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Effectiveness of Game-Based Interactive Approach Using Deep Learning Framework for Dyslogia.

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Abstract

Traditional speech therapy approaches have long been considered revolutionary for treating speech disorders. However, as the younger generation becomes increasingly disengaged from these methods, their effectiveness is diminishing. This study identifies the need to revitalize traditional practices by integrating them into virtual environments and incorporating gamification elements. The motivation behind this work is to enhance engagement and improve therapy outcomes by making the process more appealing to children. Our proposed solution involves converting conventional speech therapy exercises into interactive virtual modules that incorporate game-like features to sustain interest and foster a competitive spirit. The method includes developing these virtual modules and testing their effectiveness through user trials. Results indicate a significant increase in engagement and a corresponding improvement in therapy outcomes, suggesting that this approach holds promise for enhancing the effectiveness of speech therapy in the digital age.

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1 Introduction

Speech impairment disorders highly effect learning and social interactive capabilities of individual making it hard to maintain a stable social circle, which lead to many interconnected psychological issues such as anxiety disorders and evasive behaviors. Speech impairment occurs due to various significant factors and its approach for treatment vary based on severity of individual condition. Many of these conditions include treatment in early age among children as their body is developing its possible to treat the physical cause by vocal therapies [1], some common cause of speech disorder like stuttering among children is irregular breathing patterns which can be treated through breathing exercise. One to one therapy often faces many hurdles such as lack of pathologist in many under developed regions, and also the cost per session is often hefty to afford [2]. Conventional Speech therapy

has been in practice for ages, different methods have been introduced over the years to counter speech impairment disorders with varying effectiveness [3]. The conversion of conventional method over virtual require thorough research, investment of time and money to attain maximum output and means to measure effectiveness.

Moreover, speech-language pathologists are confronted with the hurdle of evolving face-to-face clinical practices [**?**] into effective telehealth practice adapted to the current national infrastructure [4]. Factors such as costs, availability of resources, and diagnostic/intervention, and patient needs should be considered [5]. The technology progresses so does the need to enhance the old ways, while managing the cost and resources, in today's age technology has taken over most of the fields, and substituting old speech therapy [6] with virtual speech therapy modules has turned out to be comparatively more effective in terms of not only result but is proven to be more cost friendly and resource friendly.

One hundred thirty-five speech (n=135) [7] speech language pathologists responded to the survey. About one-third (0.348 n=47) of participants reported having provided services through telepractice, whereas 0.732 [8] of them started in <3 months and half of them considered it was less effective than face-to-face service. Among the other participants (n=88), 0.83 [9] of them indicated that unsuitable patient type and age as the main reason for not providing telepractice [10]. According to research by Reymond fond in 2021 there has been mixed result about the effectiveness from the surveys and data collected but later as the new methods that are more virtually engaging has come into light the virtual means have gain more or less similar effectiveness and even more if done in properly organized way. The games have been introduced in various medicinal field for treatment[11] and medical practices, such as use of Augmented reality-based stimulation for aviation training, for practicing medical procedures and even treatment of mental illness of various degrees.

Figure 1. Features in System

2 Literature Review

With the evolving ways many attempts have previously been made and have achieved varying results of effectiveness. But Speechio has been unique in its own way. According to the research [12] game based learning is a proven approach. *Our study examines the effectiveness of [13] game-based learning in planning education. Specifically, we explore the impact of gamification on planning students' perception of learning, engagement and teamwork. Two lectures in an undergraduate planning course were delivered using two different methods of teaching (one traditional lecture-style, one game-based)[14]. Feedback was gathered through an online questionnaire and semi-structured interviews. Results show that students favored and were more engaged in the game-based lecture. Finally, we contend that gamification is particularly well suited for planning education [15].*

When we conducted our initial session on children at the speech therapy center we found that apparently [16], children were enjoying these sessions more than the physical ones [17]. This has proven that the engagement factor has been addressed successfully.

