Rithm Game: Introducing and Enhancing Rhythmic Sight-Reading Through Games

Gameplay Demonstration: https://youtu.be/EEnakIn1f70

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Abstract

This dissertation explores the design and implementation of a rhythm-based serious game to support the learning of rhythmic sight-reading for real-time performances. While many commercial games focus on timing and motor skills, few are designed to teach the values and durations of musical notes within measures. Some studies on existing educational rhythm games also suggest that, beyond musical skill development, rhythm training may support broader cognitive functions, including working memory and language-related skills.

The prototype, Rithm Game, aims to bridge serious game principles, learning objectives and cognitive benefits of music learning by focusing on reading and clapping rhythmic patterns within a game environment. The design is informed by serious game frameworks and educational rhythm games with unique focuses.

Adopting a research-through-design approach, this study investigates how the educational objective of improving rhythmic literacy can be implemented with game mechanics, visual feedback, and progressive difficulty design. The findings highlight how the prototype's potential as a supplementary learning tool for rhythmic accuracy and musical engagement, with future work aimed at expanding on features and conducting empirical user testing.

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Introduction

In recent years, the integration of digital games into education, or known as serious games, has become substantially relevant. These games blends engagement and interactivity properties while also aiming for a meaningful educational outcome. Music education, on the other hand, across different areas poses unique challenges, where some require learners to develop beat timing and pattern recognition from repetition and immersed practice.

It is also important to look at key design principles and evidence-based strategies from serious games research. Effective educational games align gameplay with learning objectives, provide clear goals and feedback, and motivates players to learn through in-game challenges, while being interactive and enjoyable. Graphical choices also play a role in player immersion. Overly complex visuals can hinder learning, whereas simple, stylized graphics like PaRappa the Rapper, can enhance engagement while keeping focus on gameplay.

The outcomes of music learning show to have its benefits, but some learning methods can be quite repetitive, inaccessible, or demotivating. While some commercial rhythm games like Parappa the Rapper have demonstrated interactive experiences to enhance pattern recognition and timing, there are only a few designed with a music education outcome, particularly reading music rhythms and the ability to sightread. Some studies on recent educational rhythm games, such as Rhythm Workers, Graveyard Symphony, and iClef has shown promising results in improving music-reading and rhythm skills by combining gameplay and structured feedback with repetition, bridging learning and play, despite some limitations.

Thus, this gives an opportunity to combine rhythm game mechanics, learning strategies and main design principles in serious games, with the primary goal to educate and enhance sightreading music. This would encourage meaningful musical learning without formal instructions.

Aim and Objectives

The aim of this study is to explore how the principles of serious game design, learning theories, and music cognition can be applied to design and implement a rhythm game that facilitates rhythmic sightreading - the ability to quickly interpret and respond to rhythmic notation in real time. The resulting game prototype is then evaluated by comparing its design to principles drawn from the relevant literature in serious games and music education.

Objectives:

Review literature on serious games and educational game principles

Before implementing the prototype game, the initial focus would be looking into how serious games are applied with educational intentions. Insights into key principles of educational game design would act as a guide for decisions made in the implementation of the game prototype, ensuring it's effective educationally, while being a game for entertainment.

Review literature on music education, its effects and its connection to serious games

In addition to examining music education topics, focusing on rhythm learning and sightreading, this study also explores the cognitive benefits associated with music education. These benefits then form a basis for understanding why these topics are valuable educational goals. These considerations inform the integration of serious game principles into the development of the prototype.

Implement a rhythm game and evaluate with reviewed literature

The prototype is built with the purpose of being an educational game to enhance players' rhythmic reading and rhythmic abilities. The challenging aspects during implementation are described, and its features and mechanics takes references from principles and practices identified in literature, allowing for reflection on the game's strengths and limitations. The evaluation would also consider potential improvements and additional features that could be implemented if given further development time.

Background

Educational games and their design principles

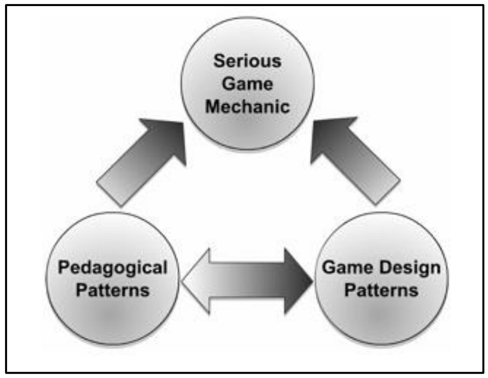


Figure 1: The relationship between Serious Games Mechanics (SGMs) and the pedagogical and game design patterns of a game [2]

