Innovative Technologies in Stuttering Treatment: An Examination of Virtual Reality, Mobile Applications, Telerehabilitation, and Artificial Intelligence-Based Solutions

Esra EROL*, Leyla TÜRKER ŞENER**

Abstract

Recent technological advances in the field of health services have been effectively applied to the evaluation and therapy processes of communication disorders in the domain of speech and language therapy. Within the framework of communication disorders, various technological interventions are also applied in the field of stuttering. Stuttering is defined as a speech disorder characterised by involuntary blocking, repetition, or prolongation of speech fluency, sounds, syllables, or words. A substantial body of epidemiological research has revealed that stuttering is a prevalent disorder on a global scale, with incidence rates as high as 5% in the paediatric population and up to 1% in adults. In the field of stuttering rehabilitation, technological applications play a pivotal role. These include virtual reality, mobile applications and telerehabilitation. Virtual reality (VR) is a technology that offers users realistic experiences in computer-aided three-dimensional environments and allows them to interact directly with these environments. In the context of stuttering therapies, this technology enables individuals to develop more effective coping strategies in challenging situations by simulating real-life speech scenarios. VR-based virtual simulations allow individuals with social anxiety to safely practice their social skills and reactions by interacting with realistic avatars in a virtual environment. Mobile applications represent a digital tool that can assist users in enhancing their speaking abilities and in comprehending stuttering-related situations they encounter in their daily lives. These applications offer individuals the opportunity to undertake speech therapy exercises at their own pace, to record their progress regularly, and to communicate easily with their therapists when necessary. Telerehabilitation has been identified as a potentially effective solution for individuals with limited access to health services, particularly those residing in remote areas, by providing easier access to rehabilitation services. This method, which can substitute for traditional face-to-face rehabilitation, enables individuals to continue their therapy processes uninterruptedly through remote connection. Within this scope, a systematic literature review was conducted using PubMed, Google Scholar, Scopus, ResearchGate, YÖK Thesis, and Web of Science databases between 2000 and 2024. Of the 55 studies identified, 13 met the inclusion criteria. Consequently, technological rehabilitation, and in particular virtual reality-based approaches, is regarded as a promising method in stuttering therapies. The findings obtained reveal that virtual reality-based rehabilitation applications can offer an innovative and successful solution in reducing social anxiety associated with stuttering.

Keywords: Stuttering, virtual reality, mobile applications, telerehabilitation, systematic review, speech therapy.

Derleme Makale (Review Article)
Geliş / Received: 22.03.2025 & **Kabul / Accepted:** 19.11.2025
DOI: https://doi.org/10.38079/igusabder.1663488
* Res. Asst., Istanbul Gelisim University, Faculty of Health Science, Department of Speech and Language Therapy, Istanbul, Türkiye. E-mail: esraerol3340@gmail.com ORCID https://orcid.org/0000-0002-5411-0331
** Assoc. Prof. Dr., Istanbul University, Istanbul Faculty of Medicine Department of Biophysics, Istanbul Türkiye. E-mail: leylasen@istanbul.edu.tr ORCID https://orcid.org/0000-0002-7317-9086

Kekemelik Tedavisinde Yenilikçi Teknolojiler: Sanal Gerçeklik, Mobil Uygulamalar, Telerehabilitasyon ve Yapay Zeka Tabanlı Çözümlerin İncelenmesi