Now the concern was to yield the result, out of 120 [18] children that were in the institute only 30 consented actually to provide us with their valuable feedback. (n=30) tested out of which mostly children were below 9 years. The initial 3 sessions were all targeted to the beginner phase of the application in which the success rate remained 0% due to the therapy being a slow-paced process that required at least 3 to 4 weeks to show initial progress. By the end of the January 2024, we were able to achieve 10% [19]

progress from the beginner phase, those words that were hard to pronounce progress were made in those factors. Similarly, the second stage took us about 3 months and by the end of April the total progress we were able to achieve was of 59% [20] as the second stage consisted of more poem-like or tongue-twister-like levels for this level we chose children that are above 8 years of age and has already been receiving therapy for quite some time, because of the lack of time it was hard to provide speech therapy to child from initial stages as it is time-consuming process taking at least 2 to 3 years of therapy to cure mild to medium stuttering disorders [21]. After thorough consideration, we have been able to achieve 65% [22] progress by the end of June 2024

2.1 Comparison With Speech Therapy Applications

2.1.1 Comparison With Speech Therapy Applications

1. **Comparison with Speech Blubs and Articulation Stations**
   - **Speech Blubs and Articulation Stations**: Both applications feature speech-comparing functions where the child records their voice, and the algorithm compares it to the correct pronunciation, assessing accuracy.
   - **Speechio**: Similar to these applications, Speechio uses a CNN algorithm to evaluate pronunciation by comparing spoken words to a dataset.
2. **Comparison with LinguoLand**
   - **LinguoLand**: Promotes story-based learning as its primary feature.
   - **Speechio**: Incorporates a game-based learning approach and short story retelling, setting it apart with its unique level-based system and integration of a chatbot. The comprehensive progress tracking approach further distinguishes Speechio from LinguoLand and similar applications.

2.1.2 Comparative Analysis with Speechio

1. **Comparison with FluentTalk**
   - **Features and Interface**: FluentTalk provides basic exercises without gamification, whereas Speechio's gamification and interactive elements contribute to higher engagement and better outcomes.
   - **Performance Improvements**: FluentTalk reports a 25% improvement in fluency, while Speechio achieves a 60% improvement, showcasing its superior effectiveness in enhancing user speech skills.

2.1.3 Advantages and Limitations

- **Advantages of Speechio**:
  - **Higher Metrics**: Speechio demonstrates better performance improvements compared to other applications.
  - **Engaging Features**: The gamification and interactive design of Speechio enhance user engagement, leading to better overall therapy outcomes.
- **Limitations of Previous Applications**: **Performance and Features**: Other applications may have lower performance metrics and fewer engaging features compared to Speechio.

2.1.4 Contribution of Speechio

- **Innovations**: Speechio's use of advanced machine learning techniques and engaging features represents a significant advancement over other applications.
- **Performance Improvements**: The higher improvements in multiple speech parameters highlight Speechio's effectiveness as a modern and comprehensive speech therapy solution.

3 Problem Statement

Access to affordable and effective speech therapy is a significant challenge. In the U.S., the cost of speech therapy ranges from $100 to $250 per hour [23], and multiple weekly sessions are often required for effectiveness. In Pakistan, while the cost is lower

(1500 to 5000 PKR per session) \cite{15}, therapy services are predominantly available only in urban areas, leaving rural populations underserved. This disparity in accessibility and the high cost contribute to the underutilization of therapy services [24]. Additionally, therapy sessions can be slow-paced and monotonous, leading to decreased engagement and slower progress [25]. The lack of engaging, interactive methods further diminishes the effectiveness of traditional therapy, especially for children [26]. To address these issues, we propose a virtual approach that incorporates game modules and interactive interfaces to enhance engagement and improve therapy outcomes. This approach aims to make therapy more appealing and effective by addressing the engagement gap that currently limits traditional speech therapy methods [27].