Educational games, or referred to as serious games, are specially crafted to combine academic content with engaging gameplay, with the primary aim to gain knowledge and develop applicable skills in real-world contexts. [1][3] In contrast to only entertainment-focused games, the core objective of serious games leverages the recreational qualities of games to reach educational, training or health objectives. [1][5] These games typically involve players with predefined rules, which leads them to quantifiable outcomes. [3] Studies from Arnab et al. [2], with the evaluation and validation of the importance of the Learning Mechanics–Game Mechanics (LM-GM) model, shows that the fundamental aspect of serious game design consists in the translation of goals and practices into mechanical elements of gameplay, serving both an instructional purpose and providing play and fun. [Figure 1] Key characteristics of computer games for game-based learning environments include the establishment of key goals, feedback mechanisms, interactive components, compelling challenges, problem-solving scenarios, and immersive narratives. [1][4] By creating an enjoyable environment in serious games, it allows the player to develop their skills and knowledge through direct, personal experiences within the game, thereby stimulating curiosity, joyfulness and intrinsic motivation. [4][6] To further support these claims, extensive research by Clark et al. [1] consistently demonstrated the effectiveness of serious games in enhancing learning outcomes like understanding of concepts, practical skill development and increased motivation, confidence, and engagement.

Designing effective educational games is a complex task, requiring many factors for learners to stay motivated and be willing to absorb content to progress in learning. [3] Gerling et al. [7] referenced a known conceptual framework in game design, the Mechanics, Dynamics, and Aesthetics (MDA) model to explore how graphical fidelity (aesthetics) interacts with game mechanics to influence player experience, stating that higher graphics made players feel more immersed and boosted motivation and sense of skills. However, Bai et al. [8] states that visual complexity can distract students from learning intended content, and that "complex art creates noise" – finding they increase cognitive load and affect memory retention. Cartoon-like styles may be preferable for learning and user experience when it comes to formal schooling settings, where children are often mandatorily motivated to learn.

Additionally, the graphical style of an educational game can significantly affect player engagement and emotional connection. Research on PaRappa the Rapper, one of the earliest commercial rhythm games, highlights how its simple, cartoon-like art style helps players easily identify with the main character and become emotionally invested in their progress [24]. Simplified visuals reduce distraction and cognitive load while encouraging players to project themselves onto the avatar, increasing feelings of pride and attachment as they succeed. With this factor in mind, the core game mechanics of a prototype game can be focused on while having a simplistic, low-fidelity graphical option, and still remaining compelling and enjoyable.

Music Education and Sightreading

With significant social and technological changes to music education, Hargreaves et al. [9] raises the question of what should be learned and taught both within and outside of school environments. They emphasize the influence of social and cultural contexts in musical learning, also introducing two conceptual models: one illustrating opportunities from music education, and the other details the outcomes that derives from it. [Figures 2, 3] Research from Gower et al. [12] finds some evidence that traditional music teaching may not be engaging young students as desired, partly because of a “narrow music curriculum lacking relevance”. In the increasing digital age, playing video games has become a key element of youth culture. This challenges educators to incorporate game technologies into their teaching to keep students engaged in learning.

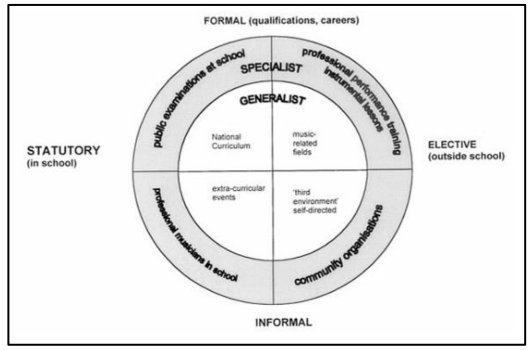


Figure 2: A “globe” model of opportunities in music education [9]

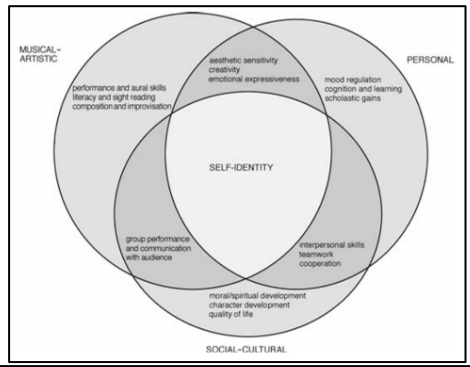


Figure 3: The potential outcomes of music education [9]

A study by Levitin et al. [10] finds that rhythm, meter and tempo are core temporal elements of music that structure how listeners interact with sound and experience music. They guide how people anticipate and align movements with music. These elements enable the brain to anticipate sound patterns and synchronize motor activity, engaging a “predictive timing” system that activates motor areas even in passive listening. This process stimulates dopamine release, creating feelings of pleasure and motivation—making music a natural candidate for educational tools that tap into the brain’s reward systems.

