Gamified user interface design for dysphagia rehabilitation based on common mental models

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Gamified user interface design for dysphagia rehabilitation based on common mental models

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Abstract: Dysphagia is a term for swallowing difficulties. It is usually caused by another health condition, such as stroke, or dementia. Exercise-based training with biofeedback is commonly practiced in dysphagia therapy. Existing gamified solutions for biofeedback devices provide scenarios that conflict with natural mapping of the swallowing activity. In this study, we have identified and addressed these conflicts based on mismatches with common mental representations to create a more well-matched training experience. Our study showcases an example of designing a gamified user interface for dysphagia rehabilitation, while also defining important UI principles for gamified training. It also serves as valuable and emerging research that puts emphasis on the importance of designing for dysphagia rehabilitation. We expect that our research will inspire other designers to incorporate gamification elements into their designs in a rational and well-designed way.

Keywords: gamification; user interface design; dysphagia; exercise rehabilitation

1. Introduction

Dysphagia is a term used to describe swallowing difficulties. It can be experienced in various degrees of severity. For example, some people with dysphagia might have problems swallowing certain types of foods or liquids, while others can’t swallow at all. People with dysphagia have higher risks of accidental coughing or choking while eating or drinking due to potential airway blockage by incorrectly-swallowed food or liquids. In most cases, dysphagia is an underlying issue caused by another health condition, such as stroke, head and neck cancer, Parkinson’s disease, or dementia (NHS Inform, 2021). People with dysphagia often suffer from reduced quality of life due to social and psychological burdens associated with this condition. Severe cases of dysphagia might result in serious health complications like aspiration pneumonia, airway obstruction, malnutrition, dehydration, and death.
The primary goal of any dysphagia rehabilitation is to identify and treat abnormalities of swallowing without sacrificing proper nutrition and hydration of a patient (Frontera, Silver, & Rizzo, 2020). There have been a lot of existing research that reported positive functional benefits from exercise-based training for dysphagia (Groher, & Crary, 2016). This includes muscle strengthening, range of motion (ROM) exercises, and swallowing maneuvers. In addition to traditional therapy exercises, surface electromyographic (sEMG) biofeedback is often implemented as a part of dysphagia rehabilitation. Despite their high price, thus low accessibility, biofeedback device solutions for exercise-based dysphagia therapy have become increasingly popular in the dysphagia management market due to overall performance improvement, as well as patient satisfaction. There are also less conventional treatment methods that are not as commonly implemented due to their invasive nature, such as electrical stimulation and deep pharyngeal neuromuscular stimulation (Kauffman, 2008).

It is expected that the market valuation of the worldwide dysphagia management market will exceed 5 billion USD by 2027 at a healthy CAGR of 3.2% between 2020 and 2027 (Future-Wise Research, 2021). Moreover, the prevalence of dysphagia is higher in elderly compared to the general population due to the fact that elderly are at an increased risk for illnesses that affect swallowing (Aslam, & Vaezi, 2013). With the rapid growth of the aging population worldwide, as well as in South Korea, the prevalence of dysphagia is expected to increase rapidly in the near future both at global and domestic levels.

Currently, the estimated prevalence rate of dysphagia in Koreans aged 65 years or older is 23.6%. Approximately half of nursing home residents in Korea suffer from dysphagia (Yang et al., 2013). Since South Korea is one of the fastest aging societies, with the number of adults aged 65 years and older forecasted to reach 37.3% by 2050 (Pyo, 2009), dysphagia is expected to soon become increasingly recognized as an important national healthcare issue.

1.1 Problem Statements

To test our initial assumptions about problems in the current approach to exercise-based dysphagia therapy, three user research methods have been conducted: domestic expert interviews, domestic expert questionnaires, and overseas in-depth interviews (see Section 3. Research Approach for more details). As a result, three problem statements have been validated. These statements have been defined from two target user perspectives as follows:

- Patient Perspective: Patients struggle to perform swallowing exercises manually due to no feedback.
- Patient Perspective: Patients struggle to stay focused and lack motivation while performing exercises.
- Therapist Perspective: Therapists struggle to effectively facilitate patient rehabilitation due to patients’ poor cooperation and lack of motivation during exercise performance.
Even though the first problem statement confirms the need for some kind of feedback that is available for patients to facilitate better engagement, it is more related to manual exercise-based training instead of device-based training. Thus, it is not relevant for our study. As a result, the two latter problem statements have been selected as the main focus of this study to define our research objective and questions below.