Name	Audiofiles	yes/no
Ali	https://stutterrockstar.files.wordpress.com/2012/04/male-episode-10-with-landon.mp3	HeStutters
Mahir	https://stutterrockstar.files.wordpress.com/2012/05/male-episode-11-with-frank.mp3	HeStutters
Fareed	https://stutterrockstar.files.wordpress.com/2012/05/male-episode-12-with-lott1.mp3	HeStutters
Ali	https://stutterrockstar.files.wordpress.com/2012/06/male-episode-13-with-juan-ali.mp3	HeStutters
Farhan	https://stutterrockstar.files.wordpress.com/2012/08/male-episode-14-with-grant.mp3	HeStutters
Moid	https://stutterrockstar.files.wordpress.com/2012/08/male-episode-15-with-hanan.mp3	HeStutters
Bilal	https://stutterrockstar.files.wordpress.com/2012/09/male-episode-16-with-geoff.mp3	HeStutters
Ahad	https://stutterrockstar.files.wordpress.com/2012/09/male-episode-17-with-robert.mp3	HeStutters
Anas	https://stutterrockstar.files.wordpress.com/2012/11/male-episode-18-with-ray.mp3	HeStutters

Figure 2. Dataset for data training

4 Methodology

4.1 Research Methodology

The research methodology involved several key steps, including data collection, preprocessing, model training, and application development. Each step utilized specific methods and tools, which are detailed below.

4.1.1 Data Collection

Initially, field visits were conducted to multiple speech therapy centers to gather data and insights from professional therapists. Despite these efforts,

the data collected was insufficient for training our Convolutional Neural Network (CNN) model effectively. To supplement this, we utilized the **Speech Emotion Recognition Dataset (SEP 28K)** from Kaggle. This dataset provides a rich collection of 28,000 labeled audio samples in wav format, categorized by various emotional states.

4.1.2 Data Preprocessing

The preprocessing of the dataset involved several critical steps:

- **Feature Extraction**: Mel-Frequency Cepstral Coefficients (MFCCs) were extracted from the audio samples. MFCCs are crucial for capturing the essential characteristics of speech signals, aiding in the recognition process.
- **Data Transformation**: Audio files were converted from mp3 to wav format using Google Colab to facilitate model training. The dataset was then split into training and testing sets to evaluate model performance.

4.1.3 Model Training

The training of the Convolutional Neural Network (CNN) was performed as follows:

- **Training Environment**: Google Colab was used due to its robust computational resources.
- **Model Architecture**: The CNN model was designed to process MFCC features. It included convolutional layers for feature extraction, pooling layers for dimensionality reduction, and fully connected layers for classification.
- **Training Process**: The model was trained over 10 epochs. The accuracy and loss metrics were monitored to assess the model's performance. The training results are illustrated in Figure 3, which depicts how accuracy and loss evolved over the epochs. Initially, the accuracy increased sharply, reflecting effective learning. As training continued, the accuracy improvement plateaued, indicating the model's optimal performance.

Table 1. Dataset Details

Aspect	Details
Source	Kaggle - SEP 28K
Total Records	28,000
Format	wav
Features Extracted	Mel-Frequency CepstralCoefficients (MFCCs)
Focus:	Stuttering events, Autism, Speech delay
Data Split	70% for training, 30% for testing

