The Impact of Gamified Auditory-Verbal Training for Hearing-Challenged Children at Intermediate and Advanced Rehabilitation Stages

Yan Xiang [1] , Zhen Zhang [1] , Danni Chang [1*] , Lei Tu [2]

[1]School of Design, Shanghai Jiao Tong University, Shanghai, China
[2]Hangzhou Ren-ai Hearing Rehabilitation Research Center, Zhejiang Province, China

Abstract

Auditory-verbal training is essential for children with hearing challenges, and the gamification approach has become a promising direction for improving the rehabilitation experience and effect. However, the specific influence of the gamified training approach on participants at different rehabilitation stages has not been empirically studied. This paper is thusly intended to investigate the research questions: (1) do the training performances of children at advanced rehabilitation stage differ before and after using the gamified training system? (2) do the training performances of children at intermediate rehabilitation stage differ before and after using the gamified training system? (3) do children enjoy the gamified training approach? For the purpose, a digital gamified auditory-verbal training system was originally developed, and a series of user experiments were organized. Particularly, 31 hearing-challenged children aging between three-six years old at an auditory-verbal rehabilitation center were recruited to take the training, and six professional therapists were also invited to assist with the experiments and attend the interviews. Based on the training performance observation and interviews with participants, their parents and the therapists, it can be found that generally the gamified training approach can effectively facilitate the training experience, and help with the basic auditory memory and expression capabilities. Moreover, it is feasible to be applied in practical training due to the high customization of digital training contents, multi-modal interactive training means, and highly enjoyable training experience. Regarding the specific influence, the gamified way can better improve the basic auditory-verbal performance of children at the intermediate stage, since they focus more on the ease of learning and adaption to the training system. While, for children at the advanced rehabilitation stage, the precise training and professional training content are more demanded, and thusly, it is not easy to achieve quick improvements. These findings and conclusions can provide insights for the further exploration and application of the gamification approach in children's auditory-verbal rehabilitation.

Keywords: Auditory-verbal rehabilitation, Games, Training performance, Training experience, Early years education

1. Introduction

Auditory-verbal therapy is important for children who are hard of hearing. With the increasing attention to hearing-challenged children's health and education, the possible rehabilitation training methods and supportive services have been widely studied. Moreover, the technology advancements in hearing aids and cochlear implants have enabled hearing-challenged children to hear sound in some degree, thus the rehabilitation training with auditory and verbal tasks for more effective training effect and enjoyable training experience is better expected.

Looking into the existing rehabilitation training services, they put more focus on the comprehensiveness of training contents and tasks, but neglecting the varying hearing states and training needs of children at different rehabilitation stages. Therefore, the training tasks are not fully tailored to fit different children characteristics. Moreover, the current training process is often repetitive and lacks the consideration of attractive and enjoyable task settings, resulting in the weak user engagement and training compliance. To tackle the issues above, diverse training theories and modes have emerged. For example, Auditory-Verbal Therapy (AVT) focuses on teaching children to listen and speak using their residual hearing (Estabrooks, MacIver-Lux, & Rhoades, 1994). Language Experience Approach (LEA) is to create a language-rich environment through a gamified way with books, stories, and activities (Dixon & Nessel, 1983). For individuals with severe hearing loss or those who may not benefit from traditional speech training, Augmentative and Alternative Communication (AAC) methods, such as communication boards, speech-generating devices, and gamified mobile apps, can facilitate effective rehabilitation (Elsahar, Hu, Bouazza-Marouf, Kerr, & Mansor, 2019). Amongst them, the gamification theory has been demonstrated effective in strengthening children’s learning performance and improving their training experience (Shaban, Pearson, & Chang, 2021; Weng & Chiu, 2023), and has been widely applied in children’s education and training products. Therefore, the integration of gamification approach in auditory-verbal training has become a promising direction for hearing rehabilitation.

In this regard, Splingo's Language Universe (Gosnell, 2011) is an app designed with typical gamification elements such as rewards, interactive games, and engaging characters to encourage children to practice listening, understanding, and responding to spoken language. LiSN & Learn (Cameron, Glyde, & Dillon, 2012) is an auditory training program designed for children with listening difficulties to identify speech

sounds and different auditory cues. AngelSound (Jeddi, Lotfi, Moossavi, Bakhshi, & Hashemi, 2019) is a computer-based auditory training program that offers interactive exercises to improve speech perception and auditory skills. Although gamification has been explored in these training products, the training effect of such gamified approach in auditory-verbal rehabilitation has not been empirically examined, especially for the influence on different rehabilitation stages.

Therefore, this research is aimed to investigate the training effect of gamified auditory-verbal rehabilitation. For the purpose, a gamified auditory-verbal training system was developed, in which training tasks are divided into different challenge levels and tailored to match the training needs of children at different rehabilitation stages. Considering that the children at initial rehabilitation stage often have more severe hearing loss and are too young to make independent game interactions, the intermediate and advanced rehabilitation stages are more emphasized. Based on the gamified training system, the training evaluation experiments are organized. Particularly, three research questions are examined: 1) Do the training performances of children at advanced rehabilitation stage differ before and after using the gamified training system? 2) Do the training performances of children at intermediate rehabilitation stage differ before and after using the gamified training system? and 3) Do children enjoy the gamified training approach? The findings from this study are expected to contribute: i) the empirical examination of the training effect of gamified auditory-verbal rehabilitation approach; ii) the detailed analysis of the influence of different gamified task settings to intermediate and advanced rehabilitation stages; and iii) the in-depth understanding of training experience of the gamified hearing rehabilitation approach.

The remaining of the paper is organized as follows: Section 2 provides an analysis of existing hearing rehabilitation research, and identifies the limitations of existing gamified auditory-verbal training studies. Section 3 introduces the experiment design and process. Section 4 presents experiment results analysis. The possible insights from this research will be discussed in Section 5, and the research is concluded in Section 6.

2. Related works

In this section, the current rehabilitation training theories and treatment approaches were analyzed. As a promising direction in children education products, gamification has been increasingly focused, and it can be anticipated that gamified training may be helpful in hearing rehabilitation. Through looking into the current gamified

auditory-verbal training products, it appears that the detailed examination of the real training effect of gamified auditory-verbal approach is still needed.

2.1 Rehabilitation training for hearing-challenged children

Generally, the rehabilitation process for children with hearing impairment comprises several distinct stages, according to their evolving hearing status and abilities. Early intervention plays a pivotal role, especially for infants and toddlers, aimed at nurturing auditory awareness and language acquisition (Novelli-Olmstead & Ling, 1984). As children grow, their rehabilitation advances to more intricate tasks, including auditory discrimination and speech production (Markman, Quittner, Eisenberg, Tobey, Thal, Niparko et al., 2011). These stages are inherently linked to the child's audiological profile, which may include variables such as the nature and extent of hearing loss, utilization of hearing aids or cochlear implants, and the residual hearing capabilities (Novelli-Olmstead & Ling, 1984). Along with the rehabilitation progress, children may gradually transition from visual cues to auditory inputs (Elliott & Hammer, 1988). The specific communication modalities like sign language or auditory-verbal approaches often need to be selected based on children’s preferences and expected rehabilitation outcomes (Ching, Scarinci, Marnane, Sjahalam-King, Button, & Whitfield, 2018). The individualized feature of these stages further highlights the importance of tailored interventions for the heterogeneous hearing status and needs.

