Designing a Serious Game for Speech Rehabilitation in Children with Speech Sound Disorder: A Feasibility Study

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Original Article

Abstract

Introduction: This paper presents a serious game (SG) that helps children with speech disorders overcome their challenges in a fun and engaging way. The game utilizes speech recognition and speech-to-text technology, along with visual feedback, to provide a comfortable and interesting experience for the child. Additionally, the game can be used both in therapy sessions with a therapist and at home under supervision, with game results being recorded and sent to the therapist for analysis.

Materials and Methods: The game was developed using Unity 3D game engine. The game character and environment were designed using Agisoft Software and Autodesk 3D Max. Then, 10 game experts from the Faculty of Multimedia, including university professors and game design masters' students, were asked to play the primary prototype of the game and complete a questionnaire. Based on our experts' opinions, we modified certain aspects of the game, such as improving visual feedback and smoothing out character movement.

Results: Of the 10 participants who played the game, 80% played flawlessly. The game was effective, but 20% of experts encountered technical issues with in-game functions. The problem was due to incompatibility with their system, so an alternative method was recommended and the issue was resolved.

Conclusion: According to the experts, the game has a promising future for use in clinics and the system may provide a beneficial rehabilitation platform for children with speech disorders. Further evaluations are required to achieve better results and confirm its efficiency.

Keywords: Speech therapy; Rehabilitation; Video games; Speech disorders

Introduction

The term speech sound disorders (SSDs) encompasses any issue related to the perception, motor production, or phonological representation of speech sounds and segments (1). There are two main types of SSDs, organic and functional. Organic SSDs are caused by motor/neurological disorders, childhood apraxia of speech, dysarthria, structural abnormalities, and sensory or perceptual disorders (e.g., hearing loss). Functional SSDs are related to the linguistic aspects of speech production with unknown etiology (2).

Speech-language pathologists (SLPs) play a central role in the screening, assessment, diagnosis, and treatment of people with SSDs. For decades, researchers have investigated the clinical efficacy of administrating rehabilitative games. Games have always played an important role in the improvement of children's behaviors in society. Medical and paramedical professionals have recently taken the advantage of the positive features of games, including but not limited to motivation, repetition, and selectivity, and have incorporated gamification into some therapeutic interventions (3). Some believe that games provide a window into the potential skills of the children, which is why therapists adopt game therapy approaches in early psychoanalytical approaches (4).

Serious games (SGs) are games designed with a goal other than pure entertainment, such as

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healthcare, rehabilitation, education, and injury prevention (5). Researches support incorporating video games into physical rehabilitation programs as most people prefer them to traditional exercises (6). Video games offer several plus points such as preventing monotony and boredom, increasing motivation, providing direct feedback, and facilitating double task training. The quality of video games is primarily based on game design with the player's amusement being a critical aspect. These games are also evaluated based on reviews and rating (7).

There are some good games available for children who have speech or hearing impairments. One such game is called Into the forest which is a 3D game (8) that challenges the player to find objects and say their names. Using speech-to-text applications, the game evaluates the child's pronunciation. Game designers are also incorporating interesting technologies, such as tongue motion-tracking (9), where the player uses a speech apparatus as the game controller. The most advanced version of this technology has been proposed by Haworth et al. (10). Additionally, there are games that are designed for children to play independently, helping them feel more comfortable and less anxious about their therapy sessions (11). For example, the game proposed by Boothroyd et al. (12) features a child character who serves as the player's friend, helping him/her to improve his/her speech and communication skills.

There exist numerous computer and mobile games specifically created for children with SSD. Take Home Game is one of such games which is among the earliest video games designed to assess and improve auditory perception in children with auditory impairment and disorder (12). This game has a character that produces a voice for the child, who must then listen and choose the correct answer. However, the game is not very engaging due to its black and white visuals and lack of interesting events. To make games more appealing to children, designers should use new and creative elements. For instance, in Into the Forest, players can control the avatar using voice commands or keyboard arrow keys (8). When the avatar collides with an object, the system plays its correct pronunciation and the child must listen and repeat it. Green and red arrows indicate proximity to the next object and a score of 1 to 100% is given for pronunciation accuracy. The game ends when all objects are found and pronounced correctly. The game Saray (13) also uses voice commands for avatar movement.