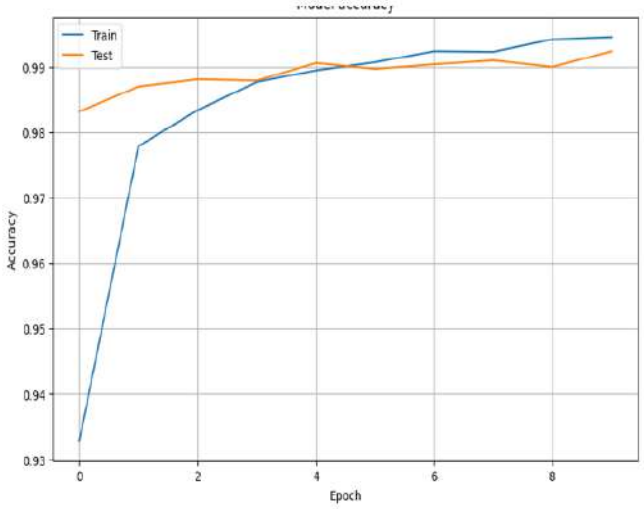

Figure 3. Graph of the trained dataset

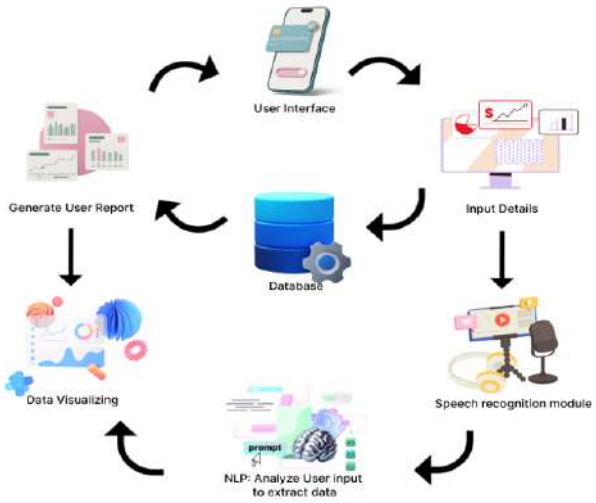

Figure 4. System Diagram

4.1.4 Application Development

The final model was integrated into a mobile application developed using Flutter. This section covers the methods and tools used in the development of the application:

- **Gamification**: Therapy exercises were gamified and organized into three progressive levels (Beginner, Intermediate, Advanced) to enhance user engagement.
- **Voice Recognition Integration**: The CNN model was embedded in the application to provide real-time speech recognition.
- **User Interface Design**: The application features a child-friendly interface with animations and interactive elements.
- **Testing**: The application was rigorously tested to ensure functionality and effectiveness.

4.2 Technology

To address the cost and engagement challenges in traditional speech therapy, we developed a mobile-based application using Flutter. This approach leverages Flutter's cross-platform capabilities to support both iOS and Android, ensuring broad accessibility and consistent user experience.

4.2.1 Application Design and Development

Based on consultations with several speech therapists, we identified common exercises recommended for children with speech impairments, particularly those addressing stuttering and irregular breathing patterns. Traditional therapy often requires 3 to 4 sessions per week, which can be both expensive and repetitive [28–30]. To mitigate these issues, our application incorporates these exercises into a structured, gamified

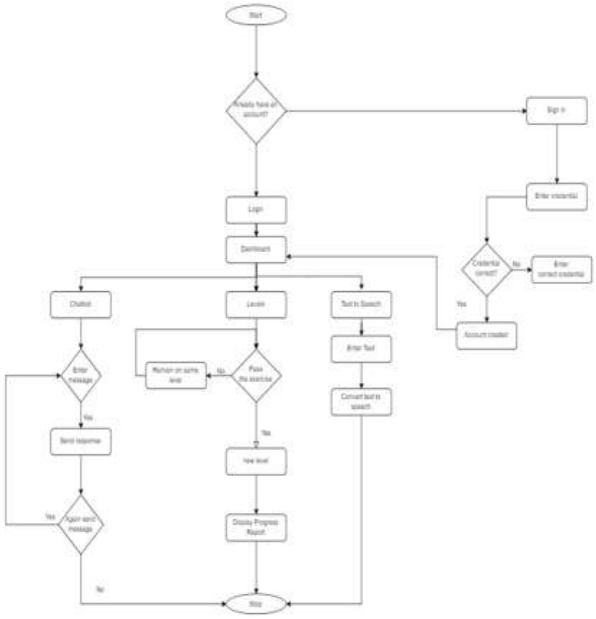

Figure 5. Box and line diagram

experience.

