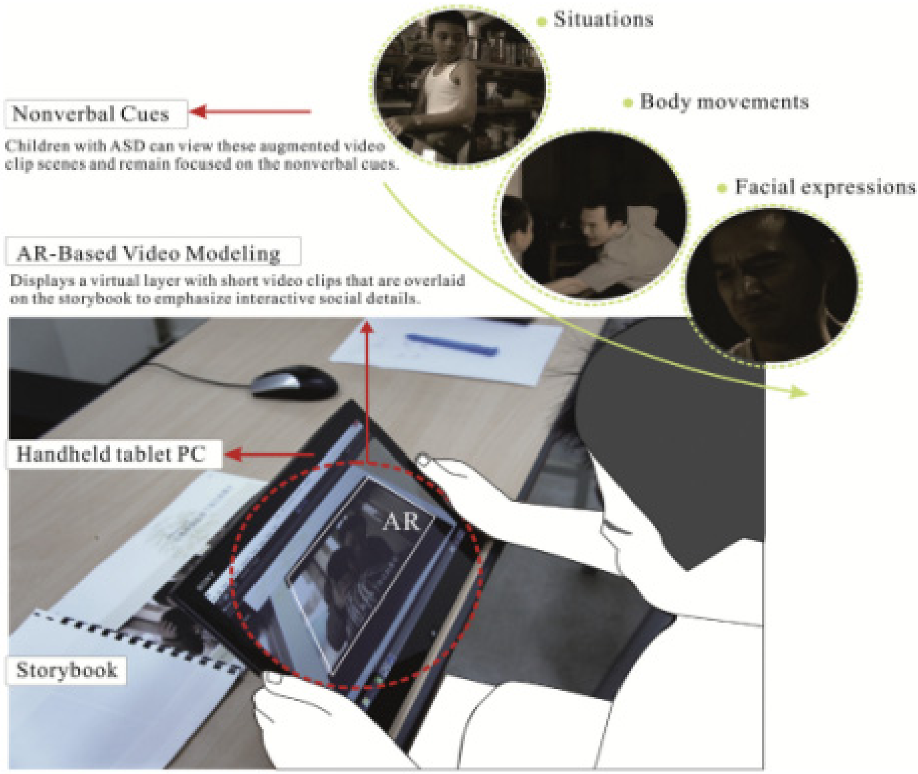

Fig. 7. AR-based video modeling and output system (Chen et al., 2016)

Taryadi and I Kurniawan (2018) reported the treatment effects of reconstructing vocabulary of a picture exchange communication system (PECS), which is widely used in the treatment of autistic children, into AR content (Fig. 8). Application of AR-based PECS treatment in 12 children with autism was reported to lead to an increase of lexical accuracy from 47% before intervention to 76% after intervention. In the study by Lorenzo et al. (2018), a statistically significant improvement was observed in the development of receptive and expressive language with the AR-based PECS when six autistic children were compared with five normal children.