A simpler form of Into the Forest is a 2D card game (14) in which the child must correctly pronounce the word shown on the card. The system records and compares the child's voice to its database. Talking to Teo (15) uses storytelling to enhance the game's appeal to Spanish-speaking children. It is like a script book. Voiced consonants must be pronounced correctly to help the character continue the story.

Mobile phones offer a vast selection of video games, including Apraxia World (16), a game in which players control a monkey to collect stars and coins on his way. The stars are in fact the speech exercises, and to receive one, the player must correctly pronounce the word associated with a picture (of animals, fruits, and etc.). Compared to computer games, mobile games have more extensive range of options, for example, there are games (17) which challenge the player to pronounce as many words as possible to score points, such as Little Bee Speech (18), Pocket SLP (19), Smarty Ears Apps (20), and Tiga Talk (21). However, few games provide feedback on speech production, even though they may have excellent designs.

The present text introduces a SG designed for children with SSD. It is noteworthy that this game is the first speech therapy game tailored to Persian-speaking children in Iran. It should be noted that the current essay has been extracted from the master's thesis of the first writer.

Materials and Methods

In this study, a serious game was developed to imitate the exercises used in traditional speech therapy, such as producing syllables, words, and combined-words, with the added benefit of the immersive virtual environment that engages the child to the point where they are not solely focused on the rehabilitation session. This serious game is called Parak, and is designed to help children with SSD restore their ability to easily articulate syllables and words. While the game's primary purpose is to recover speech articulation, it also promotes cognitive and perceptual skills including visual acuity. This means that although the idea of this game is mainly to work on speech therapy, it also trains cognitive and perceptive capabilities of the users.

Design principles

The goal of the present study was to develop a flexible game platform that can be easily installed in the clinical setting for rehabilitation sessions. After a comprehensive review of the literature and similar available platforms, based on the comments from a speech pathologist, the fundamental requirements for achieving the rehabilitation goals were listed.

The concept of the game character, Parak, was taken from a doll designed and developed by the team (Figure

1a). A 3D model of the doll was made using numerous pictures in Agisoft Software (Version 1.7.2; Agisoft LLC, St. Petersburg, Russia) and Autodesk 3ds Max (2022 release; Autodesk Media and Entertainment, Montreal, Canada) (Figure 1b). To create the game's settings in Yazd city, a prototype of the environment was designed. Figure 1c displays the watercolor drawing of the primary environment design illustrating Parak standing on a wall surrounded by charming historical houses and wind-catchers known as Badgirs.
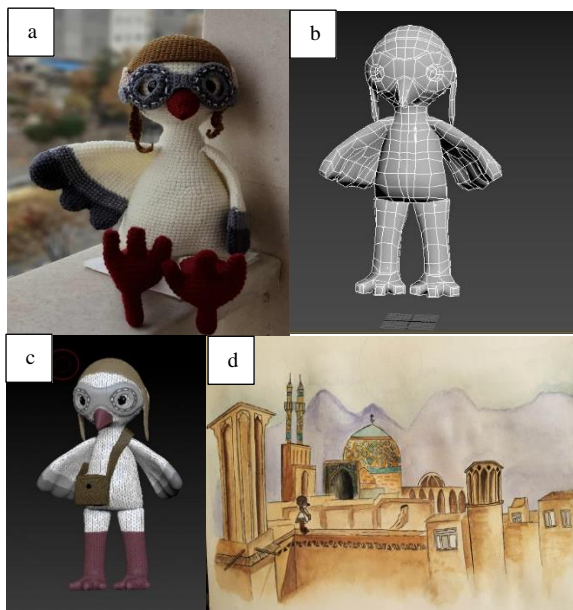

Figure 1. (a) Parak doll, (b,c) Parak 3D model, (d) Parak prototype game environment