Regarding existing theories of hearing rehabilitation, they normally emphasize a multi-facet approach that integrates auditory, linguistic, and cognitive components (Alkhamra & Abu-Dahab, 2020; Hull, 2019). The auditory brain plasticity theory underscores the brain's capacity to form the basis for auditory training in response to auditory stimulation (Kappel, Moreno, & Buss, 2011). Auditory-verbal therapy emphasizes natural auditory learning (Estabrooks, MacIver-Lux, & Rhoades, 1994), while auditory-based phonological training targets speech perception and phonemic awareness (Antonietti, 2022). Besides the self-training, technological interventions, such as cochlear implants and hearing aids, provide vital auditory inputs, and virtual reality platforms have also been considered to offer immersive listening experiences (Serafin, Adjorlu, & Percy-Smith, 2023). Moreover, robot-assisted rehabilitation training products (Hull, 2019) have been developed to teach sign language through triggering children’s audio, visual, and tactile feedback. Machine-based automatic assessment of pronunciation (Kappel, Moreno, & Buss, 2011) has shown advantages in professional and efficient assessment on the pronunciation quality of words and sentences during unsupervised exercises. Therefore, the selection of an appropriate approach based on children's hearing abilities, training goals, and available resources

is particularly important.

Although different techniques and professional tools have been explored, several limitations and challenges still exist. Basically, the distinct training requirements of different rehabilitation stages have not been fully emphasized in existing training products/platforms. The training service, which is not personalized for different hearing capabilities and rehabilitation stages, may discount the practical training effect. Another issue is the user experience, caused by the poor training interface design and the repetitive training task settings (Tarchi, Zaccoletti, & Mason, 2021). The lack of child-friendly concerns may discourage the constant use of training tools, thereby limiting the potential benefits of the rehabilitation (Hainey, Connolly, Boyle, Wilson, & Razak, 2016). Moreover, the training compliance is a significant concern in hearing rehabilitation (Simpson, El-Refaie, Stephenson, Chen, Deng, Erickson et al., 2015). For example, children with hearing impairment may struggle to reach effective training interactions, leading to weak engagement over time (Dornhoffer & Dornhoffer, 2016).

2.2 Development and application of gamification theory

To address the challenges of untargeted training service, poor user experience and training compliance, the integration of gamification approach (Ke, 2014) might be a potential direction to realize the training tailored for different hearing rehabilitation stages and increase the training attraction to improve training experience and effectiveness.

Generally, the development of gamification theory can be traced back to classic educational and psychological theories. One notable work is Jean Piaget's Constructivism (Waite-Stupiansky, 2017), which emphasizes learning through active engagement and the construction of knowledge. Gamification aligns with this theory by providing children with opportunities to explore, experiment, and discover concepts within a playful context. In addition, Lev Vygotsky's Social Development Theory (Riddle & Dabbagh, 1999) highlights the importance of social interaction and collaboration in learning. In a similar way, gamification leverages social components, such as leaderboards and collaborative challenges, to encourage peer-to-peer interaction and knowledge sharing. Several other theories have also significantly influenced the development of gamification in children's education. Albert Bandura's Social Cognitive Theory (Devi, Khandelwal, & Das, 2017) emphasizes the role of self-efficacy and motivation in learning with gamification through providing immediate feedback and progressive challenges. B.F. Skinner's Operant Conditioning theory (Skinner, 1971) advocates the use of rewards and reinforcements to shape learning behavior and learning outcomes.

Regarding the applications of gamification, it has shown profound impact on multiple domains in terms of improving user experience and service innovation (Sun, Ye, & Wang, 2015). It leverages a range of game mechanics and elements such as scoring, leveling, leaderboards, and achievements to establish a meaningful connection between user progress and the game. For example, the integration of scoring and feedback into cognitive tasks can incentivize participants to invest more effort (Wiley, Vedress, & Mandryk, 2020), resulting in improved response time and reduced error rates. Moreover, it is indicated that consistent game narrative and tasks can better attract users to be engaged, further enhancing user experience and outcomes (Schmidt-Kraepelin, Thiebes, Warsinsky, Petter, & Sunyaev, 2023). Especially in children's education, it has been applied into various educational contexts, including formal classrooms, online platforms, and informal learning settings (Acquah & Katz, 2020). Specifically, in formal education, gamification techniques are integrated into curricula to enhance engagement and facilitate learning. Scores, badges, and rewards are used to acknowledge children's achievements and motivate progress (Ronimus, Kujala, Tolvanen, & Lyytinen, 2014). Online educational platforms often utilize gamification to create immersive and interactive learning experiences. Virtual worlds, quests, and interactive challenges can provide opportunities for children to explore and apply concepts in engaging ways.

All of these works suggest that gamification can effectively encourage desired learning behaviors and outcomes in children's education, and may also be a promising solution for improving the training experience and outcomes in hearing rehabilitation.

2.3 Existing gamified auditory-verbal training systems

For the explorations of gamified auditory-verbal training, a study was conducted to examine the effects of gamification and experiential learning on the mathematics performance of 24 hearing-impaired learners (Adeniyi & Kuku, 2020). The researchers utilized the Mathematics Knowledge Check (MKC) to gather data, and revealed that the use of gamification and experiential learning instructional methods had a significant impact on the math performance of hearing-impaired learners. Interviews and surveys were also conducted (Saman, Shariff, & Nasaruddin, 2019), and found that children with hearing impairments are not exposed to appropriate sign language learning, since traditional sign language textbooks are difficult to decipher due to their static image content. A learning app called i-Sign was accordingly created, which combines simple gamification and multi-media elements, and was evaluated with 91.89% agreements from the respondents on the efficiency and effectiveness of the App learning.

On the other hand, gamified auditory language training platforms and systems are also

emerging in the market, including Hear Coach by Starkey (Olson, Williams, Livingston, & Futscher, 2018), an app developed to offer auditory training games and featured with different levels of difficulties and gamified elements to motivate users to improve their listening skills, and Hearoes (Olson, Williams, Livingston, & Futscher, 2018) providing a series of online games to educate children about hearing health and communication. Similarly, Splingo's Language Universe (Gosnell, 2011), AngelSound (Jeddi, Lotfi, Moossavi, Bakhshi, & Hashemi, 2019) and LiSN & Learn (Cameron, Glyde, & Dillon, 2012), are all based on the gamification of auditory language training. Besides, Virtual reality (VR) games (Hatzigiannakoglou & Okalidou, 2019) have been developed to enhance children's participation and immersion in rehabilitation training. These games cover sound detection, auditory discrimination, auditory recognition, and auditory comprehension (Erber, 1982), based on Erber's paradigm of auditory development stages.

Although the gamified approach has been identified as a promising direction and diverse training products and platforms have been explored, the training effect has not been empirically examined (Beacham & Alty, 2006; Barak, Ashkar, & Dori, 2011). An in-depth analysis is worthwhile to reveal the training effectiveness and training experience of gamified auditory-verbal rehabilitation (Doumanis, Economou, Sim, & Porter, 2019), and shed light on the potential of gamified auditory-verbal training in hearing rehabilitation therapies.

3. Experiment design

In this work, a digital auditory-verbal training game was originally developed. Particularly, different training tasks were designed based on children's hearing capabilities and development states at intermediate and advanced rehabilitation stages. With the training game prototype, participants were recruited to use the training game. Their training performance will be recorded and analyzed to verify if the gamified training approach has any influence on the training effect.

3.1 The digital rehabilitation game

Generally, an auditory-verbal training game named "Hear to See" was developed to assist hearing-challenged children between three to six years old. Especially, their skills in sound volume perception, auditory memory, auditory description, articulation abilities, sentence expression, and cognitive abilities will be focused and trained. Figure 1 shows the whole game structure.