Öz

Son dönemlerde sağlık hizmetleri alanındaki teknolojik ilerlemeler, dil ve konuşma terapisi alanında iletişim bozukluklarının değerlendirilmesi ve terapi süreçlerine etkili bir şekilde uygulanmaktadır. İletişim bozuklukları çerçevesinde, kekemelik alanında da çeşitli teknolojik müdahaleler uygulanmaktadır. Kekemelik, konuşma akıcılığının, seslerin, hecelerin veya kelimelerin istemsiz şekilde bloke edilmesi, tekrar edilmesi ya da uzatılması ile tanımlanan bir konuşma bozukluğu olarak ifade edilmektedir. Epidemiyolojik kökenli çalışmalar, kekemeliğin uluslararası bağlamda sık görülen bir bozukluk olduğunu göstermekte ve pediatrik popülasyonda görülme oranının %5'e, erişkin popülasyonda ise %1'e kadar çıkabileceğini ortaya koymaktadır. Kekemelik alanında, sanal gerçeklik, mobil uygulamalar ve telerehabilitasyon gibi çeşitli yöntemleri içeren teknolojik rehabilitasyon uygulamaları kullanılmaktadır. Sanal gerçeklik, kullanıcılara bilgisayar destekli üç boyutlu ortamlarda gerçekçi deneyimler sunan ve bu ortamlarla doğrudan etkileşim kurmalarını sağlayan bir teknolojidir. Kekemelik terapilerinde bu teknoloji, bireylerin günlük hayatta karşılaşabilecekleri zorlayıcı konuşma durumlarını simüle ederek, bu tür anlarda daha etkili başa çıkma stratejileri geliştirmelerine olanak tanımaktadır. Sanal gerçeklik tabanlı sanal simülasyonlar, sosyal kaygı sorunu yaşayan bireylerin, sanal ortamda yer alan gerçekçi avatarlarla etkileşim kurarak sosyal becerilerini ve tepkilerini güvenli bir şekilde pratik etmelerini sağlamaktadır. Mobil uygulamalar, kullanıcıların konuşma yeteneklerini geliştirmelerine ve günlük yaşamda karşılaştıkları kekemelikle ilgili durumları daha yakından takip etmelerine yardımcı olabilecek dijital araçlardır. Bu uygulamalar, bireylere konuşma terapisi egzersizlerini kendi tempolarında yapma fırsatı sunar, gelişimlerini düzenli olarak kayıt altına alır ve gerektiğinde terapistleriyle kolayca iletişim kurmalarını mümkün kılmaktadır. Telerehabilitasyon ise özellikle sağlık hizmetlerine erişim imkânı kısıtlı olan bireyler veya uzak bölgelerde yaşayanlar için etkili bir çözüm sunarak bu kişilerin ihtiyaç duydukları rehabilitasyon hizmetlerine ulaşmalarını kolaylaştırabilmektedir. Geleneksel yüz yüze rehabilitasyonun yerini alabilecek nitelikte olan bu yöntem, uzaktan bağlantı sayesinde bireylerin terapi süreçlerini kesintisiz bir şekilde sürdürmelerine yardımcı olabilmektedir. Bu kapsamda, 2000–2024 yılları arasında PubMed, Google Akademik, Scopus, ResearchGate, YÖK Tez ve Web of Science veri tabanları kullanılarak sistematik bir literatür taraması gerçekleştirilmiştir. Belirlenen 55 çalışmadan 13'ü dahil edilme kriterlerini karşıladı. Sonuç olarak, teknolojik rehabilitasyonun ve özellikle sanal gerçeklik tabanlı yaklaşımların, kekemelik terapilerinde umut vadeden bir yöntem olarak görülmektedir. Elde edilen bulgular, sanal gerçeklik tabanlı rehabilitasyon uygulamalarının, kekemelikle bağlantılı sosyal kaygının azaltılmasında yenilikçi ve başarılı bir çözüm sunabileceğini ortaya koymaktadır.

Anahtar Sözcükler: Kekemelik, sanal gerçeklik, mobil uygulamalar, telerehabilitasyon, sistematik inceleme, konuşma terapisi.

Introduction

Stuttering is a communication disorder that is characterized by involuntary interruptions in the flow of speech. The nature of these interruptions varies depending on the situation and is often associated with strong emotional reactions[1-3]. Stuttering is typified by a loss of fluency, pauses, the repetition of sounds and syllables, prolongations, or blocks in airflow[4]. In early childhood, stuttering affects approximately 5% of children, with a higher prevalence among boys than girls[4,5]. Stuttering typically manifests between the ages of two and five years, with approximately 75% of preschool children recovering spontaneously without the need for any treatment[6]. Despite the lack of a definitive cause, numerous researchers have developed various models to explain this condition, including structural, emotional, social, genetic, motor, linguistic, neurological, psychological, cognitive, and environmental factors[7-9].