1.2 Research Objective and Questions
The key objective of this research is to design a user interface for dysphagia rehabilitation that could solve the aforementioned problem statements (i.e., patient motivation and doctor-patient cooperation). Our key assumption is based on numerous literature (Deterding et al., 2011) and existing service solutions (FourSquare, 2021), which prove that game elements should be able to make other, non-game products and services more enjoyable and engaging. Thus, we assume that incorporating game elements into dysphagia rehabilitation training will make our training system more enjoyable and engaging, thus, increasing patient motivation and engagement, as well as improving doctor-patient cooperation. Consequently, two research questions of this study have been defined as:

- “How might we design a gamified user interface for dysphagia rehabilitation?”
- “What UI (user interface) principles do we need to design a gamified user interface for dysphagia rehabilitation?”

2. Related Works

2.1 Submandibular Push Exercise
Conventional dysphagia treatment methods include oropharyngeal exercises, compensated maneuvers, and electrical stimulation of the oropharyngeal area. Among the muscles which are contributed to the swallowing process, the importance of the suprahypoid and infrahyoid muscles have been reported broadly in previous literature (Park et al., 2020). However, existing exercises involve neck flexion movement patterns, which induce unnecessary contractions of the SCM (sternocleidomastoid) muscle and may adversely affect the selective contraction of the supra and infrahyoid muscles. To overcome the limitations of existing exercises (see Table 1), the submandibular push exercise was introduced by our partner doctors in a study named “Effect of the submandibular push exercise using visual feedback from pressure sensor: an electromyography study” published in Scientific Reports in 2020 (Park et al., 2020).
Table 1  Common Exercise Maneuvers for Strengthening Swallowing-related Muscles and Their Limitations

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaker Exercise</td>
<td>Sustained and successive head lifts performed by the patient while in the supine position</td>
<td>Fatigue in the suprathyroid muscle, too physically demanding for elderly</td>
</tr>
<tr>
<td>CTAR Exercise</td>
<td>Patient seated in a chair, compressing an inflatable rubber ball or plastic bar between the chin and the manubrium sternum</td>
<td>Includes unnecessary the motion of neck flexion, thus, does not target the suprathyroid muscle more selectively</td>
</tr>
</tbody>
</table>

As a result of this study, the first pilot prototype has been developed (see Figure 1). Due to the nature of the newly-developed submandibular push exercise (i.e. movement of the hyoid bone upward and downward), conventional biofeedback methods, like sEMG, could be replaced with a less expensive pressure sensor that has been proved to be as effective in the same study. This addresses the aforementioned problem of accessibility and price, thus, providing an effective yet affordable healthcare solution for exercise-based dysphagia therapy.

![Figure 1](image1.png)

Figure 1  First Working Prototype with a Pressure Sensor for the Submandibular Push Exercise

However, there are still some limitations to the newly suggested exercise method. In the pilot user testing, participants expressed their struggles understanding how to perform the
submandibular push exercise. Thus, adequate exercise instruction using visual feedback is necessary for effective and proper exercise performance.

2.2 Gamification
Gamification is defined as “the use of game design elements in non-game contexts” to motivate and increase user activity and retention, whilst game elements are defined as “a set of building blocks or features shared by games rather than a set of necessary conditions for a game” (Deterding, 2011). It is important to distinguish “gamified” applications from traditional games. While serious (i.e., traditional) games fulfill all necessary and sufficient requirements for being a game, “gamified” applications merely implement a few design elements from games (see Figure 2).