The game elements were designed using Solidworks 2021 (version 29; Massachusetts Institute of Technology, MA, USA) and Rhinoceros 3D 2020 (version 7; Robert McNeel & Associates, Seattle, WA, USA) and were subsequently arranged in Unity game engine (Unity 2019.4.35, Unity Technologies, San Francisco, CA, USA) as depicted in figure 2.
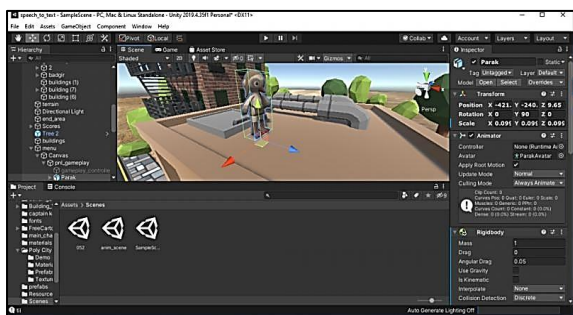

Figure 2. Unity environment

The game story

Parak is a pigeon postman designed to aid in the rehabilitation of children with speech disorder. The game is set in a beautiful environment to make the game even more interesting and exciting for the children. The game features a character named Parak, a pigeon. The story of the game revolves around a woolen-doll pigeon whose owner has a speech disorder and struggles to communicate with her loved ones. Feeling sad, the child writes letters to her loved ones, but never sends them. Parak, who loves his owner dearly, transforms into a brave pigeon postman to deliver all of his owner's letters and bring her happiness. Every week, Parak flies out of the room through the window to the rooftop to fulfill his mission, which includes delivering the letters of his owner and other children with similar disorders, as is shown in figure 3.
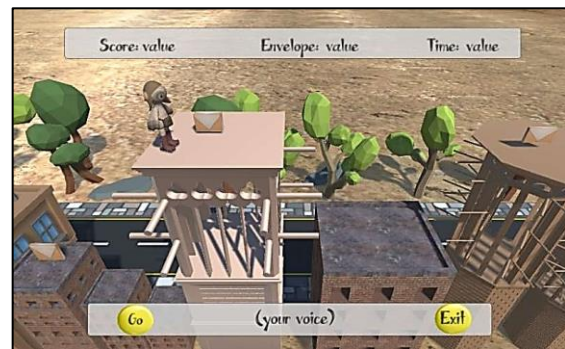

Figure 3. Parak in Yazd city

The mechanics of the game

This particular game was developed for Windows platform using Unity 3D engine and programmed with C# scripts for game mechanics. The gameplay follows a linear structure, with each level featuring Parak in one of Iran's stunning cities to carry out his job. In the initial level, Parak is situated in Yazd and has the capability to perform various actions such as walking, flying, and jumping up and down. To execute these actions, the child must pronounce the required syllable correctly.

Before the game starts, the pathologist will take a test from each child to analyze and determine the letter he/she has problem articulating. Then, the pathologist can add that letter to the game and practice it with the child. For a primary test and examination of the basic function of the game, the letter [t] was used for the first level of the game. When the game begins, the child starts with vowel and consonants like [ti], [tæ], [tɑ ː], [te], [to], and [tu], and as the levels progress, more complicated

structures such as syllables, words, and sentences are introduced into the gameplay. Each vowel is associated with a specific action, for example [ɑ] is used to fly, [i] to walk, [æ] to jump up, [e] to jump down, [o] to pick up the letter, and [u] to drop the letter. The therapist can also enter their ideal syllables and words into the game and check the procedure. These syllables were designed based on musical notes; thus, when the child pronounces the words, it will have an appealing rhythm that adds more enjoyment to the game (Figure 4).
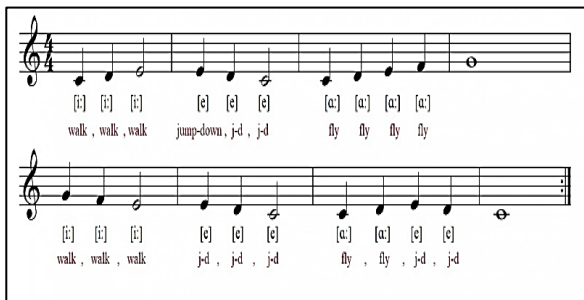