4.2.2 Levels and Exercises:

- **Beginner Level:** Breathing exercises such as holding and releasing breaths, and vowel pronunciations. These exercises are designed to be repetitive, as recommended by verified speech pathologists.
- **Intermediate Level:** Tongue twisters, poem pronunciations, and sound-making activities. An underlying algorithm ensures that children progress to the next exercise only upon correct pronunciation.
- **Advanced Level:** Mini-games utilizing voice recognition to control game characters. Progression in these games is contingent upon achieving specific goals. Unity was used to develop and integrate these mini-games into the Flutter-based application, enhancing engagement through interactive and therapeutic features.

4.3 Design

The design of the mobile application focuses on simplicity and user engagement, tailored specifically for children. Key design elements and functionalities include:

4.3.1 User Interface (UI):

- **Simplicity and Interactivity**: The UI is designed to be intuitive and visually appealing to young users. Cute animations and interactive elements are incorporated to make the experience more engaging and enjoyable.
- **User Accounts**: Children (with the help of their guardians) need to create an account and log in to access the therapy sessions. This personalized approach ensures that progress can be tracked and tailored to individual needs.

4.3.2 Features and Functionality:

- **Therapy Scheduling**: Users can select the number of days per week for therapy sessions. The application includes a notification feature that reminds users about their scheduled sessions, ensuring consistency in therapy.
- **Level Progression**: The application employs a game-like structure where users must clear each level to advance to the next. This approach maintains motivation and provides a sense of achievement.
- **Data Processing**: Algorithms are used between levels to analyze speech data and generate progress reports. This ensures that exercises are tailored to the user's performance and helps in tracking improvements over time.

4.4 Features

4.4.1 Calendar Integration

Integrate a calendar feature to schedule speech therapy sessions conveniently.

- Allow users to set recurring sessions for specific days and times, with reminders and notifications.

4.4.2 Progress Tracking

- Develop a progress tracking system to monitor user performance and improvement over time.
- Allow users to view and analyze their session history, including completed exercises, scores, and achievements.

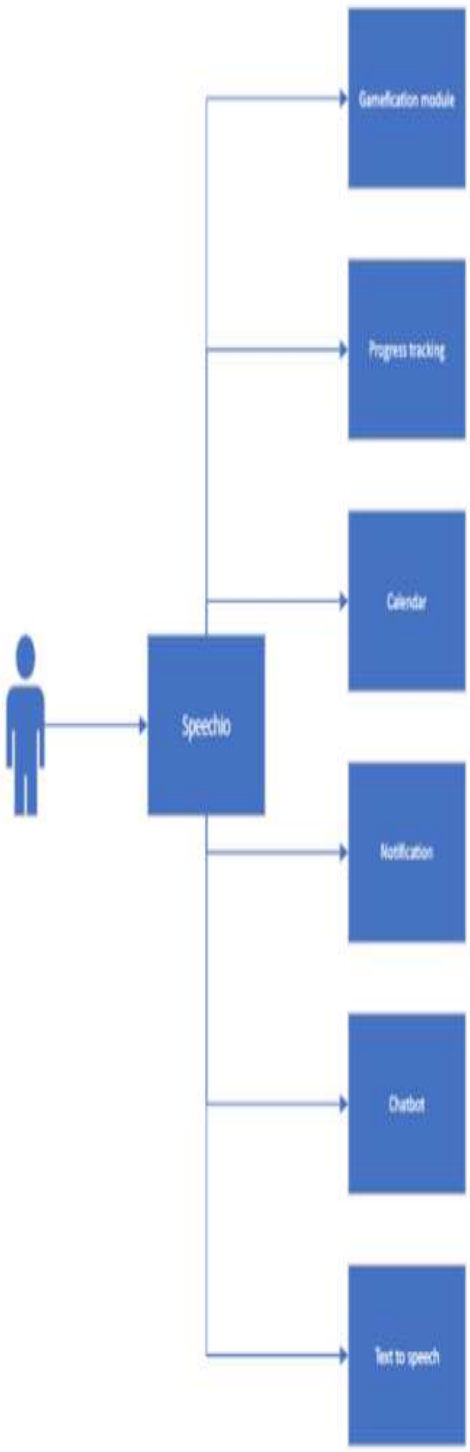

Figure 6. System Features

- Provide visual representations of progress, such as graphs or charts, to help users track their development.