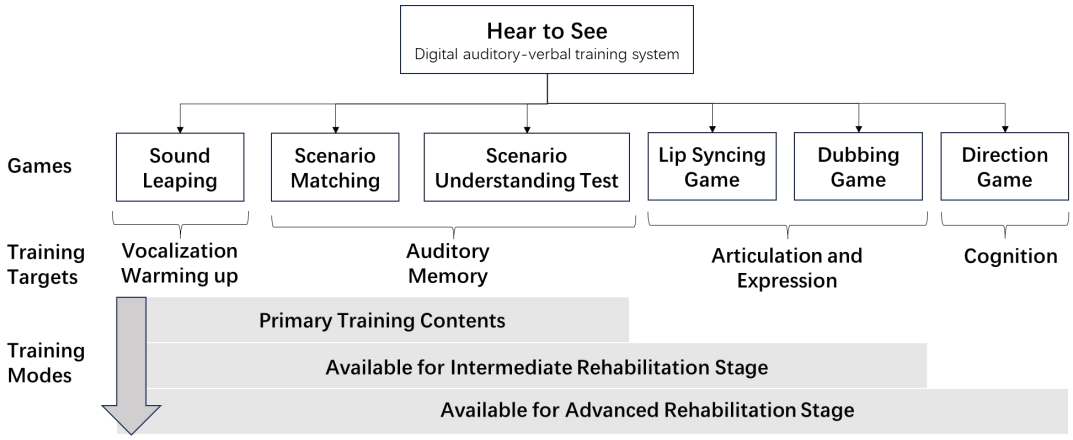


Figure 1. The training game structure

Generally, the training modes were tailored to intermediate and advanced rehabilitation stages. Basically, auditory training was arranged as the primary training tasks. Specifically, three games were arranged (as shown in Figure 2). Sound Leaping is a voice control jumping game, which is for warming up through having participants experience the control of voice volume and duration to increase their training engagement. Scenario Matching is to select the key elements based on the scenario description, and Scenario Understanding Test is to select the comprehensive right answers based on the scenario understanding. The two games are both for the auditory memory training. The former emphasizes keywords recall, while the latter emphasizes the comprehension of holistic scenarios.

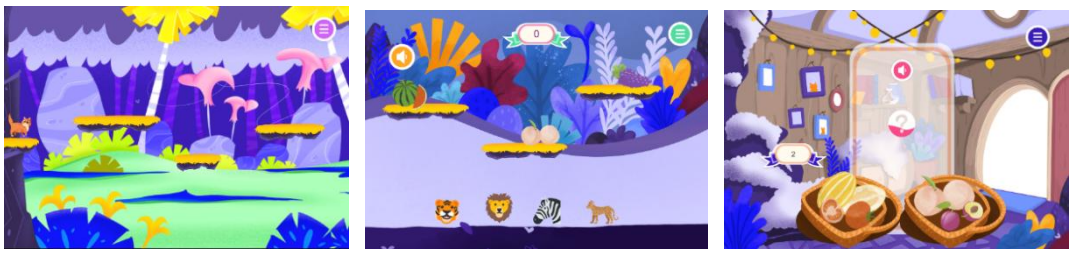


Figure 2. Interfaces of primary training games (from left to right: Sound Leaping, Scenario Matching, and Scenario Understanding Test)

Vocalization warming up: In the game of Sound Leaping, phonation volume and time will control the jumping actions of the kitten. Lower sound volumes activate the kitten to move forward, whereas higher sound volumes activate jumping behavior. Additionally, the length of the kitten's jumping depends on the phonation time.

Auditory memory training: In Scenario Matching, children are required to pair animals with fruits based on the audio descriptions, like “Please put the lion besides the watermelon”. In Scenario Understanding Test, children are asked to pick the correct fruits based on audio cues, like “It is round, and in red color”.

Figure 3. Game interfaces of articulation and expression training (from left to right: Lip-syncing Game, and Dubbing Game)

Articulation and expression training (Figure 3): In Lip-syncing Game, children need to imitate the mouth position for the pronunciation of certain vocabularies. A standard mouth position will be shown on the screen, and the children just need to follow and pronounce. The camera will record the face of the participants in real time, and the facial recognition technology of OpenCV will be applied to compare the differences of the mouth position between participants and standard patterns. In the Dubbing Game, longer sentences will be played, and the participants need to repeat the sentences and describe the scenes. The voice recognition technology of Baidu AI will be applied to recognize if the articulation of the participants is correct. These two games contribute to the training of articulation and expression abilities.

Figure 4. Direction Game interfaces

Cognitive training (Figure 4): In Direction Game, children control the movements of the kitten by correctly pronouncing "up," "down," "left," or "right" to reach the target endpoint as quickly as possible. Through the game, their cognitive intelligence in spatial and timing sense can be trained.

In the training system, the gamification elements of narrative storytelling, rewarding principles, interactive engagement and visual characters were effectively integrated. To explain, vibrant and high-saturation colors have been strategically incorporated into the visual elements. Narrative story line, e.g., a cat chatting with a lion, was

arranged to invoke children's intuitive memory and imagistic thinking to enhance training task connections and engagements. Based on children's training performance, the correct responses will get positive visual animations, such as twinkling stars and vibrations, reinforcing a sense of accomplishment and progress; while, incorrect responses will get a gentle encouragement, such as "Try again," to avoid frustration and create a positive learning atmosphere. Furthermore, the integration of multi-modal interactions through auditory, visual and verbal cues can further foster children's curiosity and interests, and create a cohesive learning experience.

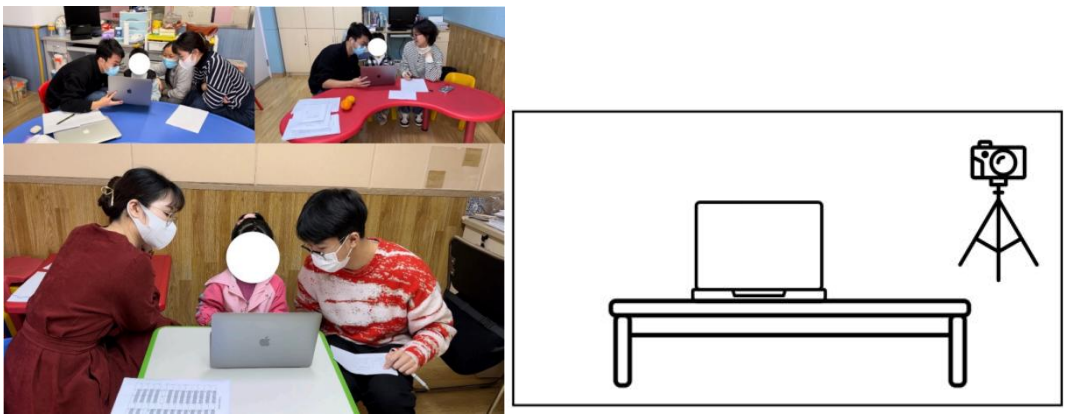
3.2 Participants

A total of 31 pre-school children aged between three to six years old undergoing different rehabilitation stages at the Ren'ai Rehabilitation Center in Hangzhou were recruited as participants. As mentioned above, children in the early stage of hearing rehabilitation are too young to independently complete the rehabilitation training, thusly only children at intermediate and advanced rehabilitation stages were involved. Specifically, 15 of them are in the intermediate stage, and the other 16 participants are in the advanced stage. Regarding the gender distribution, 17 of them are boys and 14 are girls. All the participants are healthy except of hearing, and informed consent was obtained from their guardians and the rehabilitation center. The experiment has received an approval from the Institutional Review Board for Human Research Protections of the authors' University. Meanwhile, six therapists in this center were also invited to assist with the experiment.

3.3 Experiment environment setting

Participants in the same rehabilitation stage take the experiments in the same experiment room at the Ren'ai Rehabilitation Center, where they regularly take the training. It is to minimize the unfamiliarity and anxiety feelings of the children. Each experiment room was assigned with three roles: the experimenter, the participant, and the teacher of this rehabilitation center (Figure 5a). Since these participants are three-to six years old children, the teacher can provide emotional trust and support to them, helping them take the experiment naturally. During the formal experiment, the teacher would be just there and the participants need to complete the experiment independently. The guardians can observe the whole experiments outside of the room.