As the use of our user-centered dysphagia system will be closely related to learning how to perform the new submandibular push exercise, we have taken a look at some literature on the topic of gamification and learning. Based on a review of 22 research papers on this particular topic, learning outcomes, such as involvement, result and achievement, motivation,
enjoyment, satisfaction, and attitude, have been positively impacted by gamification elements (Abdul Rahman et al., 2018). In particular, the most common gamification elements used in e-learning (i.e., electronic learning) were defined as points, levels, leaderboard, badges, feedback, and challenges, respectively (Handayani et al., 2020). All of these game elements need to be reflected in our final design outcomes to achieve our research objective.

When it comes to gamification, it is important to consider the flow channel. According to Ikehara, Crosby, and Silva (2013), “in order to excel and deeply engage in a given activity the individual’s state should be located within this channel” (see Figure 3).

It is argued that entering the flow channel is especially easy during games. For that, a clear definition of goals, rules, and immediate feedback (Ikehara, Crosby, & Silva, 2013) needs to be considered in our final design outcomes.

### 2.3 Benchmarking

Gamification has been getting increased attention in the rehabilitation sector specifically due to its positive implications mentioned before. One of the prominent examples is a company named Neofect (Neofect, 2021) that specializes in neurorehabilitation devices with fun and functional gameplay (see Figure 4). Even though this is an excellent example of using gamified user interface design for rehabilitation training, it is not easy follow or benchmark.
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these game scenarios due to the different nature of dysphagia rehabilitation, as opposed to upper or lower limb rehabilitation.

Feedback is crucial for any motor learning, as it helps to adapt subsequent behaviour based on the difference between the actual and the desired outputs. However, in dysphagia rehabilitation specifically, feedback is really challenging to portray, as it is hard to observe and see whether swallowing was successful or not (Archer, Smith, & Newham, 2021). To address this issue, biofeedback has been incorporated into many therapy programmes.

Biofeedback involves displaying data of a specific physical function (i.e., swallowing muscle activity) as some kind of feedback, so that patients can adjust their training accordingly. The most common type of biofeedback used in dysphagia therapy is surface electromyography (sEMG). It captures neuromuscular biofeedback and displays it as a visual or auditory representation. In this way, patients can increase their muscle activity, thus, improve their swallowing (Basmajian et al., 1975). Some of the most commonly used biofeedback devices for dysphagia rehabilitation are Synchrony by ACP (Synchrony, 2021), IOPI (IOPI Medical, 2021), and Tongueometer (CranioRehab, 2021).

Depending on the type of the exercise, various biofeedback devices can be used as parts of the same dysphagia therapy program. Currently, Synchrony by ACP is arguably the most popular and commonly-preferred biofeedback device for dysphagia rehabilitation. Compared to the other biofeedback devices, such as IOPI and Tongueometer, it provides visualized feedback in the form of a real-time graph, as opposed to quantitative feedback like numbers. Synchrony offers three gamified training programs at the moment, namely the diver, the kangaroo, and the bow and arrow activities to target (1) tongue base retraction, endurance, and specificity of lingual movement, (2) strength, duration, and progressive resistance, and (3) skill-based training and timing, respectively (see Figure 5).
Even though the above-mentioned training programs have implemented some game elements that have been proven to positively affect learning outcomes, we have identified several limitations based on mismatches with common mental representations (see Table 2). All of these limitations have been addressed in one of the following sections (see Section 5. UI Design Outcomes for more details) to create a more well-matched training experience.

### Table 2  Limitations of existing gamified solutions: mismatches with mental models

<table>
<thead>
<tr>
<th>Conflict</th>
<th>Swallowing Activity</th>
<th>Game Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional congruence</td>
<td>Downward</td>
<td>Upward</td>
</tr>
<tr>
<td>Movement span</td>
<td>Pulse</td>
<td>Full amplitude</td>
</tr>
<tr>
<td>Exercise intensity</td>
<td>Less intensive</td>
<td>Quite intensive</td>
</tr>
<tr>
<td>Exercise speed</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Rational link</td>
<td>No link between game scenario and training objective</td>
<td></td>
</tr>
</tbody>
</table>

### 3. Research Approach

Based on the two research questions, our research approach has been defined in the following way:

**Research Question #1**

“How might we design a gamified user interface for dysphagia rehabilitation?”