Figure 4. The notes used in the game

Fujii and Wan (22) have fully discussed the significant role of rhythm in speech and language rehabilitation in their previous work. When Parak wants to move, the system plays the vowel for the child. The child listens to the correct pronunciation, and then, must repeat it. Voice recorders and speech-to-text applications have been used in Unity to convert the child's voice into text and compare it with a pre-assigned database (Figure 5a). The database includes voices that have been recorded previously. A Unity speech recognition package was used and customized according to the speech exercises, and vowel and consonant combinations were added to conform to the child's voice. At the elementary levels, the sensitivity of the recognition system is low, but it increases gradually, so that finally the child must pronounce the words in exactly the same way as the recorded voice. If the child pronounces the syllable correctly, Parak moves to the next syllable. If the child pronounces 3 consecutive syllables correctly, he/she gains an envelope. If the pronunciation is wrong, Parak will be blown back by the wind and the child has to try again. As recommended by the psychologist, the game does not have any winners. Instead, their results are recorded and compared to their previous records to estimate their improvement. Still, the child must collect a required number of letters to progress to the next level; otherwise, they will receive a message to try

again. Figure 5b is a screen-shot of the game play. There are 3 icons at the top of the screen which show the score (the correct pronounced words), the numbers of envelopes collected, and time (the time the child has spent to finish the level).
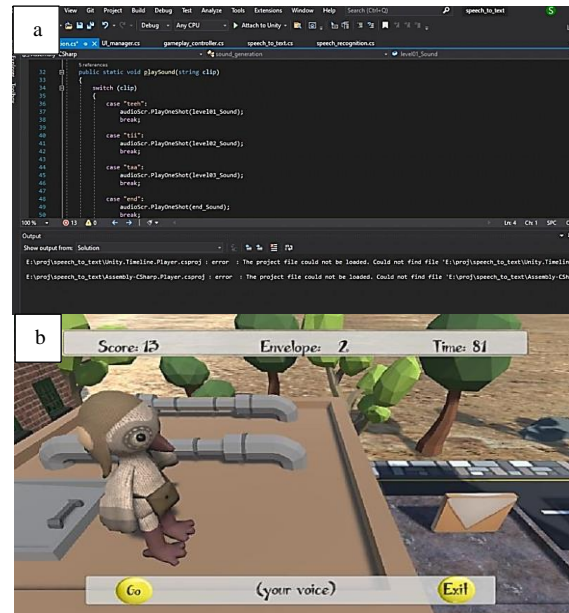

Figure 5. (a) Unity speech to text, (b) The Score, Envelope, and Time icons

Each level of the game has a set number of syllables that can be adjusted by the therapists to suit each child's needs. The game portal offers 3 options. The first is for typically developing children who can play the game independently as well as for children with speech disorders who want to play the game without the supervision of a therapist. In this option, the results of the game are sent to the child's parents via email. The second option is for children who are playing the game under the guidance of a therapist. In this case, the therapist can customize the syllables and words, and receive the results for further analysis. The third button allows users to save and compare their results on each level with previous scores (Figure 6).

Feasibility Study and Evaluation

To evaluate the feasibility of the game performance, a pilot study was carried out at Tabriz Islamic Art University of Iran. The main goal of the study was to evaluate the game function in achieving the therapeutic objectives.

There are various quality characteristics for the evaluation of SGs from different perspectives. Calderon and Ruiz (23) proposed 18 characteristics to evaluate SGs, which include design, user satisfaction,