One of the main focuses on this project is sight reading, a challenging skill in music education. It’s defined as “the unrehearsed performance of music from a printed score for the first time without practice”, involving a series of overlapping perceptual, cognitive, and motoric processes. Proficient sight readers can interpret note patterns, read ahead, detect errors in music sheets, and engage auditory imagery, which are skills cultivated through extensive practice. Kopiez et al. [11] found that these abilities rely heavily on mental processing speed and tend to develop most effectively before age 15, suggesting a critical period for acquisition.

Despite the challenges of needing early training for sight reading and other musical skills, Gower et al [12] found that music video games still served as a modern and effective means to foster foundational musical development and literacy from an early age, including crucial skills like dexterity, inter-limb coordination, hand-eye coordination, pitch and rhythm, which are transferable to traditional instruments. More importantly, Fiveash et al. [21] emphasize that rhythmic ability is not a single skill, but a set of multidimensional capabilities including beat perception, pattern reproduction, sensorimotor synchronization, and tempo tracking. Their findings support the use of rhythm-based tools in music learning, particularly when these tools engage learners in dimensions of rhythms instead of just simple beat-keeping.

Therefore, even while considering the critical period for learning sight reading, interactive rhythm games offer accessible and engaging ways to develop musical abilities that support broader music literacy. This translates to the design of the prototype rhythm game, targeting the development of rhythmic sight-reading by integrating music that encourages movement along with gameplay.

Studies in music games, their effects and benefits

The feeling of pleasure from music would be one of the reasons why rhythm games to this day is still popular and growing. This can also become the bridge to creating a pedagogically beneficial rhythm game while simultaneously learning and enjoying music with gameplay. A study by Dalla Bella et al. [16] explores the use of rhythmic serious games for training auditory-motor synchronization in rehabilitation, focusing on patients with movement disorders like Parkinson's disease, while also considering other neurological disorders like dyslexia and autism. Despite the limitations of music-based serious games allowing self-monitoring that may cause isolation and reduce social interactions, studies consistently highlight their cognitive, motor, and motivational benefits. For instance, Bégel et al [15] investigated the effects of playing, emphasizing how rhythm-based games enhance auditory-motor coupling, temporal processing, and engagement, making them beneficial for applying towards therapeutic and educational purposes. Keeler Jr. [14] investigated the effects of playing music games like Guitar Hero and Beat Saber on beat competency and rhythmic imitation among music students, particularly when structured feedback and repetition are embedded in gameplay.

Another influential title is *PaRappa the Rapper*, one of the first commercial rhythm games, which demonstrates core design techniques that elicit emotions such as pride and affection through goal-oriented persistence and real-time collaboration between the player and mentor characters [24]. By having players copy the rhythms of mentor NPCs, the game fosters a sense of rapport and accomplishment as players gradually improve and receive praise for their success. Its cartoon-like art style and lighthearted narrative make it easy for players to identify with the avatar and feel emotionally connected to the mentors, illustrating how rhythm games can build motivation and emotional investment alongside skill development.

Figure 4: Screenshot of gameplay in Parappa the Rapper

Some music games also show to have a relationship with the development of sight-reading abilities. A study by Kylie et al. [22] investigated the impact of rhythm action game Rock Band on children's musical skills and interests. They observed that there's a positive correlation between nine months of playing the game and improved assessment results in rhythm transcription, music echoing, and sight-reading. Because of the constant engagement with rhythm by synchronizing movements or action in game examples utilized by Dalla Bella et al. [16], it provides a direct training ground for rhythmic abilities, which also are tightly linked to general cognitive functions, including language and reading skills, also mentioned by Bégel et al. [15] Therefore, using music games to learn and practice rhythms may display improves in these cognitive areas critical to literacy and, by extension, sight-reading. While it cannot serve as a replacement for traditional music education, these games can still be provided to students as a valuable supplementary tool to enhance rhythmic skills and potentially draw more students into the world of music.

