Game Based Learning Rehabilitation for Children with Speech Disabilities: Presenting Two Bespoke Video Games

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Rehabilitation and exercises for children with speech disabilities can be tedious. To address this issue, we created two different types of video games that will hopefully act as a motivation to children to keep playing while also practicing their words. The games were created using a user-centered approach with experts on accessibility and speech rehabilitation. We used pre-trained natural language models to detect the word the children are saying. The performance of their game is correlated to the performance of their articulation of the words; namely, the confidence level of the spoken word to the representation of the word in our pre-trained model. We are now in the process of testing the effects of these games in the rehabilitation process of children with speech disabilities.

Speech, Disabilities, Game Based Learning, Accessibility

1. INTRODUCTION

Learning proper vocabulary at a young age for children that have learning disabilities such as Autism Spectrum Disorder (ASD) and Dysarthria (Pennington et al. 2016) can be challenging and cumbersome. Rehabilitation is often not available in specialised centres, especially in developing countries. Therefore, children will often need to perform daily exercises at home, supervised by their non-expert parents or carers whom they need communication with (Patel and Salata 2006). It is also common knowledge that home exercises are often neglected or performed in a sub-optimal way, leading to a reduction in results. One way to entice children into learning is with gamification; an instructional method that makes learning into a game (Zainuddin et al. 2020). Students work through or play activities to learn. This is usually done by using the material to be covered combined with gaming elements and has often been shown since early computer game capabilities even to be effective (Krichevets et al. 1995). It allows children to practise for longer and without the assistance of a clinician (Nasiri et al. 2017). Our work focuses on designing and testing games that include a ”fun” factor and can help increase the duration of a practise session, increase retention of the child’s longitudinal willingness to participate and simultaneously alleviate the burden of having a carer intervention - who by definition is also not a specialist. The main objective is to provide children with speech impediments learning and pronouncing

words from a pre-selected list in addition to providing player with suitable audio-visual components.

2. RELATED WORK

Our theoretical basis for creating this game is the effective gamification examples of other serious games which help and motivate disabled children with their learning. ”Into the Forest” is a game that was designed for children with speech as well as hearing disorders. It was built using Unity 3D engine with C# as its programming language. The game has two different sections. The first section shows the player how to play the game. The second phase tests the player by allowing them to play while their progress is tracked. During the game, the player’s character has to touch objects that represent words they have to pronounce. The game evaluates the player’s performance on a scoring scale of 0-100 based on the player’s ability to speak certain words clearly (Nasiri et al. 2017).

Another similar game is the ”Roman Palace”. The main objective of this game is to help players memorise the vocabulary of foreign languages. The main scene has a Roman-era theme in which the player has to search for cards placed in out-of-sight spots. The player’s knowledge is tested because they have to memorise and remember the words. The game makes of the Loci Method suggesting that remembering the names of objects within specific locations is easier (Toma et al. 2017).

3. THE GAMES

We have developed two games for children playable to children with speech disabilities. One of the games follows a vertical scrolling shoot em up approach while the second follows more of an adventure level challenge approach. We follow basic instructions that cross reference theories like variable rewards (Eyal 2014) to keep end-users playing as well as effective game design. By using machine learning and our own trained language models we are able to create highly interactive games that are controlled by voice. The children are prompted to read words on the screen. The data is sent to our Raspberry Pi server with our pre-trained model and the accuracy with which the children have spoken the given words and will give it as an output to the game to be processed. If the accuracy is high enough, the players will be somehow rewarded in the game. If the child finds it especially hard to read a word, even after encouragement and several attempts, that word will be added to a list for future reference. The games provide settings that allow the player (or the carer) to adjust the difficulty of the game and any other aspects so that the experience will be optimised to

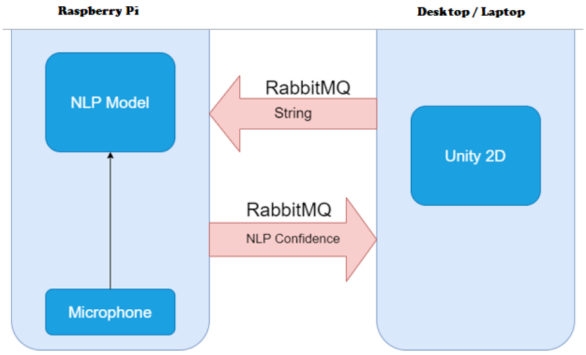

Figure 1: *Architecture of our game based system, coupled with out server that judges word pronunciation based on our pre-trained model*