A fixed computer (Macbook2020) with 13.3 inches and 2560*1600 resolution, and with macOS 13.0 operation system was set for the rehabilitation game (Figure 5b). Additional recording cameras were set to record the participants' facial expressions, lip movements, and operation behaviors during the experiment. Once the experiment begins, the screen recording and the participant recording start simultaneously.



a b

Figure 5. Experiment environment (a. Experimenting scenes; b. Experiment devices setting)

3.4 Experiment procedures

The whole experiment lasts for two weeks. The training frequency was set referring to the current training plan for intermediate- and advanced-rehabilitation-stage children of the center, that is once a week. Therefore, the participants take the gamified training every week, and their training performance will be compared before and after the experiment. To be noted, tasks for the same training game will be offered in different designs. For example, different animals and fruits will be given for Scenario Matching. The task order will be randomly assigned for the same training game during each experiment.

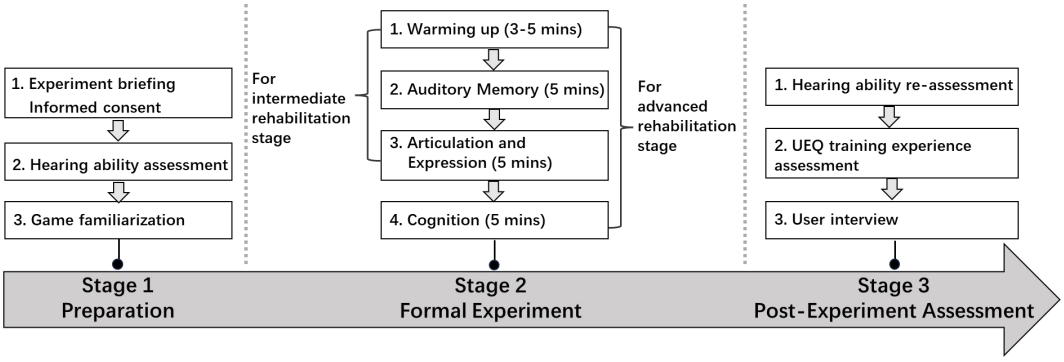


Figure 6. Experiment process and specific procedures

Regarding the experiment process, it covers three main stages (as shown in Figure 6). The first stage is the preparation. The experiment purpose, procedures, and guidelines were explained to the participants and their parents. With the assistance of the therapist in the rehabilitation center, basic information of the participants was recorded, and their hearing ability will be assessed. For the purpose, the acknowledged professional assessment tools of "Brief Evaluation Form for Auditory Rehabilitation of Hearing-Impaired Children" (Sun, Zhang, Huang, & Zhang, 2009), " Brief Assessment Form for Articulation and Phonological of Hearing-Impaired

Children" (Qiu, 2004), "Brief Evaluation Form for Language Abilities Assessment of Hearing-Impaired Children" (Wang, 2021), and "Speech Intelligibility Grading Questionnaire" (Wang, Wu, & Zhang, 2019) were used. With the primary introduction and hearing assessment, the participants will be familiarized with the game content and rules, and can try the necessary operations.

During the experiment, participants were assigned with training games matching with their rehabilitation stage. For example, the children at intermediate rehabilitation stage need to try the Warming up, Auditory memory, and Articulation and expression games. Correspondingly, the children at advanced rehabilitation stage need to try all the games from Warming up to Direction recognition. For each game, 5 minutes were assigned for participants to practice, so that 20-25 minutes in total was spent for each round of training. The whole game process of all participants was recorded. Considering that the Sound Leaping game is a warm-up game, no data analysis will be performed. The specific data recorded are summarized as below.

- ***Scenario Matching***: Participants' completion time, and the number of times the scenario description has been played until the participants can correctly complete the training task.
- ***Scenario Understanding Test***: Participants' completion time, scores, the number of times the scenario description has been played, and the incorrect answers from participants.
- ***Lip-syncing***: Participants' facial expressions (especially the mouth position), the number of times the audio description has been played, the completion time, the number of pronunciation errors, and specific errors in sound and mouth positions.
- ***Dubbing Game***: Participants' completion time, the number of times the audio description has been played, the number of pronunciation errors, and specific errors in sound and intonation.
- ***Direction Game***: Participants' completion time and pronunciation errors.

The third stage is the post-experiment assessment. After the training of two weeks, participants' hearing abilities will be re-assessed with the assistance from the therapists using the assessment tools abovementioned. Besides, User Experience Questionnaire (UEQ) is employed to evaluate the training experience with this gamified rehabilitation system. Moreover, in-depth interviews are arranged to collect the comments and suggestions from the participants (their guardians) and the therapists in the rehabilitation center.

With the experiment data recorded, participants' training performance will be

compared before and after experiment, in order to evaluate whether the gamified training approach can effectively improve their auditory-verbal performance and the training performance. The experience rating scales and interview feedbacks will be analyzed to investigate if the gamified training approach is emotionally satisfying and enjoyable.

4. Results Analysis

In this section, the following questions will be emphatically analyzed: (1) Do the training performances of children at advanced rehabilitation stage differ before and after using the gamified training system? (2) Do the training performances of children at intermediate rehabilitation stage differ before and after using the gamified training system? (3) Do children enjoy the gamified training approach? For the purpose, the data collected in Section 3.4 will be analyzed, and the training performance will be accordingly investigated. Particularly, an analysis strategy consisting of auditory memory evaluation, articulation and expression evaluation, direction cognition evaluation, training engagement evaluation, and training experience evaluation was proposed. Specifically,

Auditory Memory Evaluation: The data in Scenario Matching and Scenario Understanding Test will be integrated to evaluate the auditory memory ability. For the purpose, the game performance data of task completion time and error rate will be jointly considered to evaluate the game performance level, which will be directly compared before and after the training.

Articulation and Expression Evaluation: The performance data in task completion time, the number of times the audio description has been played and error rate of Lip Syncing and Dubbing games will be jointly considered to evaluate the training performance level, and will be compared before and after the training. Moreover, the assessment tool of “Brief Evaluation Form for Auditory Rehabilitation of Hearing-impaired Children”, “Brief Assessment Form for Articulation and Phonological Rehabilitation of Hearing-impaired Children”, and “Speech Intelligibility Grading Questionnaire” were used to professionally assess the children’s articulation and expression ability. Particularly, children’s ability in auditory description with given hints, auditory description without any hints, and the ability to speak clearly will be assessed.

Direction Cognition Evaluation: The performance data of Direction game, such as completion time, will be compared before and after the training.

Training Engagement Evaluation: The assessment tool of “Brief Evaluation Form

for Language Abilities of Hearing-impaired Children" was used to professionally examine if children have effective training engagement. For example, the performance of using language to express (e.g., describe, make comments, narrative skills), using language as a tool to query, demand and order, using language to coordinate during the tasks, and enjoying the language as a kind of entertainment are measured.

Training Experience Evaluation: The UEQ (Schrepp, Thomaschewski, & Hinderks, 2017) scale was used, and the dimensions of "attractiveness," "perspicuity," "efficiency," "stimulation," and "novelty" will be rated to represent the subjective feedback of participants on this training system.

Generally, paired T-test was adopted to examine the difference before and after the training. Normal distribution tests were performed for every round of analysis, and it shows that T-tests can be applied. The software of SPSS Statistics v29 was used as the analysis tool.

4.1 Do the training performance of children at advanced rehabilitation stage differ before and after using the gamified training system?

Following the analysis strategy explained above, children's training performance was investigated in terms of different auditory-verbal capabilities. The results of Auditory memory, Articulation and expression and Training engagement are shown in Table 1.