In addition to the benefits shown, rhythm games can maintain long-term engagement when paired with dynamic gameplay elements. Octaviani et al. [17] explored a hybrid genre of rhythm games, rhythm fighting games, which merges rhythmic input with combat-style feedback, damaging enemies with well-timed actions. Through the analysis of titles like Rhythm Fighter and Skybolt Zack, they highlight that by incorporating action alongside rhythmic challenges, it enhances motivation and a sense of progression. This design structure offers a model for an educational rhythm game implemented for this project, aiming to teach sight-reading while keeping players entertained through a battle mechanic.

Existing Educational Rhythm Games

Rhythm Workers (2018) [18]

Rhythm Workers is designed to train rhythmic skills, presented as a building construction game where a level is completed upon building a structure. It has two versions: perception version where players judge if percussion sounds are aligned to the beat of the stimulus or not, and tapping version is for players to tap to the beat of the stimulus as accurately as possible. Feedback is provided through the aesthetic quality of the building, and a star rating system based on performance. [Figure 5]

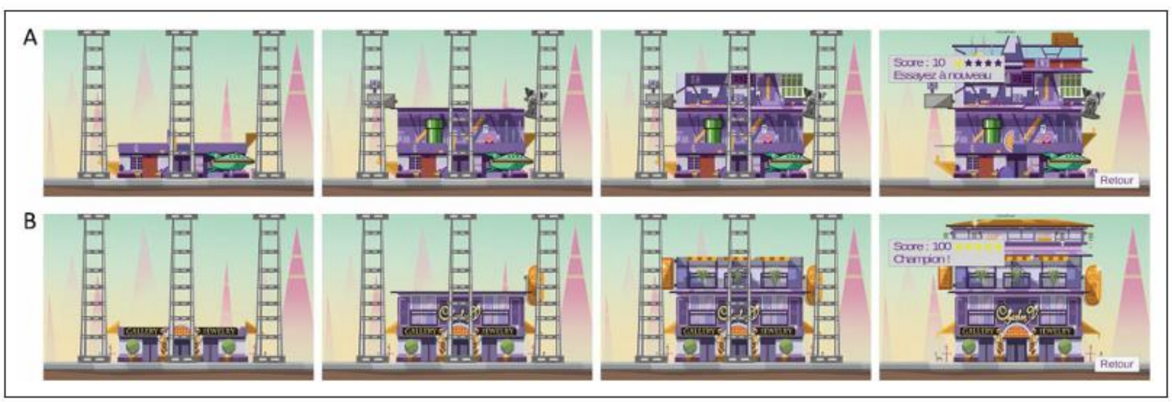


Figure 5: Two examples of buildings built by a player in Rhythm Workers. Aesthetic quality of the building and star rating depends on the player's performance. [18]

The study aimed to test the usability and compliance of the game, and gathered evidence on its effect on players beat perception and sensorimotor synchronization in young adults. Over a two-week training period, the study showed a significantly improved beat perception for most participants showing large improvements. However, the tapping version showed less consistent improvement, with some who had worsening performance. Another limitation of the tapping version for this study was the ceiling effect – the participants' performance were already at ceiling level before training began, making it unreliable to assess for improvements.

Despite the results on tapping-based interaction not leading to improvements to rhythmic abilities, it still provided meaningful training through visual pattern recognition, fostering rhythmic awareness, timing, and coordination. The game's use on feedback-driven interaction also serve as a strong design reference. By giving players live feedback during gameplay, it would encourage learning through immediate reinforcement, adjust performance in real time and build a better sense of rhythm.

Graveyard Symphony (2025) [19]

Graveyard Symphony is an RPG-style music game, where the player uses a MIDI keyboard to play beats to dispel evil. The game mechanics involve playing lower octaves for character movement and higher octaves for interaction, which encourages specific hand positions on a piano. Game progression comes from playing music notation, completing quests around the map and collecting items, with the notation complexity gradually increasing. Players are rewarded based on how they maintain their beat-based streaks from following the background music, which is synchronized with visual and audio metronomes. [Figure 7]

Initially the game was not made with the intention of a practice tool, but Brett et al. [18] aimed to utilize the game to evaluate the effectiveness of it in enhancing musical notation reading skills among adult novice musicians, compared to a traditional practice tool for sightreading [Figure 8]. Results indicated, despite usability ratings being similar for both, the group who played the game had more improvement in overall Standard Assessment of Sight Reading (SASR) scores, and the participants perceived the game to have a greater educational value and showed higher levels of engagement, indicating they were more encouraged to continue playing and looking forward for future work.

The game itself has good educational value on learning piano hand placement on the MIDI keyboard, along with encouraging players to sight read music notations to the beat of music. This has a small similarity to the prototype game implemented for this project, which shifts the focus toward reading rhythm notations along a single rhythmic line, instead of performing steady-beat melodies by reading notes on a traditional five-line staff.