The use of technology in rehabilitation has grown in popularity in recent years, driven by advances in technology itself. Technological rehabilitation offers a number of benefits, including the ability to engage patients, encourage active participation in therapy, enhance the effectiveness of rehabilitation through repetition and variation in motor learning, strengthen motor learning, and provide feedback to improve patient outcomes[10].

The methods and devices employed in technological rehabilitation across the globe and in Turkey encompass virtual reality (VR), mobile applications, and telerehabilitation. It has been observed that the utilization of virtual reality has increased in rehabilitation with the advancement of technology and enhanced accessibility.

Method

In the course of our literature review, we searched the following databases in English and Turkish between 2000 and 2024: PubMed, Google Scholar, Scopus, ResearchGate, YÖK Thesis and Web of Science.

The following keywords were used in the literature review: 'stuttering' and 'virtual reality' or 'stuttering' and 'VR', 'stuttering' and 'mobile applications' or 'stuttering' and 'telerehabilitation', and 'stuttering' and 'virtual reality' or 'stuttering' and 'VR'.

The results of the literature search yielded a total of 55 studies. Among the studies identified, 14 were found to have other diseases, 15 lacked an open version, one was written in a different language, 12 were not evaluated, and 38 were excluded due to these factors. Following the exclusion process, 13 studies were deemed eligible for inclusion.

The exclusion criteria of this study were as follows: studies published in languages other than Turkish or English, inability to access the full text, absence of any technological rehabilitation intervention applied by speech and language therapists, the implementation of an additional integrated therapy alongside the technological rehabilitation provided by speech and language therapists, and the presence of incomplete outcome assessments within the studies.

The article also conducted patent results from both Turkey and the world to determine which patents exist for individuals who stutter regarding artificial intelligence: Espacenet, Turkish patent and trademark office.

Stuttering

Stuttering is defined as a speech disorder characterized by disruptions in the natural fluency and timing of speech. Such disruptions manifest as the repetition of sounds, syllables, or monosyllabic words; the prolongation of sounds; and the obstruction of airflow during speech[5]. Additionally, stuttering may be accompanied by secondary behaviors such as avoidance of eye contact, facial and head movements, and increased physical tension[11]. Stuttering is a condition that affects not only the individual's speech but also their psychological and social life[12]. It is widely acknowledged that the emotions and thoughts of the person can affect stuttering, and conversely, that stuttering can affect

Istanbul Gelisim University Journal of Health Sciences (IGUSABDER) is indexed by TUBITAK ULAKBIM TR Index.
Web site: https://dergipark.org.tr/en/pub/igusabder
Contact: igusabder@gelisim.edu.tr

these emotional and intellectual processes. Despite the lack of consensus regarding the precise etiology of stuttering, researchers have proposed a number of models to elucidate this condition. These models encompass a range of factors, including structural, emotional, social, genetic, motor, linguistic, neurological, psychological, cognitive and environmental influences[9,8]. Despite the absence of a current study on the frequency and prevalence of stuttering in Turkey, it is estimated that approximately 900 000 individuals in the country are affected by this condition[13]. It has been reported that the prevalence of stuttering is similar between boys and girls at the beginning of childhood, but that it is more common in boys as they grow older. The ratio of boys to girls with stuttering is estimated to be 4:1[14,15]. The prevalence of stuttering is estimated to be approximately 5% of the general population, with the age of onset typically occurring between the ages of 2 and 5 years[11]. Approximately 75% of preschool children spontaneously recover from stuttering without intervention. Furthermore, the lifetime prevalence of stuttering decreases to 1%[6].