Table 1. Paired t-test for training performance of children at advanced rehabilitation stage

Evaluations	Mean ± Standard deviation		Difference Value	t	p
	Before experiment	After experiment			
Auditory memory					
Auditory memory[1]	4.56±0.51	4.75±0.45	-0.19	-1.861	0.083
Articulation and Expression					
Articulation performance[1]	20.88±3.98	22.38±2.68	-1.5	-3.674	0.002**
Auditory description with hints[2]	3.69±0.48	3.88±0.34	-0.19	-1.861	0.083
Auditory description without hints[2]	2.75±0.77	2.88±0.72	-0.13	-1.464	0.164
Speech intelligibility[2]	4.44±0.51	4.63±0.50	-0.19	-1.861	0.083
Training Engagement					
Language for	7.31±1.30	7.63±0.96	-0.31	-2.611	0.020**

expression[2]					
Language as game tool[2]	7.63±1.41	7.69±1.30	-0.06	-1	0.333
Language for coordination[2]	7.56±1.31	7.63±1.31	-0.06	-1	0.333
*p < 0.05, **p < 0.01					

[1] represents the analysis results are obtained based on game performance data

[2] represents the analysis results are obtained based on the auditory-verbal assessment

Based on Table 1, it can be observed that significant differences exist in "Articulation performance" and "Language for expression" dimensions. It suggests that the gamified training has positive effect on enhancing speech abilities of children at advanced rehabilitation stage. However, in "Auditory memory", "Auditory description with hints", and "Auditory description without hints" dimensions, the impact of gamified training is not statistically important. It can be understood that children at advanced rehabilitation stage already possess basic auditory-verbal capabilities, and thusly, noticeable improvements in auditory aspects are not easy to achieve. Similarly, no significant differences were observed in "Speech intelligibility", "Language as a game tool" and "Language for coordination". For these dimensions, children are required to have higher skills to express them clearly and use language or speech as a functional tool. Therefore, long-time training is often necessary, and the training during this experiment may not be enough to influence these dimensions.

Regarding the specific training games, several tasks were performed by participants. As explained in Section 3.4, different tasks are prepared for the same training game. During the five-minutes training for each game, the participants can practice several tasks. Apart from the comparison before and after the whole training, the performance of different rounds of training tasks will also be investigated. For Lip Syncing game, the performance data is shown in Table 2. To be noted, since the task order is random for two rounds of training, only the same tasks will be compared.

Table 2. Paired t-test for training performance of children at advanced rehabilitation stage in lip syncing game

Evaluation metrics	**Mean ± Standard deviation**		**Difference**	**t**	**p**
	The 1st training	**The 2nd training**	**Value**		
Completion time of Task A	7.31±4.25	4.50±0.97	2.81	2.505	0.024*
Errors in Task A	1.13±1.50	0.19±0.40	0.94	2.7	0.016*
Completion time of Task B	10.31±14.08	4.50±1.37	5.81	1.767	0.098
Errors in Task B	1.88±2.36	0.31±0.60	1.56	2.854	0.012*
Completion time of	6.69±6.49	3.88±0.89	2.81	1.733	0.104

Task C					
Errors in Task C	1.19±1.52	0.31±0.60	0.88	2.333	0.034*
*p < 0.05, **p < 0.01					

Based on Table 2, it is clear that generally the completion time and task errors get improved through two rounds of training. Particularly, the task errors (i.e., inaccurate pronunciations) have significantly reduced. Since the bias caused by repeated training was considered in the random arrangement of tasks for each participant, it may suggest that the training system can effectively improve the training effect.

For Dubbing game, the performance data is shown in Table 3.

Table 3. Paired t-test for training performance of children at advanced rehabilitation stage in dubbing game

Item	Mean ± Standard deviation		Difference value	t	p
	The 1st training	The 2nd training			
Completion time of Task A	57.94±52.29	45.00±37.84	12.94	2.97	0.010**
Errors of Task A	1.56±1.86	1.88±2.13	-0.31	-1.431	0.173
Completion time of Task B	29.19±52.43	15.88±15.50	13.31	1.361	0.194
Errors of Task B	0.75±1.57	0.75±1.24	0	0	1
Completion time of Task C	80.19±53.02	67.69±43.09	12.5	3.619	0.003**
Errors of Task C	3.06±2.52	3.06±2.17	0	0	1
*p<0.05, **p< 0.01					

For Dubbing Games, the completion time of Task A and Task C significantly decreased. However, no significant differences were observed in terms of task errors. This is possibly caused by their increasing familiarity with the training game. However, the training difficulty remains similar to them despite of two rounds of training. The dubbing tasks require participants to have a good understanding of the narrative story, and then describe the scene correctly. The proficiency needed to successfully complete this task is actually high, and the limited training period and the training just focusing on the auditory-verbal training is not enough to support the implementation of this tasks.

For Direction game, the performance data is shown in Table 4.

Table 4. Paired t-test for training performance of children at advanced rehabilitation stage in direction game

Direction Cognition	Mean ± Standard deviation		Difference value	t	p
	The 1st training	The 2nd training			

Completion time	141.50±63.02	106.50±26.26	12.94	35	0.005**
*p<0.05, **p< 0.01					

In the Direction game, notable improvement in completion time was observed. It indicates that children became more proficient in recognizing direction targets and pronouncing directional cues. The training approach can effectively improve their direction cognition performance.

4.2 Do the training performances of children at intermediate rehabilitation stage differ before and after using the gamified training system?

Based on the paired T-test between pre- and post-experiment results, it shows that hearing-challenged children at the intermediate rehabilitation stage achieved improvements in auditory memory, articulation and expression performances.

Table 5. Paired t-test for training performance of children at intermediate rehabilitation stage

Evaluations	**Mean ± Standard deviation**		**Difference Value**	**t**	**p**
	Before experiment	**After experiment**			
Auditory memory					
Auditory memory[1]	3.67±0.49	4.00±0.53	-0.33	-2.646	0.019*
Articulation and Expression					
Articulation performance[1]	16.20±1.57	18.93±4.28	-2.73	-4.771	0.000**
Auditory description with hints[2]	2.73±0.59	3.07±0.70	-0.33	-2.646	0.019*
Auditory description without hints[2]	1.20±0.86	1.33±0.72	-0.13	-1.468	0.164
Speech intelligibility[2]	3.47±0.74	3.53±0.64	-0.07	-1	0.334
Training Engagement					
Language for expression[2]	5.00±1.81	5.60±1.68	-0.6	-3.154	0.007**
Language as game tool[2]	5.60±2.29	5.73±2.15	-0.13	-1.468	0.164
Language for coordination[2]	5.40±1.76	5.53±1.85	-0.13	-1.468	0.164
*p < 0.05, **p < 0.01					

[1] represents the analysis results are obtained based on game performance data

[2] represents the analysis results are obtained based on the auditory-verbal assessment

As shown in Table 5, “Auditory memory” was significantly improved. Different from

children at advanced rehabilitation stage, the auditory-verbal capability of such participants is still in a preliminary stage. Therefore, the training appears very helpful to enhance their basic auditory abilities. Moreover, the dimensions of “Articulation performance”, “Auditory description with hints” and “Language for expression” got significantly improved, which further demonstrates that the gamified training can effectively enhance their articulation and expression performance.

However, "Auditory description without Hints" shows no significant difference. The dimension appears more challenging for children at the intermediate rehabilitation stage to get quick improvement. Besides, no significant differences were observed with "Speech intelligibility," "Language as a game tool," and "Language for coordination”. Similar with children at advanced rehabilitation stage, such dimensions require better mastering of the functional use of language, and are not easy to be influenced by limited training. Therefore, the influence on participants’ effective training engagement is limited.

For Lip syncing game, the performance data is shown in Table 6. It can be found that there is a significant decrease in completion time for all the tasks, which suggests the training performance can be effectively improved in mouth position learning and the pronunciation of single consonants. However, the influence on task error is not very clear, which indicates that the training is not useful enough to improve the training effect.