Figure 7: Screenshot of gameplay in Graveyard Symphony [19]

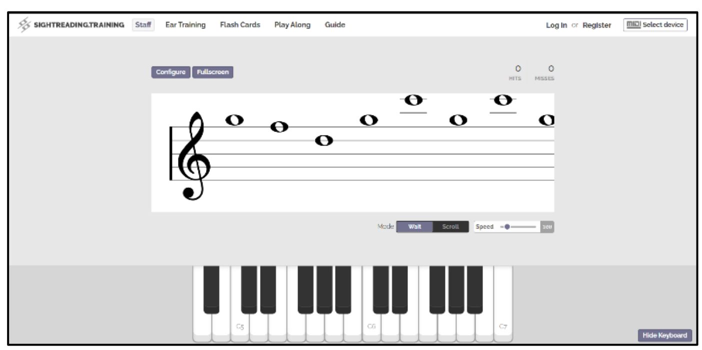


Figure 8: Screenshot of the sight-reading practice tool [25]

iClef (2023) [20]

iClef is a serious mobile game designed to promote sight-reading music on the five-line staff, where the primary objective is to identify the note pitch correctly and achieve as high a score as possible. It involves the three clef symbols placed on the lines, and the player would interact by tapping the lower part of the screen to tap the correct note. [Figure 9] There are 4 difficulty levels, where each difficulty varies from the amount of clefs that appear from the 9-clef system.

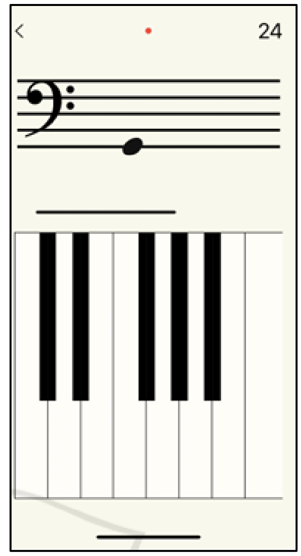


Figure 9: The graphical interface of iClef [20]

Feedback is provided through a final score and visual cues in-game (green for success, and red and mistake). Similar to Rhythm Workers and Graveyard Symphony, live feedback is provided, but the design appears similar to the training tool [25], which Brett et al. [19] found a higher engagement through Graveyard Symphony than the tool. However, because the game is designed to be a mobile game, it becomes more easily accessible for players to simply turn on their phone, open the application and practice.

Background Summary

The reviewed literature highlights various approaches in educational games, especially those to improve music literacy through gameplay. A common factor between each of the research is how they all emphasize the importance of aligning gameplay with learning objectives, offering immediate feedback and maintaining player engagement through clear goals. Additionally, visual and aesthetic choice is highlighted through Parappa the Rapper [24], since it is a great inspiration for the graphic choice made towards the prototype to keep players engaged and be able to focus on learning. Each study has a different approach on serious game design, game mechanics, and educational impact, which helped frame the development of the prototype for this project.

The studied educational rhythm games each has unique focuses and strengths: Rhythm Workers [18] emphasized beat perception and tapping accuracy, its strength relying in its use of immediate feedback. Graveyard Symphony [19] focuses on musical pitch and hand positioning on a keyboard, improving the development of sight-reading skills. iClef [20] also targets note pitch recognition across different clefs, with accessibility as one of its advantages due to its mobile format. Graveyard Symphony and iClef support musical learning on pitch and clef recognition on a measure, but do not train rhythm. In contrast, Rhythm Workers supports training rhythm but lacks elements that encourage reading rhythmic notation. This highlights a gap in existing tools to directly combine rhythmic sight-reading with interactive gameplay. Moreover, studies like Bégel et al. [15] and Fiveash et al. [21] indicate that rhythm training can affect cognitive functions positively like working memory and language skills, reinforcing the importance of rhythm-based tools in both musical and cognitive development.

Design

Rithm Game is a prototype rhythm game that encourages the learning of reading rhythms in music. Mike, controlled by the player [Figure 11], repeats his archnemesis Teto's rhythm in order to defeat her. The game's initial inspiration came from Rhythm Hell [23], challenging players to repeat complex rhythms for as long as they can endure.