Stuttering can result in individuals being subjected to ridicule, stigmatisation and discrimination in social interactions, which may subsequently lead to a decrease in self-confidence and self-esteem[16]. Furthermore, individuals who experience difficulties in professions that require fluent speech may encounter constraints in their educational and career options[17]. Furthermore, stuttering can impede an individual's ability to engage in daily activities, such as making phone calls, speaking in public, or meeting new people. These challenges can have a detrimental impact on an individual's social life and overall quality of life[18]. The experiences of stuttering are dependent on a number of factors, including age, gender, culture and personality characteristics[19]. As a result, each individual's difficulties are unique. In light of the impact of stuttering, it is of great importance to ensure that individuals have access to appropriate treatment and support services to improve their quality of life[20].

Technological Rehabilitation Devices used in Stuttering

Technological rehabilitation is a modern intervention approach that integrates traditional therapy methods with digital technologies to enhance individuals' physical, cognitive, and communicative functions. This approach encompasses various tools such as robotic systems, VR, mobile applications, artificial intelligence (AI) based software, and telerehabilitation platforms[21]. Particularly in neurological or communication-based disorders, these technologies provide high-intensity, repeatable, and individually adaptable exercises that support neuroplasticity and enhance the effectiveness of the therapeutic process[22]. Technological rehabilitation is increasingly being utilized in fluency disorders such as stuttering, as its interactive structure boosts individual motivation, facilitates engagement in therapy, and helps optimize outcomes[23].

Virtual Reality

Virtual reality (VR) can be defined as a technology that enables users to actively interact with three-dimensional environments that have been created by a computer. This technology offers a rich and multisensory experience that resembles the real world, as it allows users to feel as though they are in the virtual environment, particularly through the use of VR glasses[24]. In the context of stuttering treatment, this technology offers a number of potential benefits[25]. Virtual environments can simulate stressful scenarios that may be encountered in reality, thereby assisting individuals in enhancing their capacity to cope with such circumstances[26]. Virtual reality-based social environments permit individuals with social anxiety to cultivate responses to authentic social challenges through interaction with realistic avatars (Figure 1). Virtual reality provides a secure and regulated environment in which individuals with anxiety can cultivate coping mechanisms while concurrently attenuating their social anxiety[24]. The active involvement of individuals in therapy through virtual reality games or simulations has been shown to enhance adherence to treatment and facilitate the utilization of virtual reality technology as an efficacious instrument in the management of stuttering[25].

Figure 1. Stuttering rehabilitation with VR

Mobile Applications

The term 'mobile health' is used to describe software applications related to health information and research that are used by healthcare professionals and patients with the aim of improving healthcare services and public health[24]. Such applications effectively transform a mobile platform into a regulated medical device. The utilization of mobile applications in the domain of health services is becoming increasingly prevalent[27,28]. Mobile applications developed for individuals who stutter can assist users in enhancing their speaking abilities and monitoring stuttering-related occurrences in their daily lives. Such applications permit users to undertake speech therapy exercises, observe their progress, and maintain communication with their speech therapist[29].

Tele-Rehabilitation

The field of telerehabilitation has emerged as a pivotal aspect of healthcare, particularly in the context of the ongoing pandemic. The term "telerehabilitation" is used to describe the provision of remote rehabilitation services using information and communication technology (ICT)[30]. This modality has the potential to enhance accessibility to healthcare, particularly for patients in rural or underserved communities, and may also offer a viable alternative to traditional face-to-face rehabilitation[31]. Despite the growing body of research attesting to the efficacy and feasibility of telerehabilitation, its comprehensive implementation, particularly in developing countries, is hindered by technological, logistical, and regulatory constraints[30].

Artificial Intelligence

Artificial intelligence studies on stuttering are also gaining great importance. Real-Time voice analysis, personalized therapy programs, speech correction and synthesis, virtual therapists and voice assistants, emotional and psychological support are the prominent ones of these studies.

The patent application numbered 2022/016828, submitted to the Turkish Patent and Trademark Office, introduces a mobile application system designed to enable individuals with stuttering to conduct their own therapy sessions anytime and anywhere, without the need for a speech and language therapist. This system utilizes voice analysis software and artificial intelligence to incorporate therapy models such as slow speech, soft speech, and voluntary stuttering.