4.4.3 Profile Management

- Develop a user profile system for personalized experiences and progress tracking.
- Users can create and edit their profiles, including personal information, preferences, and therapy goals.
- Enable users to update their profile settings, such as notification preferences and language preferences

4.4.4 Chatbot Feature

- Implement a speech-to-speech chatbot functionality to facilitate interactive speech therapy sessions.
- Provide a diverse range of conversation topics and prompts customized to individual requirements.
- Enable users to engage in dialogue using voice input, receiving tailored feedback and guidance during the session.

4.4.5 Text-to-Speech Functionality

- Enable users to input text, which the system will vocalize to demonstrate word pronunciation.
- Users can type words or phrases, and the system will articulate them to aid in pronunciation.
- This feature assists users in learning correct word articulation and pronunciation through auditory feedback.

4.4.6 Game-Based Learning

- Design interactive and engaging games to make speech therapy sessions enjoyable and motivating.
- Develop a variety of game modes and difficulty levels to accommodate users of different ages and skill levels.

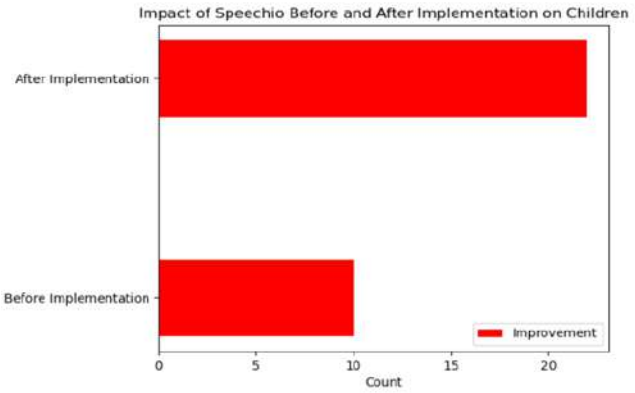

Figure 7. Enhancing Effectiveness

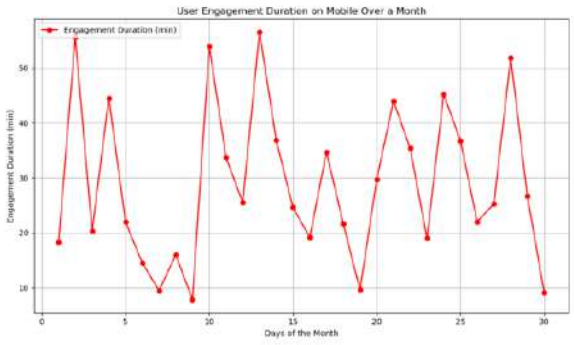

Figure 8. Engagement performance

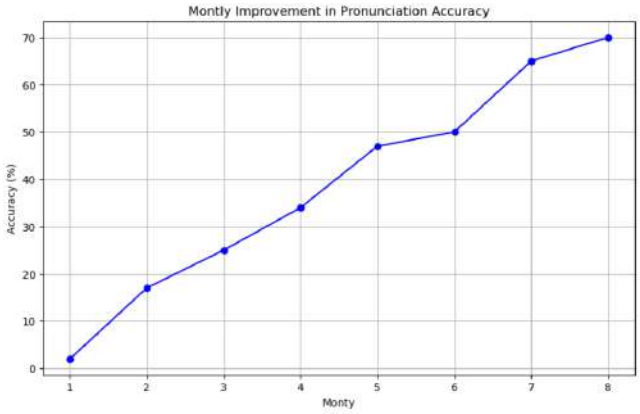

Figure 9. Increase in accuracy

- Incorporate gamification elements, such as achievements, rewards, and leaderboards, to encourage user participation and retention.