Gameplay

When a level is selected from the menu, the player is brought to a level and a countdown sound cue is prompted to inform the player the beats per minute (BPM) of the song. The key gameplay [Figure 13] involves Teto [Figure 10] following the music and clapping the music notes that appears on the stage below her, then the player would repeat the pattern as accurately as possible. An accurate hit that isn't a missed hit would enable an attack on the enemy. The baguette [Figure 14] acts as a pointer guide to help players understand each note when it is being clapped, and a spotlight shines onto each Teto and the player, indicating their turn. After playing through the level, the final score is shown, and high scores would be saved. [Figure 16]

In the bottom right of the menu [Figure 12], the player has the option to disable audio cues, where Teto does not clap the pattern and it would be up to the player to read the music measure and play the rhythm pattern that appears on the stage on their turn. This gives players the option to challenge themselves.

An additional feature in-game is the speakers alongside the stage in Figure 13. They pulsate to the BPM of the music to provide a visual representation of the song tempo.

Graphic

The general design and animation choice is simplistic, including damage, idle and clapping. Simple animations maintains the entertainment of the game, as inspired by Parappa the Rapper [24]. Below are the hand-drawn graphics made on ibisPaint [26] that appears in the game.

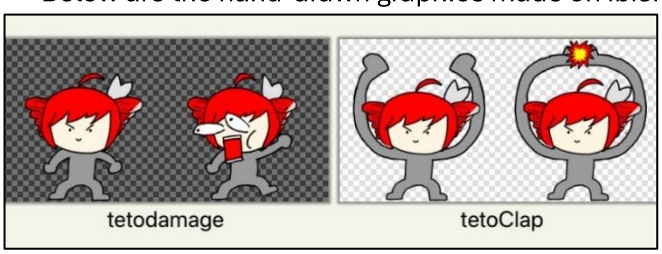


Figure 10: Enemy character animation

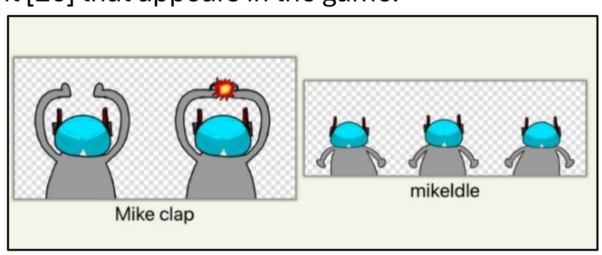


Figure 11: Player character animation frames

Figure 12: Menu screenshot

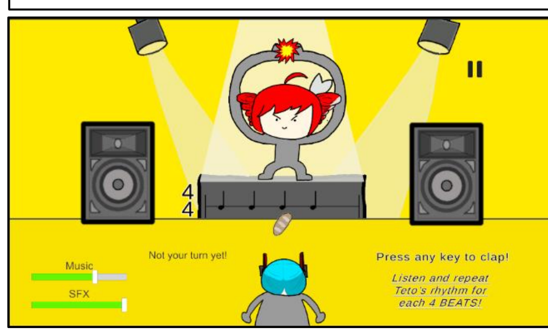


Figure 13: Gameplay screenshot

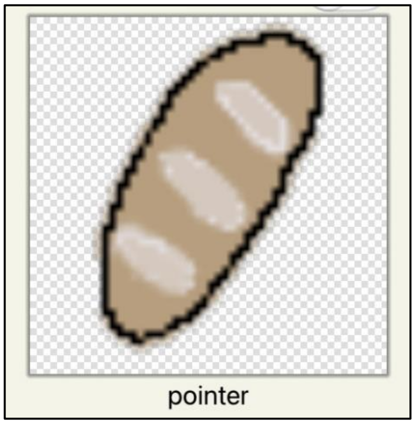


Figure 14: Guide pointer

Figure 15: Judgement effects

Figure 16: Results screenshot

Key Implementations

There were multiple challenges when implementing the game, and they are mainly audio based since the gameplay heavily involves players interacting with the game with the music as their cue. The initial challenge that changed the flow for the rest of the game implementation was synchronizing the audio with in-game elements. With Unity's AudioSource scripting API [27], the audio's sample rate (frequency), time samples [28], with the BPM value of the song playing can be used to precisely calculate elapsed beats during a song. [Figure 17]

$$\text{current beat in audio} = \text{current elapsed audio sample time} \;/\; \text{Fq} * (60/\text{BPM})$$

Figure 17: equation to calculate the beat count at a selected sample time

With this equation, it helped resolve a lot of audio synchronization features. For example, for the speakers to pulse, [Figure 18] demonstrates how the equation would make the feature work, and how it could take in any BPM value to accommodate to any song.

```
songBPM = 90
while song is playing from audioSource:
        currentBeat = audioSource.timeSample/(audioSource.frequency * (60/songBPM) + 1)
        if currentBeat is exactly at a full number:
                PulseGameObject()
        endif
endwhile
```