Additionally, the application numbered 2008/09165 presents a utility model for a training and therapy device aimed at addressing issues such as concentration difficulties, attention deficits, and auditory perception disorders in individuals with stuttering. The device also helps mitigate related problems, including asymmetric hearing and painful hearing.

Another study focuses on generating a speech transcript from the voice of individuals with stuttering during their speech. Following optimization, the contextual information of the transcript is linked, and a correction module improves the speech. Finally, speech synthesis is performed.

The patent numbered US2021315516A1 introduces innovative algorithms for the biomedical analysis and treatment of speech disorders such as stuttering and rhotacism. It utilizes voice assistant technology and digital applications for data collection and personalized therapy.

The patent numbered CN118553248A presents a speech correction method that employs advanced language models, including T5 for error correction and VITS for speech synthesis, to enhance the treatment of speech disorders. By integrating the BERT model, it improves language representation and personalization, offering a more effective solution for stuttering correction.

The patent numbered US2024386813A1 describes a speech recognition system that applies machine learning to analyze voice signals in real time and generate personalized speech therapy reports. By evaluating various speech parameters such as pitch, intensity, and phonetic structure, it provides users with customized feedback to improve their speech performance.

The invention introduces a speech correction method and device designed for individuals with speech impairments, along with a corresponding storage medium. It falls within the field of speech recognition technology. The method involves converting the speech to be processed into text, generating an input text. This text is then processed through the T5 model for optimization and error correction, during which contextual information is linked within the decoder module. Once corrected, the text undergoes speech synthesis using the VITS model to generate an improved speech output. During this process, the BERT model is integrated into the VITS model, combining BERT's language representation capabilities with VITS's sequence generation effectiveness. This approach enhances the overall quality of error correction, improves adaptability to individual speech variations, and provides a more comprehensive solution for the correction of stuttering and other speech disorders.

Effectiveness of Technological Rehabilitation Used in Stuttering

The advancement of technology has led to a gradual increase in the utilisation and impact of technology in the domain of therapy and rehabilitation. Furthermore, technological advancement is also being observed in the domain of stuttering therapy within the field of speech and language therapy. A review of the literature reveals that technological advancement has the potential to enhance the efficacy of rehabilitation in the domain of virtual reality.

The findings of a study indicated that participants who underwent challenging virtual job interviews exhibited elevated levels of stuttering symptoms in comparison to those who underwent supportive interviews. These results substantiate the correlation between perceived stress and stuttering and propose that VR environments may elicit effects analogous to those observed in real-world conditions[32].

The extant literature indicates that virtual reality environments (VRs) may serve as efficacious tools for examining physiological reactivity and subjective distress associated with stuttering in adults. Virtual reality environments (VREs) have been reported to provide a safe and controlled interaction environment that is similar to real-life conversational environments. These findings suggest that VREs may provide safe and systematically applicable targets in the treatment of stuttering[33]. In particular, studies conducted with school-age children and adolescents have reported that virtual classroom environments cause anxiety at a similar level to that caused by a real audience. This suggests that virtual classrooms may be a promising tool in the treatment of social anxiety[34].

Furthermore, the severity of stuttering during speaking and reading tasks in real and virtual environments was also examined. It was found that virtual environments were less stressful and provided a more significant decrease in stuttering severity. This demonstrates that virtual reality can play a significant role in stuttering therapy. Studies by Brundage and other researchers suggest that VR can be a reliable tool for assessing and treating stuttering, especially in stressful speech situations[35-37].

Virtual reality exposure therapy (VRET) has been identified as an efficacious approach for the reduction of social anxiety. The findings suggest that these techniques should be adapted to individualized approaches targeting social anxiety associated with stuttering.