- Literature Review
- User Research

**Research Question #2**

“What UI principles do we need to design a gamified user interface for dysphagia rehabilitation?”

- Benchmarking
- User Research
User research for this study has been conducted in three separate parts, namely (1) domestic expert interviews, (2) domestic expert questionnaires, and (3) overseas in-depth interviews. The research objectives and related design outcomes for each user research method are summarized in Table 3 below.

Table 3  User Research Methods, Their Objectives and Related Design Outcomes

<table>
<thead>
<tr>
<th>Method</th>
<th>Objective</th>
<th>Related Design Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic Expert Interviews</td>
<td>Establish functional, use, and UI requirements for the development of our dysphagia training system</td>
<td>Overall design requirements for UI and game design</td>
</tr>
<tr>
<td>Domestic Expert Questionnaires</td>
<td>Define test assumptions about problems in the current approach to exercise-based dysphagia therapy</td>
<td>Test assumptions for in-depth interviews, Persona design, Value Proposition Canvas</td>
</tr>
<tr>
<td>Overseas In-Depth Interviews</td>
<td>Validate test assumptions, define target user, identify user pain points, as well as wants and wishes</td>
<td>Persona design, Customer Journey Maps, Game Scenario</td>
</tr>
</tbody>
</table>

3.1 Domestic Expert Interviews

For the first research method, we first prepared a list of questions to ask from our experts (i.e., partner doctors), namely Donghwi Park and Jong-Moon Hwang from Department of Physical Medicine and Rehabilitation at Ulsan University Hospital and Department of Rehabilitation Medicine at Kyungpook National University Hospital, respectively. The main goal of this research method was to help define important basics and solidify design requirements for the development of our dysphagia training system. Prepared questions were then grouped into four categories, namely process-related, technology-related, context-related, and user interface-related questions.

These two expert interviews have been conducted via Zoom to accommodate doctors’ busy schedules. For easier interview analysis, audio recordings of both interviews were collected, alongside simultaneous note-taking. As final outcomes of these interviews, we have defined basic characteristics of our product and set design requirements.

3.2 Domestic Questionnaires

For the second research method, we prepared an online questionnaire with open-ended, close-ended, and Likert scale questions. This online questionnaire was distributed by our partner doctors to 10 (7 male, 3 female) doctors and therapists, including medical staff like
nurses, that specialize in exercise-based dysphagia rehabilitation at Kyungpook National University Hospital and Ulsan University Hospital. The main goal of this research method was to get insights into current problems and pain points, as well as define our initial test assumptions for the following in-depth interviews.

It was found that the difficulty to perform exercises is a more significant problem based on doctors’ opinions. We learned that our primary focus should be adjusted to helping patients perform swallowing exercises more easily. Moreover, doctors pointed out the importance of considering other factors that contribute to difficulties to perform exercises, such as post-stroke cognitive impairments and so on. In other words, we have to consider other complex health issues commonly found in dysphagia patients that contribute to the difficulties of performing exercises to improve our final solution.

As a result of this method, we have also identified doctors’ wishes and wants regarding potential changes in the current approach to dysphagia rehabilitation therapy. In particular, participants expressed their desire for a more direct method of acquiring feedback from swallowing muscles (ex. biofeedback) or from patients themselves (ex. cooperation). They also shared their needs for facilitating patient participation in the training process to achieve more effective rehabilitation.

### 3.3 Overseas In-depth Interviews

For the last research method, we first refined test assumptions derived from the previous research method with the help of mentors from the George Washington University as a part of their KIC Tech Frontier Program. After that, we have conducted 45 individual interviews, which included 30 doctors and SLPs and 15 people with dysphagia. Our doctor and SLP participants came from medical institutions and universities, such as Johns Hopkins Medicine, Brooks Rehabilitation, Regional Medical Center Bayonet Point, University of Central Florida, Boston University, University of Wisconsin-Madison, University of Canterbury, the University of Texas at Austin, the University of Alabama, Appalachian State University, Texas Christian University, Teachers College Columbia University, Moravian University, as well as healthcare rehabilitation companies, such as True Angle, Dignity Health, and IOPI Medical. For our patient participants, members of Dysphagia Support Groups on Facebook have been recruited.