Figure 18: Pseudocode for object pulsing at 90 BPM with equation

Displaying and clapping music rhythms

The next challenge was to have Teto clap to music measures to the BPM of the song. The solution to having the game do that from a music sheet is to utilize another Unity scripting API [29], making the game have a data-driven chart loading feature through reading a JSON file, inspired by ABC notations [30]. This way it would be straightforward to translate a piece of music into a JSON chart by using tables 1 & 2 to interpret. [Figure 21]

To know how many beats are in a bar, a time signature is indicated at the start of the music. The most appropriate time signature to introduce to beginners is the time signature 4/4 [Figure 20]. The top number means how many beats there are in a measure (bar), and the bottom number determines which note type gets the beat in the bar. Hence for 4/4, there can only be maximum 4 crotchet notes in each bar (4 beats per bar).

currentBeat from Figure 18 returns a float value at each frame from 1 to the max beat count of the song. Implementation of each character taking turns simply checks for 8 beats – first 4 beats is Teto's turn, and last 4 beats is the player's turn, before the beat counter resets to 1. The BPM of the song is also included in the JSON file, which enables accurate note type comparison when having Teto clap, or to judge the player's accuracy for immediate feedback. [Figure 19]

```
function loopBeat():
        beatInLoop = (currentBeat % 8) + 1
        return beatInLoop
endfunction

while song is playing:
        beatInLoop = loopBeat()
        if beatInLoop is between 1 and 4.9:
                Teto’s turn
        else:
                Player’s turn
        endif
endwhile
```

Figure 19: Pseudocode to check for whose turn it is using currentBeat from Figure 18

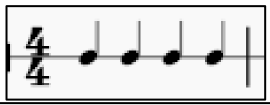


Figure 20: 4/4-time signature

Table 1: Singular unflagged and flagged note symbols and their corresponding rest symbols’ duration with their allocated JSON symbols

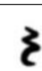
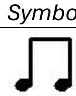
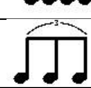
Name	*Note symbol*	*JSON symbol*	*Rest symbol*	*JSON symbol*	*Duration*
Crotchet (Quarter note)		X		R	1 beat
Quaver (Eighth note)		X/2		R/2	½ beat
Semiquaver (Sixteenth note)		X/2		R/4	¼ beat

Table 2: Connected note symbols with beams and special symbols and their allocated JSON symbol

Symbol	*JSON symbol*	*Duration*	*Details*
	D/2	1 beat	Double quaver notes
	D/4	½ beat	Double semiquaver notes
	Q/2	2 beats	Quadruple quaver notes
	Q/4	1 beat	Quadruple semiquaver notes
	T	1 beat	Triplet note – playing three notes in one beat
	X.	1 ½ beat	Dotted note – if a note has a dot, its duration is extended by ½ the correlated symbol’s duration

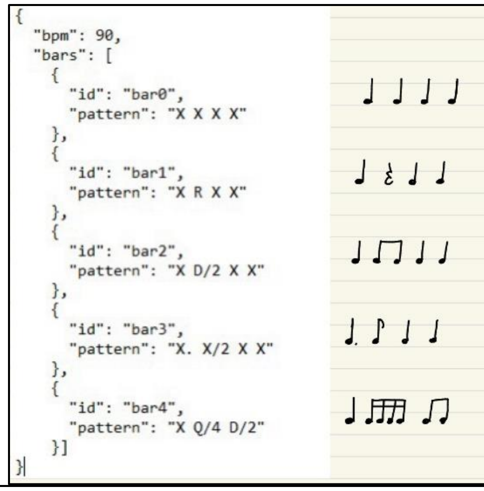


Figure 21: example JSON file format translating to music symbols

In music rhythm notation, each singular note (crotchet, quaver and semiquaver) represent sounds of different durations with flags, while rests corresponds to periods of silence [Table 1]. Multiple quaver and semiquavers notes are connected with a beam equivalent to the number of flags on a singular note. [Table 2] Some notes also have other notations like a dot to indicate its extended duration. Combinations of different notes can be used within a measure of time signature 4/4 to create unique rhythms, as long as the total duration does not exceed 4 beats.