usability, usefulness, understandability, motivation, performance, playability, pedagogical aspects, learning outcomes, engagement, user experience, efficacy, social impact, cognitive behavior, enjoyment, acceptance, and user interface.
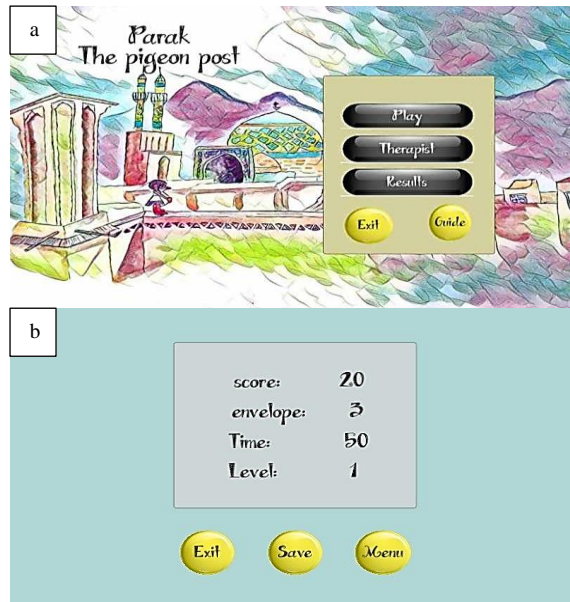

Figure 6. (a) Parak game Portal, (b) game results

In order to test the game's feasibility and assess its performance, 10 experts were chosen using convenience sampling method, 6 of whom were professors at Tabriz Islamic Art University with specialties in different aspects of game design, and the remaining 3 of the experts were master's students of game design. These experts were asked to play the game and answer the researcher-designed questionnaire which consisted of the characteristics proposed by Calderon and Ruiz for evaluating SGs (23). The questionnaire consists of the following questions:

1. Did the voice recognition system, avatar movement, and coordination of the two work properly in the game?
2. Is the game designed properly according to its goal, which is children's speech therapy?
3. Do you think this game had enough fun and attractive aspects and feedbacks for children?
4. What are the strengths and weaknesses of the game?
5. What is your general opinion about the game?

Results

We asked 10 game design experts to play the game and fill a questionnaire. Half of the experts were men and half of them were women. These experts were experienced in the field of game design and were qualified to examine the feasibility of the game performance according to its goal. They answered the questions with their specialized opinions. In order to get a better view of their suggestions, their answers were analyzed based on 7 characteristics proposed by Calderon and Ruiz for evaluating SGs (23). These characteristics are explained in the following sections.

A. Game Design

According to the panel of experts the game design was intriguing and appealing to children. However, 3 of them felt that the game settings and graphics could benefit from more creativity and vibrant colors. They suggested the addition of dynamic objects to the environment to make it more engaging. Additionally, one expert recommended designing the buildings and their surroundings in a cartoon to increase the game's attractiveness.

B. User's satisfaction and experience

Based on the feedback from our participants, the avatar and the game mechanics were easy to control and suitable for children. They were confident that children could learn and play the game without difficulty and the game environment was enjoyable and engaging for them. There were no gender-specific elements in the game environment or avatar; thus, both boys and girls can have fun playing it.

C. Usability

According to the international standard ISO 924111, usability refers to how well "a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" (24). Based on this definition, all of our participants agreed that the new version of the Parak game was suitable for use in therapy sessions and can help the children continue their therapy more effectively and with greater satisfaction. They also noted that the game's innovative concept can motivate children to practice their articulation skills without becoming bored.

D. Usefulness and motivation

Due to time constraints and the COVID-19 pandemic, the game was not tested on children. However, according to feedback from the expert team, the game has the potential to be extremely useful for children who are resistant to speech therapy and those who are unable to attend therapeutic sessions regularly due to distance or high costs. The game's motivational appeal is likely one of its main advantages (25). The pleasant environment and challenging tasks in the Parak game stimulate the

children's curiosity and encourage them to engage in their articulation practices.

E. Performance and playability

The experts tested the game and its components. The majority (80%) reported successful speech recognition with only 2 individuals experiencing slight difficulties. An expert suggested providing better feedback for correct pronunciations while another recommended incorporating more entertaining elements. A third expert suggested adding written words at the bottom of the screen to assist parents and therapist in guiding the child through the game.

F. Pedagogical and learning outcomes

In the Parak game, each level showcases a different city in Iran and its unique features. This game also serves as a fun and educational tool for children to learn about different cities and their environments, although its primary goal is to assist children in pronouncing sounds that they may struggle with and provide them with practice opportunities. The majority of the experts have found the game to be beneficial for children who need help learning and producing difficult sounds.