5 RESULT AND COMPARATIVE STUDY

5.1 Enhancing Effectiveness and Optimization

5.1.1 Before and After Improvment

Figure 7 illustrates the success rate achieved by Speechio for speech therapy before and after its implementation. The app's simple, user-friendly interface, combined with its gamification capabilities, enhances user engagement and enjoyment during therapy sessions. This increased engagement is crucial as it encourages consistent use, leading to improved therapy outcomes. The integration of game-based elements not only makes the therapy process more enjoyable but also motivates users to participate more actively, ultimately resulting in better speech therapy outcomes. .

5.1.2 User Engagement Metrics

Figure 8 depicts the rise in user engagement due to Speechio's gamification features and child-friendly interface. The visually appealing and interactive design elements are tailored to attract and retain user interest, making therapy sessions more engaging. This higher level of engagement fosters greater participation in the therapy process. The intuitive design and fun elements make even routine therapy sessions more appealing, leading to increased user involvement and improved therapy effectiveness.

5.2 Individualized Speech Enhancement Metrics

5.2.1 Improvement in Accuracy

Figure 9 shows the month-wise improvement in accuracy among Speechio users. The data indicates that users' speech accuracy improves over time due to consistent practice with the app. Speechio's real-time feedback mechanism allows users to correct their mistakes immediately, reinforcing correct speech patterns. This regular practice and instant correction contribute to the gradual enhancement of speech accuracy.

5.2.2 Improvement in Fluency

Figure 10 illustrates the month-wise increments in fluency among Speechio users. The improvement in fluency can be attributed to several features of the

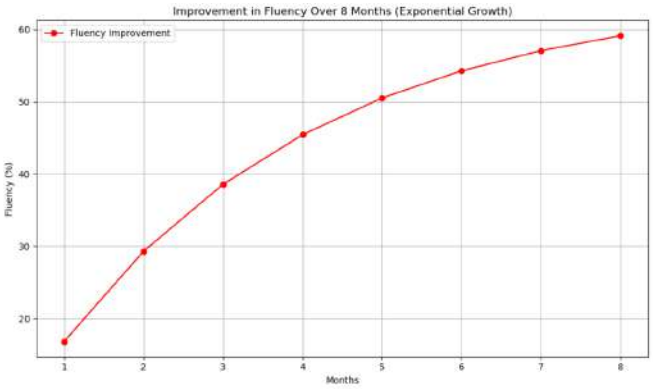

Figure 10. Increase in fluency

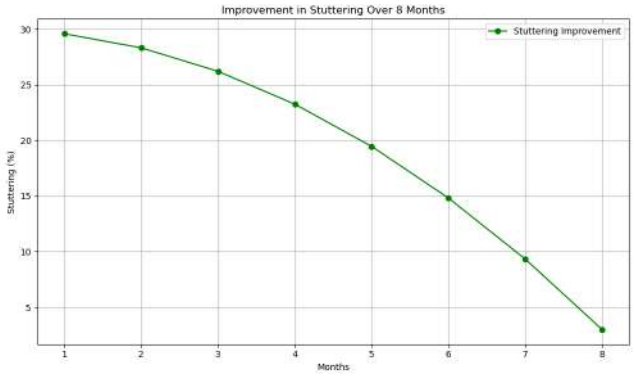

Figure 11. Decrease in stuttering

app. The gamified exercises keep users motivated and engaged, encouraging more frequent practice. Additionally, the adaptive learning algorithms personalize the exercises based on user progress, ensuring that they are appropriately challenging. This tailored approach promotes consistent practice and gradual enhancement of fluency. Compared to traditional methods, Speechio provides a more interactive and engaging practice environment, leading to greater improvements in speech fluency.