Istanbul Gelisim University Journal of Health Sciences (IGUSABDER) is indexed by TUBITAK ULAKBIM TR Index.
Web site: https://dergipark.org.tr/en/pub/igusabder
Contact: igusabder@gelisim.edu.tr

In particular, automated VRET methods and inhibitory learning techniques have been reported to be effective in treatments developed for stuttering[38]. However, it was observed that VRET had a limited effect on social anxiety in the short term in pilot studies. It was emphasized that larger sample groups and personalized protocols are needed for long-term effects[39].

However, the complex effects of virtual reality applications on social anxiety must also be considered. It has been reported that feelings of 'presence' and 'social presence' are effective in reducing fears of negative evaluation but may have mixed results on social anxiety[40]. These findings highlight the importance of individualized and targeted treatment protocols.

The utilisation of mobile health applications for the management of social anxiety associated with stuttering is also becoming more prevalent. For instance, apps such as BroiStu and Speakup provide users with the ability to record their speech status and visualize their progress. These apps seek to bridge the gap between traditional methods and automated solutions by offering practical tools for daily speech monitoring and stuttering treatment[24,28,29,41,42].

Conclusion

Preliminary evidence suggests that technological rehabilitation approaches particularly those utilizing VR may offer promising benefits in the treatment of stuttering. VR provides individuals with opportunities to develop coping strategies and engage in simulated social interactions within a controlled and safe environment, where they can be gradually exposed to speech-related stressors resembling real-life situations.

Research has indicated that VR environments can be useful for examining both physiological responses and subjective distress levels, while also enabling the replication of realistic speech scenarios through structured interaction settings. Specifically, studies involving school-age children and adolescents have shown that virtual classroom simulations can elicit stress responses comparable to those experienced during real audience exposure, suggesting potential utility in addressing social anxiety symptoms. Moreover, VR-based interventions have been associated with reductions in both stuttering severity and perceived anxiety during speaking and reading tasks.

Taken together, these findings point to the potential of VR-supported rehabilitation as a complementary method in the management of social anxiety associated with stuttering; however, further high-quality, controlled studies are needed to confirm these outcomes and establish clinical efficacy.

Recommendations

It is of significant importance to conduct a comprehensive investigation and development of technological rehabilitation as a treatment for stuttering. It is essential to tailor virtual reality environments to suit individual requirements, to develop applications that resonate with different age groups and to evaluate the efficacy of these applications. Furthermore, while the long-term effects of VR therapy represent a crucial area of monitoring for identifying permanent changes in the treatment process, the integration of VR with traditional therapy methods also warrants further investigation.

Furthermore, additional research is required to ascertain the potential advantages of mobile applications and telerehabilitation in the treatment of stuttering, with a view to enhancing the accessibility of these technologies. Such technologies have the potential to provide greater accessibility to therapy, particularly for individuals residing in remote areas or with limited access to face-to-face therapy. In order to ensure the effective utilisation of technological rehabilitation, it is imperative that scientific studies in these fields are intensified and a multidisciplinary approach is adopted.

REFERENCES

1. Bloodstein O. The development of stuttering. I. Changes in nine basic features. *J Speech Hear Disord*. 1960;25:219-237. doi: 10.1044/jshd.2503.219.

2. Wingate ME. A standard definition of stuttering. *J Speech Hear Disord*. 1964;29:484-489.

3. Yaruss JS. Application of the ICF in fluency disorders. *Semin Speech Lang*. 2007;28(4):312-322. doi: 10.1055/s-2007-986528.

4. Guitar B. *Stuttering: An Integrated Approach To Its Nature and Treatment*. Pennsylvania: Lippincott Williams & Wilkins; 2013.

5. Craig A, Hancock K, Tran Y, Craig M, Peters K. Epidemiology of stuttering in the community across the entire life span. *J Speech Lang Hear Res*. 2002;45(6):1097-1105.

6. Yairi E, Ambrose NG. Early childhood stuttering I: Persistency and recovery rates. *J Speech Lang Hear Res*. 1999;42(5):1097-1112. doi: 10.1044/jslhr.4205.1097.