G. Social impact and cognitive behavior

Since the Parak game can be played in the presence of the therapist or parents, the child can communicate with them during the game. Moreover, the game helps the children to overcome and cure their speech disorder and enables them to communicate with other people without any problem and gives them self-confidence to enter society and improve the quality of their life. Still as the game was not tested in children, some game characteristics like engagement, acceptance, and user interface have not been analyzed.

Discussion

This paper reports the details of the development of a video game for children older than 3 years of age who require speech rehabilitation. The child can control the avatar by voice commands using speech recognition and speech-to-text systems in the game. According to the comments by the expert panel, the gameplay was easy, interesting, entertaining, and suitable for children.

Recently speech therapists and game designers have been working together to improve therapeutic achievements in children. Video games can motivate children to engage more efficiently in their therapeutic process (26). In addition, therapeutic games are more accessible, as they may be used at home. Therefore, the child may have more practice sessions in a day. Furthermore, remote access to rehearsal results makes the supervision by the therapist easier, while it considerably reduces the financial and temporal costs associated with attending the clinics.

Limitations

The present study had 3 major limitations that could be addressed in future research. First, it was not possible to test the game on children with SSDs due to the COVID-19 pandemic. Second, we had a long-distance relationship with our speech pathologist and that may have caused a poor supervision of the process and enabled her to have full control on the game design procedure. Third, the game is exclusively designed for pc platform, which may have reduced its accessibility to all children.

Recommendations

Further evaluations of Parak game in children with SSDs are recommended. Installation of the game in a clinical setting to collect data under the supervision of speech therapists and comparing the final results of therapeutic exercises using Parak with that of traditional approaches will provide valuable data for the improvement of the game. Moreover, more features are going to be added to the game, such as artificial intelligence to create flow, as suggested by Mekler et al.(27), in the game based on each child and add more levels and better visual feedbacks. By using artificial intelligence, the child's performance in the game will be analyzed by the game system and the difficulty of each level will change according to the player's performance. For example, if the game determines that the game is too easy for the child and they may get bored, it increases the difficulty level of the game to make the game more challenging, and if the game is too difficult for the child and they might get frustrated by continuous failures, it decreases the level difficulty. This procedure is called having flow in the game and can be implemented using advanced artificial intelligence.

The authors plan to develop similar games for children speaking other native languages and dialects of Iran, like Azari, Kurdish, Mazani, Arabic, Lori, Tati, and Baluch, and international languages like English, Spanish, Arabic, Turkish, and Portuguese. In addition, they are planning to design a mobile version of the game for Android and IOS.

Conclusion

In general, the idea and the scenario of the Parak game seem to be suitable to assist in speech therapy

for children with SSD; however, the game design and avatar's movements can still be improved.

Authors' Contribution

Project design and ideation: Faezeh Bargi
Providing financial resources for the project: Yoones Sekhavat
Scientific and executive support of the project: Samira Poodratchi
Providing equipment and the statistical sample: Faezeh Bargi
Data collection: Faezeh Bargi
Analysis and interpretation of the results: Raziyeh Sahlabadi
Specialized statistics services: Ali Dehestani
Manuscript preparation: Faezeh Bargi, Yoones Sekhavat, Samira Poodratchi, Raziyeh Sahlabadi, and Ali Dehestani
Specialized scientific evaluation of the manuscript: Faezeh Bargi, Yoones Sekhavat, Samira Poodratchi, Raziyeh Sahlabadi, and Ali Dehestani

Confirmation of the final manuscript to be submitted to the journal: Faezeh Bargi, Yoones Sekhavat, Samira Poodratchi, Raziyeh Sahlabadi, and Ali Dehestani
Maintaining the integrity of the study process from the beginning until publication, and responding to the reviewers' comments: Faezeh Bargi, Yoones Sekhavat, Samira Poodratchi, Raziyeh Sahlabadi, and Ali Dehestani

Conflict of Interest

The authors did not have a conflict of interest. Dr. Sekhavat obtained the funding for the present work from Tabriz Islamic Art University.

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