be pleasing for the player. This could include the adjustment of the frequency of the text prompts that the player needs to speak if there should be a timer that the player has to say the word (which would add additional challenge) how many tries a player has to say the prompted word (to prevent exhaustion and fatigue). It could also include the accuracy threshold that would count as saying the word correctly. The Technology Architecture can be seen in Figure 1. Code was written using the programming language C# (version 6.0) in the source-code editor Visual Studio Code (Release 1.77) Assets used were found either online from itch.io or from the Unity Asset Store. AMQP client library for Unity 3D was used to integrate the RabbitMQ Client. RabbitMQ Client was used to queue messages which are sent to the Raspberry Pi. The bolt package was installed in Unity to provide easy access to saving backups of the game. Our bespoke language model has been created specifically to facilitate the needs of the games as well as other research experimentation. The publication is in-press and will be published soon.

3.1. Game 1: Planetary Protector - Vertical Shooter

The first game can be seen in Figure 2. Our end user is able to shoot at asteroids heading his way and has to protect the earth from collisions from the asteroids passing by. In order to do this the user points and shoots at them from their spaceship using a targeting system with a mouse. They are then prompted to say a word to determine if the laser fire was accurate and hits the target. The game settings can be changed to provide more or less of a challenge, depending on the users’ abilities and progress; both in terms of the confidence levels of the pronounced words and the speed of the game. It is worth noting that the game may produce difficulties in playing for users that also suffer from a motor disability such as cerebral palsy

due to the mouse controls. Figure 2 shows how the game-play looks.

3.1.1. Game details
The game includes five screens, introduction, main menu, options, game-play and prompt. **Introduction Screen/ Tutorial** includes a small paragraph that explains the player's purpose. It also displays the controls of the game and how to play it. The **Main Menu Screen** consists of three main buttons, play, options, and quit. **Options Section Screen** has two sliders, one to adjust the volume of the sound effects and one to adjust the music of the game. There is also a toggle button o allow the player to include "camera shake" effect when they take damage. The second page of the Options screen include more detailed settings. This is set to be used by the player's guardian to see what the player is comfortable with. Figure 3 shows more details of the screen including prompt rating thresholds, prompt difficulty and prompt words. **Game-Play Screen** consists of multiple UI elements including the health bar, the points scored and the number of meteors left to complete the level. Finally, the **Prompt Screen** is shown when the the player clicks on a meteor. A random word is generated and then shown on the screen.

3.2. Game 2: Adventures in Vocal-Land - Adventure Play

Our second game follows a more adventure type scenario and is also suitable for a less motor interactive end-user profile. Each stage (see Figure 4) produces an obstacle for the game hero and a prompt for the child to say a word. Should the child pronounce the word correctly (acceptable confidence level of our pre-trained model), our character overcomes the obstacle and comes face to face with the next one. We note that each level associates the word with the obstacle our user needs to pronounce and overcome. Figure 4 shows the different words encountered at different stages in the game.

3.2.1. Game details
This game consists of ten stages. (1)The "Pop" stage: The player must throw a rock to pop a balloon. (2) The "Cow" stage: The player encounters a cow and must pronounce correctly to make it moo. (3)"Ball" stage: The player must kick an American football over a set of goalposts. The force of the kick corresponds to the accuracy of pronunciation. (4)"Duck" stage: A duck flies at the player and they must "duck" to avoid it. (5)"Tree" stage: The player swings an axe at a tree,if pronunciation is accurate, the tree will fall down. (6)"Jump" stage: The player encounters a drawbridge and must jump to reach the string which opens it so they can cross a moat into a castle. The height of the jump corresponds to the accuracy of the pronunciation. (7)"Wash" stage: The player enters a shower and must pronounce accurately to turn on the water and wash. (8)"Eat" stage: The player encounters a large pizza and must eat the entire pizza to pass. The number of slices consumed corresponds to the accuracy of the pronunciation. (9)"Ant" stage: the player encounters an excited ant and must pronounce correctly to jump and squash the ant. (10)"Stop" stage: the player encounters a stop sign and must pronounce correctly to end the game.

Both games are suitable for updates that would add levels, complexity and keep the games interesting going forward. It is our goal to keep adding capabilities and levels for a longitudinal capable play and therefore be able to keep the interest of a child in the long term.

4. TESTING

Participants. There were three participants aged between 6-10. These children were healthy with English as their first language. We were also interviewing the parents of the participants (one parent each).

Ethical Considerations Prior to the test, participants were provided with consent forms outlining the collection of their information, usage of their information, and other GDPR principles. Additionally, the form included a description of the test's methodology and process. The participants were rewarded with a voucher at the end of the testing process. The consent forms were given to the parents.