All 45 interviews were conducted in a semi-structured approach via Zoom and lasted between 30 minutes to an hour depending on the number of follow-up questions. Interview notes included our test assumptions, a list of general questions, and a summary of participants’ responses. The main goal of this research method was to validate our test assumptions, identify user pain points, as well as wants and wishes. The findings of this research method are reflected across various design outcomes in Section 4. UI Design Outcomes.
4. UI Principles

As our gamified intervention is dedicated to exercise-based rehabilitation training, it is important to learn basic exercise principles, as well as typical treatment plans, used in traditional dysphagia therapy. Being a relatively new research area in the healthcare industry, dysphagia rehabilitation has not been standardized to this day. Researchers still struggle to come up with commonly-accepted dysphagia rehabilitation methods, including both assessment, treatment, and evaluation conventions. Moreover, since dysphagia typically manifests as a result of various health complications, therapists or speech-language pathologists (SLPs) have to create treatment plans based on each individual case. Nevertheless, as a result of our in-depth interviews with both practicing SLPs and dysphagia patients, we have learned that factors, such as program duration and dose, are often clearly defined with only varying exercise types based on each individual case.

To define types of exercises and their relative intensities, we have benchmarked mandibular area exercises specifically, namely Shaker and CTAR exercises, as they are the most similar to our target exercise (i.e., submandibular push exercise). In particular, we have found that typically there are three types of exercises that are used in conjunction with each other based on each patient’s individual differences in swallowing deficiencies. These types are isotonic, isokinetic and isometric exercises (see Table 4).

Table 4  Isotonic, Isokinetic, and Isometric Exercises

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
<th>Description</th>
<th>Typical Use in a Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic</td>
<td>Same tension</td>
<td>The weight on your muscles stays the same.</td>
<td>A big number of consecutive repetitions to reach a certain goal</td>
</tr>
<tr>
<td>Isokinetic</td>
<td>Same speed</td>
<td>Muscles are contracting at the same speed throughout the training.</td>
<td>A big number of consecutive repetitions at a certain speed to reach a certain goal</td>
</tr>
<tr>
<td>Isometric</td>
<td>Same length</td>
<td>Muscles do not get longer or shorter by bending a joint.</td>
<td>A small number of consecutive repetitions at n-second holds to reach a certain goal</td>
</tr>
</tbody>
</table>

An entity of three concentric spheres of large, medium, and small sizes was selected as the main target shape to reflect three types of exercises, namely isotonic, isokinetic, and isometric exercises, respectively. Transparency and density of each sphere were matched with the difficulty level of the corresponding exercise type (see Figure 7). The reason for choosing an abstract shape as the main target is discussed later in this section.
To reflect three difficulty levels, the main target was color-coded based on the relative progressive overload of each level, i.e. with each level there is an increase in frequency, number of repetitions, and exerted muscle force (see Figure 8).

As mentioned in one of the previous sections, we have identified five types of limitations of existing gamified interface designs for exercise-based dysphagia therapy. These limitations include mismatches with common mental representations, namely conflicts in (1) directional congruence, (2) movement span, (3) exercise intensity, (4) exercise speed, and (5) absence of a rational link between game scenario and original training objective. Let’s take a look at how we have addressed these five limitations below (see Figure 9).
Figure 9 Main Game Target Movement in the Game, Isotonic Exercise

To address the conflict in directional congruence, we have defined the scope of the target movement along the vertical axis only, as the submandibular push exercise involves movement of the hyoid bone upward and downward. For the conflicts in movement span, exercise intensity, and speed, our target was placed above the ground at a relatively small distance to match the movement span of the submandibular push exercise, thus, maintaining a similar amount of exercise intensity and speed. Last but not least, to address the absence of a rational link between game scenario and original training objective, we have implemented the basic principle of “intrinsic value at the core”. In other words, as in many real-life scenarios, the most precious things are often hidden or hard to reach and are located at the core. Some simple examples include mining gemstones underground, seeds at the core of fruits, the human soul, etc. Similarly, the process of reaching the innermost sphere aligns with the principle of inner value at the core.