Table 6. Paired t-test for training performance of children at intermediate rehabilitation stage in lip syncing game

Item	Mean ± Standard deviation		Difference value	t	p
	Before the Experiment	After the Experiment			
Completion time of Task A	16.80±14.01	9.20±5.23	7.6	3.111	0.008**
Errors of Task A	1.47±1.81	0.80±1.01	0.67	2.197	0.045*
Completion time of Task B	4.80±2.14	3.73±0.59	1.07	2.256	0.041*
Errors of Task B	0.07±0.26	0.13±0.52	-0.07	-0.435	0.67
Completion time of Task C	8.47±7.39	4.67±1.05	3.8	2.153	0.049*
Errors of Task C	0.40±0.63	0.27±0.59	0.13	1.468	0.164

*p<0.05 **p< 0.01

For Dubbing game, the performance data is shown in Table 7. Significant influence was observed only on the completion time of two tasks. As mentioned above, dubbing games have higher requirements on users’ scenario understanding and descriptive

expression abilities. It is difficult for the children at intermediate rehabilitation stage to achieve marked improvement in their training performance.

Table 7. Paired t-test for training performance of children at intermediate rehabilitation stage in dubbing game

Item	Mean ± Standard deviation		Difference value	t	p
	The 1st test	The 2nd test			
Completion time of Task A	78.00±37.18	72.07±33.54	5.93	1.771	0.098
Errors of Task A	4.13±2.47	3.73±1.83	0.4	1.702	0.111
Completion time of Task B	117.40±86.44	98.87±87.39	18.53	2.875	0.012*
Errors of Task BB	4.80±2.88	4.53±2.77	0.27	1.293	0.217
Completion time of Task C	66.27±53.79	44.53±28.82	21.73	2.311	0.037*
Errors of Task C	3.33±3.15	2.67±2.44	0.67	1.128	0.278
*p<0.05 **p< 0.01					

4.3 Do children enjoy the gamified training approach?

The tool of UEQ (https://www.ueq-online.org/) was adopted to measure the user experience from five dimensions, i.e., "attractiveness", "perspicuity", "efficiency", "stimulation", and "novelty". Based on the rating scores, five evaluation levels can be labelled, including "Excellent", "Good", "Above Average", "Below Average" and "Bad". With the ratings from 31 participants, the post-training UEQ results are presented in Table 8 and Figure 7. It can be seen that the scores of "attractiveness" and "novelty" of the training system are 2.17 and 2.15, labelled as "Excellent", indicating that the gamified training approach is very attractive and innovative to participants. Besides, the scores of "perspicuity", "efficiency" and "stimulation' are 1.79, 1.68 and 1.60, which are positioned as "Good", implying that users have positive experience in the practical use of this system. Therefore, users have generally very positive evaluation on the gamified training approach.

Table 8. UEQ evaluation results

Scale	Mean	Comparison to benchmark	Interpretation
Attractiveness	2.17	Excellent	In the range of 10% best results
Perspicuity	1.79	Good	10% of results better,75% of results worse
Efficiency	1.60	Good	10% of results better,75% of results worse
Stimulation	1.68	Good	10% of results better,75% of results worse
Novelty	2.15	Excellent	In the range of 10% best results

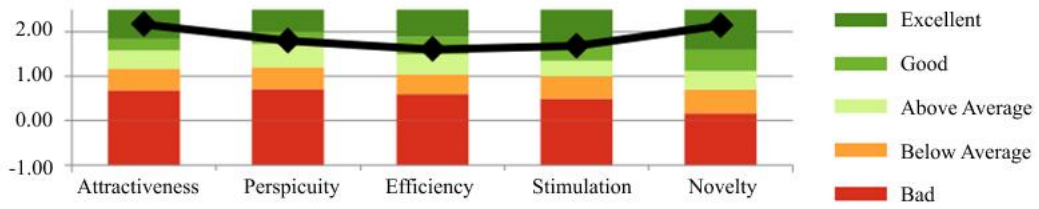


Figure 7. Benchmark Bar Chart of UEQ results

Moreover, interviews were conducted with the 31 participants and their parents, and six therapists in the rehabilitation center. Compared with traditional classroom teaching, they expressed stronger interest and higher preference on the gamified system.

For the 15 participants at the intermediate rehabilitation stage, the majority enjoy "Sound Leaping" the most. As a warm-up process, it can effectively trigger participants' engagement and enhance their training acceptance. In terms of auditory training, they also expressed very positive experience with Scenario matching and Scenario understanding test, and commented that they have higher enthusiasm to take training with the gamified system. However, Lip syncing and Dubbing were less favored by them, due to the high requirement for precise pronunciation.

For participants at advanced rehabilitation stage, the Direction game was highly rated by most participants, followed by Dubbing game. Such training can help them with the learning of simple sentences and the precise control and use of pronunciation via an enjoyable way. However, the auditory training of Scenario matching and Scenario understanding test are less favored, since the training content is basic and the training tasks appear too repetitive to them.

Based on the interview among participants at intermediate and advanced rehabilitation stages, it is clear that for different rehabilitation stages, the suitable training approach is different. Therefore, it is very important to provide multi-type and multi-level training content to fit different rehabilitation needs.

For the therapists, they all agreed that the gamified training approach can greatly strengthen children's training intention and increase their training compliance. Especially compared with classroom teaching, the gamified training approach shows clear advantage in the interactive training means and vivid construction of narrative training scenario. Meanwhile, they pointed out possible improvements, such as the adaption to colloquial expression in technical recognition of participants' pronunciation and mouth positions, and make a good balance between auditory-verbal training and the gamified visualization, avoiding too much visual distractions. In addition, more elaborate distinction in training contents and task difficulties can be

considered (e.g., setting more difficulty levels and training types) to further meet the training characteristics of different rehabilitation stages.

Based on the UEQ results and interview analysis, it can be reached that the gamified training approach is attractive to participants, and can effectively improve their training performance. However, the specific influence of the gamified approach on training performance varies among different rehabilitation stages. Therefore, it is important to tailor the training tasks and gamification elements to fit different hearing states.

5. Discussion

Based on the results analysis in Section 4, the gamified system can generally achieve positive influence on participants' auditory memory, articulation and expression, training engagement and training experience. The detailed comparison between different rehabilitation stages will be further discussed.

5.1 The varying impact of gamified training on children's auditory-verbal abilities at different rehabilitation stages

Through comparing children's training performance between advanced and intermediate rehabilitation stages (Tables 1 and 5), it can be found that the gamified approach generally shows more effective influence on children at intermediate rehabilitation stage, especially in the basic auditory (i.e., auditory memory) and verbal (i.e., articulation, auditory description with hints, language for expression) capabilities. It can be understood that for children at the preliminary rehabilitation stage, the training measure which can attract them to practice more may lead to obvious improvements. However, for the children at advanced rehabilitation stage, it is not easy to achieve quick improvement just through the gamification of the training content.

Looking into the specific training games, the significant influence can be observed in the error rate for the children at advanced rehabilitation stage in the Lip-syncing game (Tables 2 and 6); however, the influence is more presented in the completion time for the children at intermediate rehabilitation stage. It strongly indicates that children at the advanced stage are more targeted at the precise pronunciation, and children at the intermediate stage are still adapting to new training measures. The professional training content should be differentiated for meeting the distinct training purposes. In this regard, the performance of Scenario understanding test was extendedly analyzed (Tables 9 and 10). Through a comparison, it is extremely clear that children with intermediate auditory-verbal capabilities can achieve better improvements. The Scenario understanding test is helpful to change the training performance of children

at intermediate rehabilitation stage, but appears not effective enough to influence children at the advanced stage. The finding is consistent with above that the more complex and professional training content may better fit the children at advanced stage, and the specific gamification methods and elements should match with participants' skill levels well.