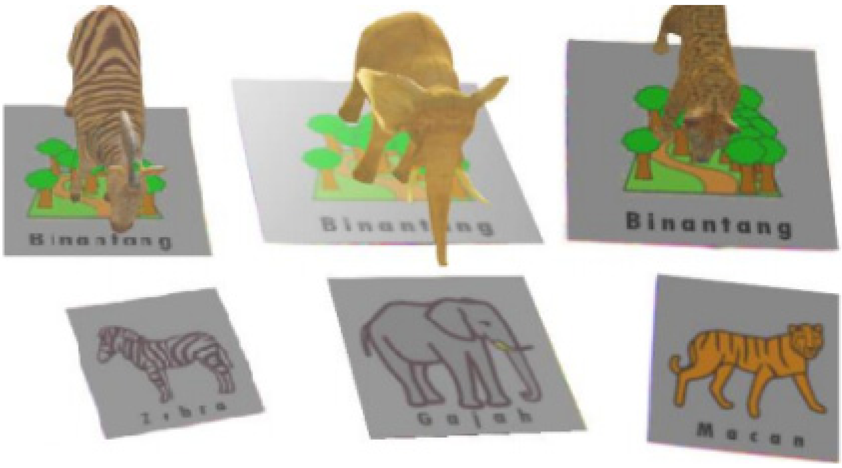

Fig. 8. Application of AR-based PECS treatment

2.4.3 Intellectual Disability

Ahn et al. (2018) reported the effects of AR content using Applied Behavior Analysis reversal design in four children with intellectual disability aged 4 to 6. Among the verbs frequently used in speech therapy, 30 verbs with the highest usage frequency were selected and the effects observed after a total of 12 sessions administered with image cards and AR content. As a result, the positive response rate of the verbs increased during intervention (AR content) from the baseline (image cards). Chang et al. (2014) provided training to three adults with intellectual disability aged 20 or older by recreating the vocabulary related to their occupation as AR contents, and reported 100% acquisition of occupation-related vocabulary in the retention phase after the intervention.

3. Limitation and Potential Benefits of AR Therapy in Communication disorders

Although a number of attempts have been made to investigate whether augmented reality-based speech-language therapy is effective in treating children and adults with communication disorders, the current evidence may not provide strong evidence regarding the effects of augmented reality-based speech-language therapy.

The major issue is that previous studies were implemented without a rigorous experimental design. The majority of the studies were conducted as case studies. Several were conducted with a one-group pre-test/post-test design or single-subject experimental design. Although these designs demonstrated positive effects on outcome behaviors, without a control group it is difficult to show the effectiveness of one treatment over a traditional intervention.

Another issue is the quality of simulation technology used in the previous research. Augmented reality has also been adopted in the areas of fine arts, archeology, and architecture to provide spectators with rich sensory experiences. Augmented reality is now available in our daily lives. While augmented reality is greatly developed in these areas, the simulated images that appeared in a number of papers on speech-language interventions seem somewhat flimsy and unrealistic. It is not certain whether the quality of such simulations would have treatment effects as effective as traditional face-to face methods.

Finally, there is significant lack of linkage from research to current practice. Although previous studies have successfully inspired practitioners and encouraged them to implement augmented reality in their clinical practice, they are not sure where or how to start applying augmented reality, since current existing augmented reality consists mostly of research laboratory prototypes. Research evidence still remains without application to real clinical practice. Given the successful outcomes of application with a larger number of normally developing children, it is unfortunate to find no application and follow-up studies with children with language impairments.

Several potential benefits and uses of AR therapy have been proposed for both service patients and speech language pathologists. First, AR therapy brings interactivity and motivation to patients. Repetition, which may be necessary in an actual therapy situation, may reduce patients' motivation. AR therapy may help overcome the repetitive nature of rehabilitation by providing patients with fun and interesting opportunities to exercise, and during intervention may help to reduce feelings of embarrassment when a breakdown takes place in real-world communication.

AR therapy is also considered useful for clients' or patients' improvement and generalization, in that virtual therapy may effectively control the number of factors affecting patients at each stage of treatment procedures. In other words, during the early phases of treatment, a clinician may reduce the number of distractions to improve learning, but the number of distractions can be increased in a later phase of intervention to promote generalization. Holden argues that virtual therapy may be superior to real-world practice in this regard.

Second, AR therapy may be useful by allowing for immediate feedback on a patient's learning process, which is not always plausible in real-world settings.

4. Conclusion

This paper reviewed current available research showing the effectiveness of augmented reality speech-language intervention in children and adults with communication disorders. Although current evidence is somewhat limited, future studies should be conducted with a rigorous experimental design such as randomized controlled design as well as advanced technology. New technology is being developed every year, and our lives rely increasingly on technology. Instead of ignoring it, we need to adopt technology to take advantage of it. However, several challenges must be overcome for this to take place.

One challenge is equipment costs. Although therapeutic and educational equipment costs have dropped significantly in recent years, current prices are still prohibitive for clinics and schools. Furthermore, AR therapy is increasingly provided via telehealth. An inadequate communication infrastructure may make practitioners hesitant to adopt AR therapy. Finally, it is not certain whether existing virtual therapy can accommodate specialized individual needs when necessary. This is particularly important to clinical practitioners because each patient needs a customized treatment plan. Thus, the development of more user-friendly or easily accommodated virtual therapy programs is highly desirable. Without overcoming these limitations, the pervasive application of virtual therapy remains uncertain.

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