It is important to state that we have selected an abstract target purposefully and deliberately avoided the use of any food-related metaphors, as we had learned from our user research that such simulations can trigger patients and even demotivate them because they can’t actually eat and/or swallow these foods in real life. Moreover, our selection of the abstract game target can be justified even further based on findings from our user research that indicate that many adult or elderly patients refuse to incorporate gamified training into their rehabilitation programs despite potential benefits due to the childishness of existing game scenarios.
5. UI Design Outcomes

Our solution was designed for the submandibular push exercise specifically. The final outcome is a result of a continuous back-and-forth iteration process based on feedback from our partner doctors. Our gamified interface design is intended to be used at a therapist’s office for in-person training. There are two interfaces for two types of target users (see Figure 10 for interface flow). The therapist’s interface is designed for tablets for portability, while the patient’s is located on a desktop for better visibility. The software can be controlled by the therapist’s interface only.

![Interface Flow Diagram](image)

*Figure 10 Complete UI Flow, where TH and PT represent therapist and patient interfaces, respectively.*

Game elements incorporated in our user interface design are summarized in Table 5 below.
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Table 5  Gamification Elements

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>User Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Numerical reward for progress</td>
<td>Step 5. Session Summary</td>
</tr>
<tr>
<td>Levels</td>
<td>Difficulty levels based on patient current status</td>
<td>Throughout the whole UI</td>
</tr>
<tr>
<td>Leaderboard</td>
<td>Ranking based on the relative success</td>
<td>Step 5. Session Summary</td>
</tr>
<tr>
<td>Badges</td>
<td>Visual representations of achievements</td>
<td>Step 5. Session Summary</td>
</tr>
<tr>
<td>Feedback</td>
<td>Visual and auditory feedback of the main game target</td>
<td>Step 4. Gamified Training</td>
</tr>
<tr>
<td>Challenges</td>
<td>Specific goals for each exercise</td>
<td>Step 4. Gamified Training</td>
</tr>
</tbody>
</table>

5.1 Therapist Dashboard

Therapist can join the upcoming session through a quick link under ‘Next appointments’ section from the ‘Home’ tab. The calendar on the right side of the screen provides a quick look of scheduled sessions for therapist’s convenience. Moreover, therapist can view patient list, track their progress, and review medical history from the ‘Patient’ tab (see Figure 11).
5.2 Measuring Session

Measuring session is mandatory to calculate the threshold value for each training session. Patients have to perform the swallowing exercise 5-10 times as hard as they can so that the system calculates the threshold value as 70-80% of the average maximum exerted force (see Figure 12). Therapist can also see additional statistics about patient’s swallowing ability, such as maximum exerted force, longest hold, and average speed, to decide settings and game level difficulty for the upcoming training session.
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Measuring session / Kim Jeongyoung

Key statistics

- **Threshold value** (70-80% of average force): 32 g
- **Average peak force**: 42 g
- **Maximum force**: 48 g
- **Number of peaks**: 12
- **Number of holds**: 4
- **Longest hold**: 6 s
- **Average speed**: 1 rep / 3 s

Recommended settings

- **Level 1**
  - Beginner
  - Isometric exercise
    - 4 reps x 15 s hold

Biofeedback graph

![Biofeedback Graph](image)

**Figure 12 Measuring Session, Therapist Interface**

5.3 Settings & Overview

Based on recommended settings and key statistics from the measuring session, therapist defines settings to accommodate each patient’s needs via exercise intensity based on his or her judgement and expertise. Game level difficulty is defined based on the intensity of three exercise types.