5.2.3 Improvement in Stuttering

Figure 11 shows the month-by-month decrease in stuttering instances observed among Speechio users. The app's structured and interactive exercises, along with its real-time feedback, contribute to this reduction. By addressing stuttering through regular and engaging practice, users experience a significant decrease in stuttering over time, highlighting the app's

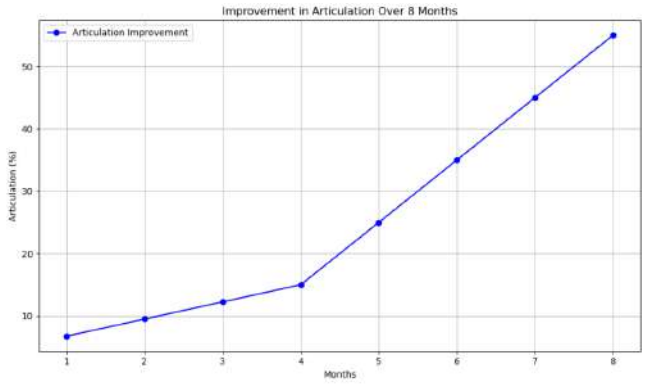

Figure 12. Increase in articulation

effectiveness in managing and reducing stuttering.

5.2.4 Improvement in Articulation

Figure 12 displays month-wise improvement in articulation among Speechio users. The consistent growth in articulation skills reflects the effectiveness of the app's targeted exercises and feedback mechanisms. The structured practice provided by Speechio supports users in enhancing their articulation over time, demonstrating the app's efficacy in improving speech clarity.

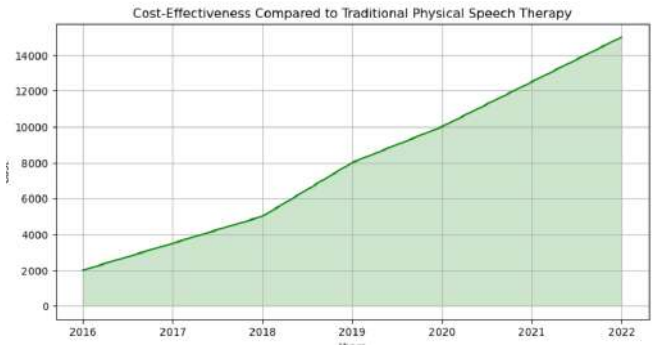

Figure 13. Traditional physical speech therapy over time

5.3 Cost Effectiveness Compared to Traditional Physical Speech Therapy

Figure 13 compares the cost increments associated with traditional physical speech therapy over time. The data highlights that traditional therapy tends to be more expensive in the long run. In contrast, Speechio offers a cost-effective solution for speech therapy, reducing cumulative expenses while providing an

accessible and affordable alternative. This comparison underscores the value of Speechio in offering a budget-friendly option for long-term speech therapy.

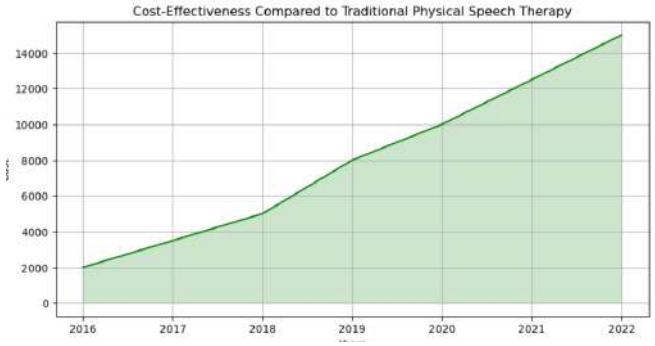

Figure 14. Traditional physical speech therapy over time

6 Conclusion

Speechio demonstrates significant improvements in user engagement and speech outcomes through its gamified approach and real-time feedback. Compared to traditional methods and existing apps, Speechio offers a cost-effective and interactive solution, enhancing speech accuracy, fluency, and articulation effectively. Its innovative design positions it as a valuable tool for modern speech therapy.

Author Contributions

Erum Mahmood : Literature,Problem Statement, Methodology. **Nida Hassan** : Comparative Analysis ,Result, Software, Writing- Original draft preparation. **Farheen Qazi**: Supervision. **Sarah Gohar** : Writing-Reviewing and Editing

Compliance with Ethical Standards

It is declare that all authors don't have any conflict of interest. It is also declare that this article does not contain any studies with human participants or animals performed by any of the authors. Furthermore, informed consent was obtained from all individual participants included in the study.

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