7. Smith A, Weber C. How stuttering develops: The multifactorial dynamic pathways theory. *J Speech Lang Hear Res*. 2017;60(9):2483-2505.

8. Walden TA, Frankel CB, Buhr AP, Johnson KN, Conture EG, Karrass JM. Dual diathesis-stressor model of emotional and linguistic contributions to developmental stuttering. *J Abnorm Child Psychol*. 2012;40(4):633-644. doi: 10.1007/s10802-011-9581-8.

9. Ward D. *Stuttering and Cluttering: Frameworks for Understanding and Treatment*. United Kingdom: Psychology Press; 2017.

10. Stieglitz T. Neuroprothetik und neuromodulation. *Bundesgesundheitsblatt-Gesundheitsforschung- Gesundheitsschutz*. 2010;53:783-790.

Istanbul Gelisim University Journal of Health Sciences (IGUSABDER) is indexed by TUBITAK ULAKBIM TR Index.
Web site: https://dergipark.org.tr/en/pub/igusabder
Contact: igusabder@gelisim.edu.tr

11. Bloodstein O, Bernstein-Ratner N. *A Handbook on Stuttering*. 6th ed. New York: Thomson-Delmar; 2008.

12. Ambrose NG, Yairi E, Loucks TM, Seery CH, Throneburg R. Relation of motor, linguistic and temperament factors in epidemiologic subtypes of persistent and recovered stuttering: Initial findings. *J Fluency Disord*. 2015;45:12-26.

13. Cangi ME, Toğram B. Stuttering therapy through telepractice in Turkey: A mixed method study. *Journal of Fluency Disorders*. 2020:66:105793.

14. Yairi E, Ambrose N. Epidemiology of stuttering: 21st century advances. *J Fluency Disord*. 2013;38(2):66-87. doi: 10.1016/j.jfludis.2012.11.002.

15. Månsson H. Childhood stuttering: Incidence and development. *Journal of Fluency Disorders*. 2000:47-57.

16. Klompas M, Ross E. Life experiences of people who stutter, and the perceived impact of stuttering on quality of life: Personal accounts of South African individuals. *J Fluency Disord*. 2004;29(4):275-305. doi: 10.1016/j.jfludis.2004.10.001.

17. Bricker-Katz G, Lincoln M, McCabe P. Older people who stutter: Barriers to communication and perceptions of treatment needs. *Int J Lang Commun Disord*. 2010;45(1):15-30. doi: 10.3109/13682820802627314.

18. Ma Y, Oxley JD, Yaruss JS, Tetnowski JA. Stuttering experience of people in China: A cross-cultural perspective. *J Fluency Disord*. 2023;77:105994.

19. Boyle MP, Milewski KM, Beita-Ell C. Disclosure of stuttering and quality of life in people who stutter. *J Fluency Disord*. 2018;58:1-10. doi: 10.1016/j.jfludis.2018.10.003.

20. Hunsaker SA. The social effects of stuttering in adolescents and young adults. [master's thesis]. Carbondale, ABD: Southern Illinois University Carbondale; 2011.

21. Castelli L, Iacovelli C, Fusco A, et al. The role of technological rehabilitation in patients with intensive care unit weakness: A randomized controlled pilot study. *J Clin Med*. 2023;12(2612). doi: 10.3390/jcm12072612.

22. Colombo V, Aliverti A, Sacco M. Virtual reality for COPD rehabilitation: A technological perspective. Pulmonology. 2022;28(2):119–33. doi: 10.1016/j.pulmoe.2020.11.010.

23. Ain Q, Imtiaz R. The role of technology in speech-language therapy: Perceptions, effectiveness, and challenges in a resource-limited setting. *J Health Rehabil Res*. 2025;5(1):1–8. doi: 10.61919/jhrr.v5i1.1754.

24. Walkom G. Virtual reality exposure therapy: To benefit those who stutter and treat social anxiety. *2016* International conference on interactive technologies and games (ITAG). IEEE, 2016.