Table 9. Paired t-test for training performance of children at advanced rehabilitation stage in Scenario understanding test game

Game performance	Mean±Standard deviation		Difference value	t	p
	Before the Experiment	After the Experiment			
Completion time of Task A	13.00±5.74	13.00±4.55	0	0	1
Completion time of Task B	19.56±16.35	14.00±7.28	5.56	2.014	0.062
Completion time of Task C	12.81±6.36	11.94±3.59	0.88	0.76	0.459
Completion time of Task D	11.50±3.46	12.50±3.10	-1	-3.464	0.003**
Completion time of Task E	15.88±12.27	12.38±3.98	3.5	1.475	0.161
*p<0.05 **p< 0.01					

Table 10. Paired t-test for training performance of children at intermediate rehabilitation stage in Scenario understanding test game

Game performance	Mean±Standard deviation		Difference value	t	p
	Before the Experiment	After the Experiment			
Completion time of Task A	20.87±13.29	15.53±6.35	5.33	2.442	0.028*
Completion time of Task B	23.20±10.88	18.40±6.78	4.8	3.091	0.008**
Completion time of Task C	17.93±11.66	13.87±6.49	4.07	2.8	0.014*
Completion time of Task D	20.73±13.42	15.60±6.27	5.13	2.464	0.027*
Completion time of Task E	24.87±16.90	15.67±6.95	9.2	3.03	0.009**
*p<0.05 **p< 0.01					

For Dubbing game, the influence only exits in task completion time no matter for children at advanced stage or intermediate stage (Tables 3 and 7). It implies that the

gamification may bring about more complex factors, such as the more complex training visualization and understanding, which may require supportive capabilities to complete, not just relying on auditory-verbal aspects. Therefore, it is challenging for children to adapt in short time and not easy to reach effective training effect.

For Direction game, it is only prepared for the children at advanced rehabilitation stage to train their direction cognition ability. The training performance data and the post-training evaluations all revealed that children enjoy such training measure and can achieve effective improvement in spatial perception and orientation. It suggests that the cognitive training may be suitable in the gamified way, and it can be further considered to strengthen the auditory-verbal training supplying with cognitive contents.

Moreover, it is interesting to find that the significant differences can be more easily observed in the dimensions based on game performance data, which are directly recorded during the game practicing. Most of the dimensions derived from the professional assessment tools, which needs to be assessed by professionals, are not showing meaningly influence. It indicates that the training performance can be changed along with the training, but the real hearing ability is not easy to achieve effective improvements. The gamified way is suitable to the capability which can be changed in a short time. However, for the comprehensive language competence, a long-term training is still needed to make further validation.

5.2 Feasibility of the gamified auditory-verbal training approach

Based on the joint analysis of participants' and therapists' interviews, it can be reached that the gamified approach is better preferred compared with traditional training, and it contains great potential to practically help hearing-challenged children to realize self-training. Particularly, the high customization of the gamified training approach can facilitate the feasibility in supporting children with different hearing states. It can effectively motivate children to exercise, and meanwhile, the digital training content can be flexibly tailored and updated to meet different training purposes. Moreover, the technical implementation of sound detection and visual recognition is adaptable to various sounds and visual characteristics, which further enhances the technical feasibility of the training system.

Regarding the training content, it is highly consistent with the professional training materials. Based on the training textbooks and references, proper gamification elements were applied to create multi-modal training environment. Therefore, it ensures the basic professionality, and provides additional value in improved training experience. Moreover, the gamification design should be careful to provide attractive

training tasks, and meanwhile, avoid too much distraction caused by unnecessary gamification elements.

Generally, clear advantages can be identified with the gamified auditory-verbal training approach. It can assist with the enjoyable training experience and enhanced training compliance. However, varying impacts should be considered during the gamification design of training tasks for children at different rehabilitation stages. The proper gamification should respect participants' skill levels, subject to the professional training contents, avoid too much visual distractions and adapt to different pronunciation behaviors. These insights also shed light on the promising direction of gamified auditory-verbal training as a valuable rehabilitation tool for hearing-challenged children.

6. Conclusion

This study is intended to empirically examine the influence of gamified auditory-verbal training on children at different rehabilitation stages. Particularly, three research questions were investigated to reveal i) the influence of gamified auditory-verbal training on the training performance of children at the advanced rehabilitation stage; ii) the influence of gamified auditory-verbal training on the training performance of children at the intermediate rehabilitation stage, and iii) the training experience of the gamified approach. For the end, a digital gamified training system was originally developed and prototyped. 31 hearing-challenged children aging three to six years old were recruited to take the training on the digital gamified system. Through the comparison before and after the training and the comparison between children at advanced and intermediate rehabilitation stages, it can be found that generally the gamified training can bring positive influence on basic auditory memory, articulation and expression capabilities, training engagement, and training experience. For children at the intermediate rehabilitation stage, the gamification which can attract them and trigger their training motivation is more important. Therefore, it can influence their training completion performance relatively easily. However, for children at the advanced rehabilitation stage, the gamification is required to be proper with reasonable gamification elements, and professional with precise practice contents. Therefore, it is not easy to improve their training performance in short time. In addition, the feasibility of such gamified training approach has been demonstrated, which shows that the gamified training approach contains clear potential to further support the auditory-verbal rehabilitation, owing to the high customization of digital training contents, the multi-modal interactive means, and the enjoyable training experience.

This work is expected to contribute: i) the empirical examination of the influence of gamified auditory-verbal training on the training performance of hearing-challenged children at different rehabilitation stages; ii) an in-depth evaluation of the training experience and training feasibility of the gamified auditory-verbal training system; and iii) valuable insights on the further explorations of the gamification approach in hearing-challenged children's rehabilitation and education.

However, there are still some limitations of this work. For example, the sample size of 31 hearing-challenged children and six therapists is still limited. The training period of two weeks is relatively short, due to the time limitation and the consideration of not interfering too much in the normal training at the rehabilitation center. In future work, a larger sample size will be considered to achieve more reliable statistical analysis, and the training will last for a more effective period to validate the practical training effect. Moreover, the digital training system will be further optimized to deliver the training contents in a more proper gamification way, so as to reduce the distraction or influence caused by unnecessary gamification elements.

References

Acquah, E. O., & Katz, H. T. (2020). Digital game-based L2 learning outcomes for primary through high-school students: A systematic literature review. *Computers & Education*, *143*, 103667.

Adeniyi, S., & Kuku, O. (2020). Impact of gamification and experiential learning on achievement in mathematics among learners with hearing impairment in Lagos State, Nigeria. *African Journal of Educational Studies in Mathematics and Sciences*, *16*(2), 51-65.

Alkhamra, R. A., & Abu-Dahab, S. M. (2020). Sensory processing disorders in children with hearing impairment: Implications for multidisciplinary approach and early intervention. *International Journal of Pediatric Otorhinolaryngology*, *136*, 110154.

Antonietti, A. (2022). Music-based and auditory-based interventions for reading difficulties: A literature review. *Heliyon*.

Barak, M., Ashkar, T., & Dori, Y. J. (2011). Learning science via animated movies: Its effect on students' thinking and motivation. *Computers & Education*, *56*(3), 839-846.

Beacham, N. A., & Alty, J. L. (2006). An investigation into the effects that digital media can have on the learning outcomes of individuals who have dyslexia. *Computers & Education*, *47*(1), 74-93.

Cameron, S., Glyde, H., & Dillon, H. (2012). Efficacy of the LiSN & Learn auditory training software: randomized blinded controlled study. *Audiology research*, *2*(1), e15.

Cameron, S., Glyde, H., & Dillon, H. (2012). Efficacy of the LiSN & Learn auditory training software: randomized blinded controlled study. *Audiology research*, *2*(1), e15.

Ching, T. Y., Scarinci, N., Marnane, V., Sjahalam-King, J., Button, L., & Whitfield, J. (2018). Factors influencing parents' decisions about communication choices during early education of their child with hearing loss: A qualitative study. *Deafness & Education International*, *20*(3-4), 154-181.

Devi, B., Khandelwal, B., & Das, M. (2017). Application of Bandura's social cognitive theory in the technology enhanced, blended learning environment. *International Journal of Applied Research*, *3*(1), 721-724.

