Straw Fighter: A Gamification-based System for Supporting Vocal Exercise by Tube Phonation

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***Abstract*—Tube phonation, or straw phonation, is a commonly used vocal exercise technique to improve the efficiency of the vocal mechanism by repeatedly producing a speech sound in a tube or a straw. Trainees need to maintain daily vocal exercise for a month to improve their voice; however, the exercise is monotonous and boring, and trainees find it hard to keep themselves motivated. This study therefore proposes the use of straw fighter, a biofeedback system for tube phonation based on a gamification framework. Straw fighter is a shooting game implemented using an IoT device with an LCD display, M5Stack Basic, taking into account cost-effectiveness and ease of development. A user can beat enemies by phonating into a straw and can improve phonation by simply enjoying the game. Possible system function enhancements include sharing an exercise log with a speech therapist using cloud storage.**

***Index Terms*—Straw phonation, Semi-occluded vocal tract exercise (SOVTE), IoT, e-Health, phoniatrics**

I. Introduction

Tube phonation, or straw phonation, is a semi-occluded vocal tract exercise (SOVTE) for vocal training and therapy in which the vocal tract is partly constricted to maximize interaction between vocal fold vibrations and vocal tract resonance [1]. It is considered a good way to strengthen and balance laryngeal musculature and to regulate the glottal airflow, and is therefore widely used in the treatment of patients and in the warm-ups of singers. In this method, a trainee must maintain a comfortable level of phonation through a tube or straw, as shown in Fig. 1, for repeated intervals lasting between 5-10 s. To improve daily automatic speaking, it is usually recommended that there be 50 exercise phonations per day for one month (a total of 1,500 exercises); however, it is difficult to keep the trainee motivated during this period. Another reason for the difficulty is the fact that a trainee tends to have limited awareness of the improvement of voicing in daily exercise.

When the interaction between vocal fold vibration and vocal tract resonance increases during tube phonation exercise, and when the trainee achieves effective phonation, they feel strong vibrations around the lips, indicating that the acoustic energy is focused around this area. Thus, the vibratory feeling is used as a target of the exercise [2]. However, vibratory sensations differ from person to person and cannot be directly observed by a speech therapist. Kawamura *et al.* [3] therefore developed a biofeedback system that fed back the vibration amplitude visually on a PC screen, and most recently, Kawamura *et al.* [4] proposed its low-cost version – Smart tube. It is a straw with an attached acceleration sensor and an LED strip that can measure vibrations and provide corresponding feedback through LED lights in real-time. Smart tube offers simple and easy-to-understand visual feedback; however, it is not sufficient to overcome the monotonous nature of the exercise. This study thus aims to develop a biofeedback system based on a gamification framework [5], [6] and incorporates enjoyment and addictiveness of games into daily vocal exercises.

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Fig. 1. A speaker demonstrating tube phonation.

II. Straw Fighter system

A. System description

Straw fighter supports vocal (re)habilitation through a shooting game in which a user hits the enemy by phonating into a straw. The system was implemented using an M5Stack Basic, a small (54 mm×54 mm×17 mm) IoT development module with a 320×240 TFT color display and a microSD card slot, which makes it convenient and cost-effective. The device can be programmed in the Arduino integrated development environment and other development platforms and languages. Figure 2 shows the proposed system. Straw fighter uses a plastic straw measuring 10 mm in diameter and 210 mm in length. The vibration of the straw is measured by an on-board acceleration sensor attached to the straw in contact with the user's mouth. To maintain adequate hygiene, the acceleration sensor is adhered by tape to facilitate easy replacement.

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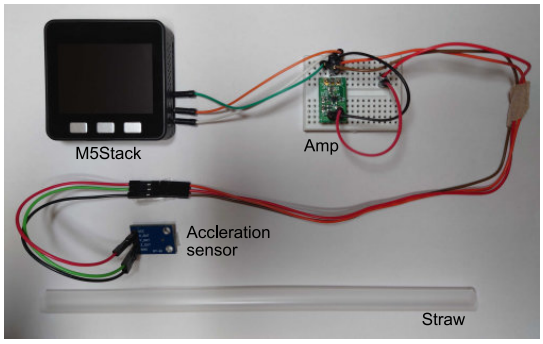

Fig. 2. Straw fighter system.

Fig. 3. Screenshot of straw fighter. Enemies (monsters) move from the right to the left and the player shoots bullets by phonating into a straw. The player can change the height (row) of the battleplane cyclically by push of the left physical button.

Straw fighter is a horizontal-scrolling or side-scrolling shooter that is viewed side-on. Figure 3 shows a screenshot of the system. Enemies (monsters) appear on the right side of the screen and move to the left, where the user's battleplane is located. The user can shoot bullets by phonating into the straw and can score by defeating the enemies, whereas the score is deducted when the battleplane crashes onto an enemy. The enemies appear along three horizontal rows on the screen, as shown in Fig. 3, and the player can move the battleplane up and down using a physical button of the M5Stack.

The acceleration sensor (Analog Devices, ADXL335) picks up the acceleration of the wall of the straw and amplifies the measured signal. The analog signal is then input to the M5Stack. If the amplitude of the time-averaged signal exceeds a certain threshold, the battleplane shoots a bullet and firing is maintained serially during the phonation. The color of the bullet changes depends on the amplitude of the vibration. We designed the enemies to appear continuously for five seconds to ensure phonation for more than five seconds involuntarily, even without explicit instruction. Sustained phonation is advantageous for obtaining higher scores in the game. On the top of the screen, the duration of phonation is displayed in real-time as well as the score and the time left.

The duration of one game is set to 100 s, and the game does not finish in that time, no matter how many times the player's battleplane crashes with the enemies; this ensures engagement of a user in their exercise. The enemies emerge at intervals of 10 s and game continues for five successive times. Therefore, the user is expected to phonate at least 50 times, the number needed daily, by just playing the game. After the user finishes the game five times, the system displays the total and highest scores. The highest score is stored on a microSD card inserted into the M5Stack and used for the next time.

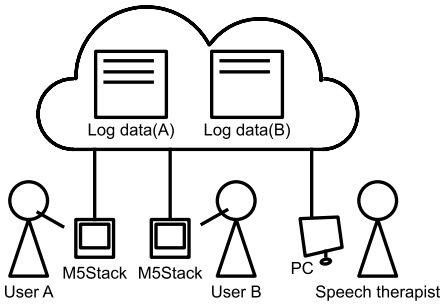

Fig. 4. Sharing exercise log data between trainees and speech therapist using cloud storage.

B. Sharing exercise log data

As a function enhancement, straw fighter can store log data (date, time, and score of exercise) on Google spreadsheet and share it with a speech therapist through Wi-Fi connection with the Internet (Fig. 4). The therapist can monitor the progress of exercise of the trainees remotely and motivate them to exercise if needed. For the next step of this study, we are planning to include a function that encourages competition among trainees.

III. Conclusions

Straw fighter offers an enjoyable vocal exercise game based on the gamification framework and low-cost IoT device by measuring the vibrations around the lips, indicating the efficiency of phonation during the tube phonation exercise. Cloud environment integration is also possible for the system for enhanced management and monitoring of vocal exercise. We hope that straw fighter will trigger the introduction of e-Health [6] in the field of phoniatrics and bring benefits to both patients and speech therapists with no time or spatial limitations.

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