25. Brundage SB, Graap K. Virtual reality: An exciting new tool to enhance stuttering treatment. *Perspectives on Fluency and Fluency Disorders*. 2004;14(2):4-9.

26. Anderson P, Rothbaum BO, Hodges LF. Virtual reality exposure in the treatment of social anxiety. *Cognitive and Behavioral Practice*. 2003;10(3):240-247.

27. Nussbaum R, Kelly C, Quinby E, Mac A, Parmanto B, Dicianno BE. Systematic review of mobile health applications in rehabilitation. *Arch Phys Med Rehabil*. 2019;100(1):115-127.

28. Prasanna V, Perera I. Speakup – a mobile application to train and overcome stuttering. In: 2019 19th International Conference on Advances in ICT for Emerging Regions (ICTer); 3-4 September, 2019; Colombo, Sri Lanka.

29. Demarin I, Leko L, Škrobo M, Germano H, Macedo P, Madeira RN. The impact of stuttering; how can a mobile app help?. In: 17th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS 2015); 26-28 October, 2015; Lisbon, Portugal.

30. Leochico CFD, Espiritu AI, Ignacio SD, Mojica JAP. Challenges to the emergence of telerehabilitation in a developing country: A systematic review. *Front Neurol*. 2020;11:1007. doi: 10.3389/fneur.2020.01007.

31. Rosen MJ. Telerehabilitation. *Telemed JE Health*. 2004;10(2):115-117.

32. Brundage SB, Graap K, Gibbons KF, Ferrer M, Brooks J. Frequency of stuttering during challenging and supportive virtual reality job interviews. *J Fluency Disord*. 2006;31(4):325-339. doi: 10.1016/j.jfludis.2006.08.003.

33. Brundage SB, Brinton JM, Hancock AB. Utility of virtual reality environments to examine physiological reactivity and subjective distress in adults who stutter. *J Fluency Disord*. 2016;50:85-95. doi: 10.1016/j.jfludis.2016.10.001.

34. Moïse-Richard A, Ménard L, Bouchard S, Leclercq AL. Real and virtual classrooms can trigger the same levels of stuttering severity ratings and anxiety in school-age children and adolescents who stutter. *J Fluency Disord*. 2021;68:105830.

35. Almudhi A. Evaluating adaptation effect in real versus virtual reality environments with people who stutter. *Expert Rev Med Devices*. 2022;19(1):75-81.

36. Brundage, Shelley B. Virtual reality augmentation for functional assessment and treatment of stuttering. *Topics in Language Disorders*. 2007;27(3):254-271.

37. Brundage SB, Hancock AB. Real enough: Using virtual public speaking environments to evoke feelings and behaviors targeted in stuttering assessment and treatment. *Am J Speech Lang Pathol*. 2015;24(2):139-149. doi: 10.1044/2014_AJSLP-14-0087.

38. Chard I, van Zalk N. Virtual reality exposure therapy for treating social anxiety: A scoping review of treatment designs and adaptation to stuttering. *Front Digit Health*. 2022;4:842460. doi: 10.3389/fdgth.2022.842460.

39. Chard I, Van Zalk N, Picinali L. Virtual reality exposure therapy for reducing social anxiety in stuttering: A randomized controlled pilot trial. *Front Digit Health*. 2023;5:1061323.

40. Chard I, Van Zalk N, Picinali L. Virtual reality exposure therapy for reducing social anxiety associated with stuttering: The role of outcome expectancy, therapeutic alliance, presence and social presence. *Frontiers in Virtual Reality*. 2023;4:1159549.

41. Yılmaz Aydoğan S. Kekeleyen Ergenlerde Sanal Gerçeklik Kullanılarak Maruz Bırakma Sonuçlarının İncelenmesi. [master's thesis]. İstanbul, Türkiye: Eğitim Bilimleri Enstitüsü; 2022.

42. Madeira RN. Building on mobile towards better stuttering awareness to improve speech therapy. In: 11th International Conference on Advances in Mobile Computing & Multimedia (MoMM 2013); 2-4 December, 2013; Vienna, Austria.