Procedure. The process consists of four main stages. In the first stage, the research team members show the participants the basics of the game, such as menu navigation, setting adjustments, character movements. In the second stage, the participants are given the freedom to play games as they please, under the supervision and support of the research team. The third stage included a questionnaire targeting their experiences with the game. The final part of the testing process included a semi-structured interview in order to further confirm the validity of the games and receive more feedback for improvements and features.

5. RESULTS

The participants' reception of the game was predominantly positive. Some participants believe that the game would be useful to learn to pronounce new words. However, certain participants did not perceive significant value in the game for words

Figure 2: *Planetary Protector Game. Top left: start menu. Top Right: options menu for volume adjustment. Bottom Left: In game-play. Bottom Right: Prompt to defeat the asteroids with a clearly pronounced and articulated*

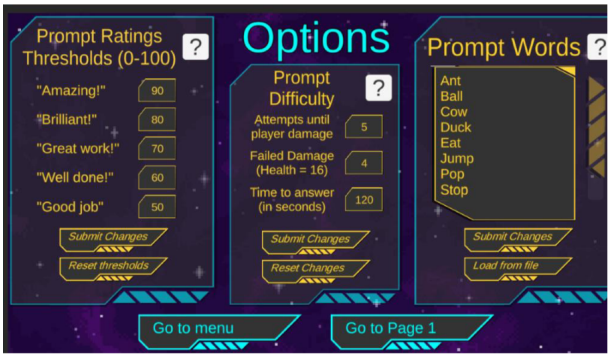

Figure 3: *Options Screen in the Planetary Protector Game*

they had already learned. None of the participants encountered difficulty with with the game controls. This shows that the game design was successful and easy to work with. The final System Usability Scale (SUS) score was 65, placing the game between the ”OK” and ”Good” usability categories. A game with ”OK” usability score is enough to prove that the concept is valuable. There are plans to improve this score in subsequent iterations of the games.

Additionally, during the semi-structured interview, we identified a recurring pattern in the responses provided by the children participants and their parents/carers. The children found the games' instructions and objectives clear. It was clear to them what they needed to focus on. However, they expressed dissatisfaction with the quality of the sound effects, primarily due to the limitations of the speakers. Similarly, the children perceived the games to be relatively easy and lacking in challenge. They recommended that the games could be upgraded to 3D graphics and should have more stages to enhance their engagement.

On the other hand, the parents and caregivers believed that this solution is highly suitable for disabled children. They found the games suitable and appropriate and were comfortable with their children playing the games. They agreed that such games will help with their children's performance. Their comments for improving the games and the experience included using high quality microphones and reducing the number of colours employed in the games' designs. They believed that the games came across exceedingly colourful, which could potentially serve as a distraction. Therefore, using less colours would enhance the overall experience and concentration of the players. They also noted that the game is more suitable for children with disabilities rather than those without.

Given that the children participating in the test were healthy, it was anticipated that they may not perceive the games as sufficiently challenging according to their personal standards. The suggestions for enhanced graphics and longer stages and game-play indicate the existence of significant potential for improvement. The feedback provided by the parents and caregivers demonstrates the considerable potential of the games with their target users, namely disabled children. These recommendations highlight the importance of ongoing testing and research to further refine the games and address the identified areas of enhancement.

Figure 4: *Adventures in Vocal Land Game: Top Left: The word "pop" needs to be pronounced for the level to be defeated. Top Right: when the user is not able to pronounce the word correctly, they are encouraged to try again. Bottom Left: A tree needs to be chopped which is successfully done to progress to the next stage - Seen in the Bottom Left.*

6. CONCLUSIONS AND FUTURE WORK

In this paper, we discussed how speech disorders can affect children lives and how games can be used to contribute to speech therapy and to make more enjoyable and less frustrating. We developed two games in order to target this issue. The projects have made significant progress towards finding a solution for children with speech impediments to have game based vocal training in their homes. All levels were implemented successfully, and the testing process went smoothly. The results show that such games are more useful for learning new words rather than words the child has already learned. The games are now fully operational and are undergoing ethical approval and preliminary testing for functionality and usability. We are setting up longitudinal study with children with speech disabilities where we will be testing our games. and system in their home environment and providing insight into the ability of our games to a) motivate children to undertake their therapy in a more fun way and b) to increase the engagement time of the children with their therapy over a period of time. The second point will of course require updates to the games with more levels and challenges as time progresses.

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