Dixon, C., & Nessel, D. (1983). *Language Experience Approach to Reading (and Writing). Language-Experience Reading for Second Language Learners*. The Alemany Press, 2501 Industrial Parkway West, Hayward, CA 94545.

Dornhoffer, J. R., & Dornhoffer, J. L. (2016). Pediatric unilateral sensorineural hearing loss: implications and management. *Current Opinion in Otolaryngology & Head and Neck Surgery*, *24*(6), 522-528.

Doumanis, I., Economou, D., Sim, G. R., & Porter, S. (2019). The impact of multimodal collaborative virtual environments on learning: A gamified online debate. *Computers & Education*, *130*, 121-138.

Elliott, L. L., & Hammer, M. A. (1988). Longitudinal changes in auditory discrimination in normal children and children with language-learning problems. *Journal of Speech and Hearing Disorders*, *53*(4), 467-474.

Elsahar, Y., Hu, S., Bouazza-Marouf, K., Kerr, D., & Mansor, A. (2019). Augmentative and alternative communication (AAC) advances: A review of configurations for individuals with a speech disability. *Sensors*, *19*(8), 1911.

Erber, N. (1982). Erber's levels of auditory functioning: Speech perception skills. *Alexander Graham Bell Association*, 92-94.

Estabrooks, W., MacIver-Lux, K., & Rhoades, E. A. (1994). Auditory-verbal therapy. *Washington, DC: Alexander Graham Bell Association for the Deaf*.

Estabrooks, W., MacIver-Lux, K., & Rhoades, E. A. (1994). Auditory-verbal therapy. *Washington, DC: Alexander Graham Bell Association for the Deaf*.

Gosnell, J. (2011). Apps: An Emerging Tool for SLPs: A plethora of apps can be used to develop expressive, receptive, and other language skills. *The ASHA Leader*, *16*(12), 10-13.

Gosnell, J. (2011). Apps: An Emerging Tool for SLPs: A plethora of apps can be used to develop expressive, receptive, and other language skills. *The ASHA Leader*, *16*(12), 10-13.

Hainey, T., Connolly, T. M., Boyle, E. A., Wilson, A., & Razak, A. (2016). A systematic literature review of games-based learning empirical evidence in primary education. *Computers & Education*, *102*, 202-223.

Hatzigiannakoglou, P. D., & Okalidou, A. (2019). Development of an Auditory Rehabilitation Tool for children with Cochlear Implants through a Mobile-Based VR and AR serious game. *International Journal of Online & Biomedical Engineering*, *15*(2).

Hull, R. H. (Ed.). (2019). *Introduction to aural rehabilitation: Serving children and adults with hearing loss*. Plural Publishing.

Jeddi, Z., Lotfi, Y., Moossavi, A., Bakhshi, E., & Hashemi, S. B. (2019). Correlation between auditory spectral resolution and speech perception in children with cochlear implants. *Iranian Journal of Medical Sciences*, *44*(5), 382.

Jeddi, Z., Lotfi, Y., Moossavi, A., Bakhshi, E., & Hashemi, S. B. (2019). Correlation between auditory spectral resolution and speech perception in children with cochlear implants. *Iranian Journal of Medical Sciences*, *44*(5), 382.

Kappel, V., Moreno, A. C. D. P., & Buss, C. H. (2011). Plasticity of the auditory system: theoretical considerations. *Brazilian Journal of otorhinolaryngology*, *77*, 670-674.

Ke, F. (2014). An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing. *Computers & education*, *73*, 26-39.

Markman, T. M., Quittner, A. L., Eisenberg, L. S., Tobey, E. A., Thal, D., Niparko, J. K., & Wang, N. Y. (2011). Language development after cochlear implantation: an epigenetic model. *Journal of Neurodevelopmental Disorders*, *3*(4), 388-404.

Novelli-Olmstead, T., & Ling, D. (1984). Speech Production and Speech Discrimination by Hearing-Impaired Children. *Volta Review*, *86*(2), 72-80.

Olson, A., Williams, R., Livingston, E., & Futscher, C. (2018). Review of auditory training mobile apps for adults with hearing loss. *Perspectives of the ASHA Special Interest Groups*, *3*(7), 12-23.

Qiu, W. (2004). Evaluation and speech therapy of dysarthria. *Chinese Journal of Clinical Rehabilitation (*28), 6155-6157. doi:CNKI:SUN:XDKF.0.2004-28-081.

Riddle, E. M., & Dabbagh, N. (1999). Lev Vygotsky's social development theory. *Retrieved June*, *6*, 2005.

Ronimus, M., Kujala, J., Tolvanen, A., & Lyytinen, H. (2014). Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Computers & Education*, *71*, 237-246.

Saman, F. I., Shariff, N. F. M., & Nasaruddin, N. I. S. (2019). i-Sign: Sign Language Learning Application via Gamification. *Asian Journal of University Education*, *15*(3), 187-197.

Schmidt-Kraepelin, M., Thiebes, S., Warsinsky, S. L., Petter, S., & Sunyaev, A. (2023, April). Narrative Transportation in Gamified Information Systems: The Role of Narrative-Task Congruence. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (pp. 1-9).

Schrepp, M., Thomaschewski, J., & Hinderks, A. (2017). Construction of a benchmark for the user experience questionnaire (UEQ).

Serafin, S., Adjorlu, A., & Percy-Smith, L. M. (2023). A Review of Virtual Reality for Individuals with Hearing Impairments. *Multimodal Technologies and Interaction*, *7*(4), 36.

Shaban, A., Pearson, E., & Chang, V. (2021). Evaluation of user experience, cognitive load, and training performance of a gamified cognitive training application for children with learning disabilities. *Frontiers in Computer Science*, *3*, 617056.

Simpson, A., El-Refaie, A., Stephenson, C., Chen, Y. P. P., Deng, D., Erickson, S., ... & Caelli, T. (2015). Computer-based rehabilitation for developing speech and language in hearing-impaired children: A systematic review. *Deafness & Education International*, *17*(2), 111-119.

Skinner, B. F. (1971). Operant conditioning. *The encyclopedia of education*, *7*, 29-33.

Sun, C. T., Ye, S. H., & Wang, Y. J. (2015). Effects of commercial video games on cognitive elaboration of physical concepts. *Computers & Education*, *88*, 169-181.

Sun, X., Zhang, F., Huang, H., & Zhang, L. (2009). Speech hearing assessment method for children with hearing impairment. *Journal of Audiology and Speech Pathology* (04), 327-329. doi:CNKI:SUN:TLXJ.0.2009-04 -006.

Tarchi, C., Zaccoletti, S., & Mason, L. (2021). Learning from text, video, or subtitles: A comparative analysis. *Computers & Education*, *160*, 104034.

Waite-Stupiansky, S. (2017). Jean Piaget's constructivist theory of learning. *Theories of early childhood education: Developmental, behaviorist, and critical*, 3-17.

Wang, H. (2021). The Language Rehabilitation of Hearing-Impaired Children on Pragmatics view——Taking the Researches on Natural Language Acquisition of Hearing-Impaired Children from Lv Mingchen as An Example. *Journal of Suihua University* (04),47-50. doi:CNKI:SUN:SHSZ.0.2021-04-012.

Wang, L., Wu, H., & Zhang, Y. (2019). Language Assessment Contents and Tools for Hearing-Impaired Children. *Chinese Scientific Journal of Hearing and Speech Rehabilitation* (03), 166-170. doi:CNKI:SUN:TLKF.0.2019 -03-003.

Weng, X., & Chiu, T. K. (2023). Instructional design and learning outcomes of intelligent computer assisted language learning: Systematic review in the field. *Computers and Education: Artificial Intelligence*, 100117.

Wiley, K., Vedress, S., & Mandryk, R. L. (2020, April). How points and theme affect performance and experience in a gamified cognitive task. In *Proceedings of the 2020 CHI conference on human factors in computing systems* (pp. 1-15).