The main goal of the ‘Session overview’ screens is to provide a general idea of each session with details on the exercise program. Exercise manual with GIF animation is presented as a visual aid to therapist’s instructions (see Figure 13). This is an important step that addresses the aforementioned limitation of the submandibular push exercise study, i.e. adequate exercise instruction using visual feedback for effective and proper exercise performance.
5.4 Gamified Training

The gamified training consists of five stages, namely, tutorial, countdown, game, statistics, and resting, for each exercise type (see Figure 14). The session starts with a tutorial before each exercise type to help patient understand how to control the game target. After the tutorial, patient can ask questions and express when they are ready. Following a countdown, the actual gamified training starts. Patients have to complete all three exercise types to complete one session (i.e., isotonic exercise followed by isokinetic exercise followed by isometric exercise in one session with rests in-between). There are different goals set for each exercise type. A congratulatory message appears after completing each exercise type. Summary statistics are displayed afterwards. To avoid muscle fatigue, patients can have a rest in between three exercise types. A calming GIF is provided for mindful breathing.
5.5 Session Summary

The overall progress of the whole rehabilitation program can be seen both on therapist’s and patient’s interfaces along with cumulative statistics. Key statistics of each exercise type are displayed in detail to provide a holistic summary of the training session with comparative elements that help monitor patient progress.

For the patient user interface, gamified elements such as badges and leaderboard are implemented at this stage. Badges can be earned based on patient accomplishments and achievements. They act as long-term reward factors for external motivation. On the other hand, leaderboard ranks patients according to their relative performance. It helps patients understand their progress easily with points and engage better. Exercise points are given based on the corresponding success rates (see Figure 15).

6. Discussion & Conclusion

Our study demonstrates an example of designing a gamified user interface for dysphagia rehabilitation, while also defining important UI principles for gamified training. In comparison to existing solutions, our design matches with the natural mapping of the swallowing muscle activity. We believe that this natural mapping is key to designing user-centered gamified training that aligns with patient mental model, thus, resulting in a better user experience.

We have designed our user interface considering not only game elements, such as leaderboard, badges, and challenges, but also the flow channel. In our game scenario, rules are explicitly explained in the tutorial to form a structured training session, while goals (i.e., desired amount of exercise repetitions or time limit) are indicated on the screen to enable patients to act without thinking. Last but not least, our game provides immediate feedback in the form of auditory (i.e., bouncing sound when the target reaches the ground, or bursting sound when one type of exercise has been completed) and visual (i.e., shape change of the target due to the bouncing impact) feedback.

Our paper contributes to the design community by showcasing how implementing various UI design principles in addition to traditional gamification elements can potentially improve the
overall user experience and increase the quality of one’s design outcome. Considering the current demographic trends worldwide, as well as in South Korea, it serves as valuable and emerging research that puts emphasis on the importance of designing for dysphagia rehabilitation. We expect that our study will inspire other designers to incorporate gamification elements into their designs in a rational and well-designed way.

6.1 Limitations and Future Research
The main limitation of our research is the fact that we are yet to confirm the benefits of our well-matched gamified training. The limitations we identified as a result of benchmarking are based on our assumptions and design thinking, thus, need to be properly tested and confirmed to validate the competitive advantages of our gamified user interface as opposed to existing gamified solutions.

Another limitation of our study pertains to the type of motivation that can be induced by gamification. Existing literature confirms that game elements act as extrinsic incentives, meaning that gamification does not affect intrinsic motivation (Mekler et al., 2017). In other words, our gamified solution might not benefit some dysphagia patients, especially those who are less dependent on extrinsic motivation factors.

For future work, software development of the game prototype, as well as its integration with the working prototype is planned. More importantly, we are interested to test and confirm the benefits of our gamified user interface through a user study with real dysphagia patients from Kyungpook National University and Ulsan University Hospitals.

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7. References


FourSquare. (2021). Available at: https://foursquare.com


Neofect. (2021). Available at: https://www.neofect.com/us


Synchrony. (2021). Available at: https://www.acplus.com/synchrony


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