The JSON utility API [29] reads the correlated file as the specific level is being loaded, converts each bar into an object [Figure 26] and creates a list of Bars. One of the main challenges when implementing the method getPatternTimings was the attempts to understand that if the current symbol is a note, it has to be first added into the timings list, then its duration is added to the current beat to continue to the next note in the pattern. If the last note's duration, adding up the previous notes' durations, goes beyond the 5th beat, the function will return null and an error message would appear in debug, ensuring the beats do not overlap between bars. The Boolean parameters for the method were added later during implementation since a discovery was made that the function could also be applied in other sections, like comparing player hit accuracy [Figure 27] and spawning in the note prefabs.

Once all the bars are on the list, the order is shuffled (other than the tutorial level) and the level begins, as shown in [Figure 13], where Teto claps the first bar's pattern [Figure 22], then moves on to the next after the player's attempt to replicate the rhythm.

The player has 3 timing windows: Perfect, Great, and Miss. [Figure 24] When the player taps any key, the game checks when the tap occurs from the audio source in beats [Figure 23] and compares the beat timing of the tap with the Bar's pattern timing list to give live feedback of the player's accuracy [Figure 25]. After playing through all the bars, the results are calculated based on these score judgements: 300 points for perfect, 100 points for great and 0 points for miss. A percentage value is also calculated to inform players of their overall accuracy.

The game menu includes 4 levels: Tutorial, Easy, Intermediate, and Hard. Tutorial introduces the game mechanics and lets the player attempt some music measures, then each level from Easy to Hard would gradually introduce more complex patterns and faster tempos to clap to. [Figure 27]

```
function clapToPattern(Bar currentBar):
    List timings = currentBar.getPatternTimings(false, true)
    for each beat in timings:
        if beat = beatInLoop (from Figure 19) & beat hasn't been played:
            play clap sound
        endif
    endfor
endfunction
```

Figure 22: pseudocode for Teto to clap to the current bar in the list

```
perfectWindow = 0.1
greatWindow = 0.25
function accuracyScoring(clapTime, currentBar):
    List timings[] = currentBar.getPatternTiming(false, true)
    for each beat in timings:
        if clapTime > beat:
            timingDifference = clapTime – beat
            if timingDifference <= perfectWindow:
                spawn perfect prefab and add score
            elseif timingDifference <= greatWindow:
                spawn great prefab and add score
            else:
                spawn miss prefab
            endif
        endif
        [repeat code with opposite symbols for if clapTime < beat]
    endfor
endfunction
```

Figure 23: pseudocode for player accuracy live feedback

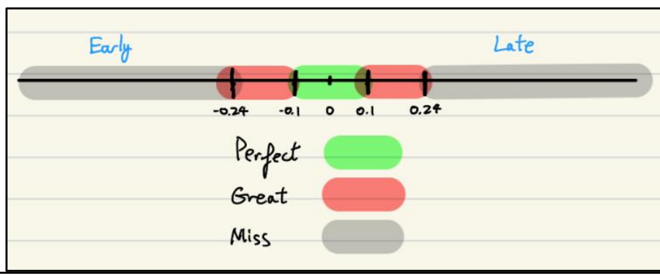


Figure 24: visualization of judgement window for the player with beats as the measurement

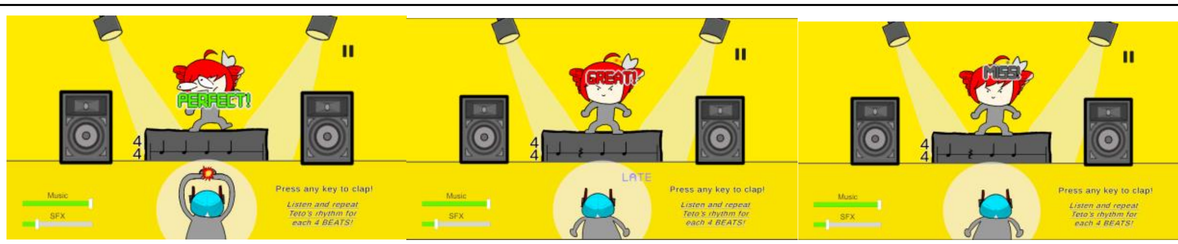


Figure 25: Screenshots of live player feedback for each judgement timing

```
class Bar:
        public string pattern
        method getPatternTimings(bool includeRests, bool includeDuplicates):
                List timings[]
                currentBeat = 1.0f
                for each note in pattern:
                        duration = calculateDuration(note)
                        if note has an X:
                                timings.Add(currentBeat)
                                currentBeat += duration
                        endif
                        elseif note has an R:
                                if includeRests = true:
                                        timings.Add(currentBeat)
                                        currentBeat += duration
                                else:
                                        currentBeat += duration
                                endif
                        if note has a D:
                                timings.Add(currentBeat)
                                if includeDuplicates = true:
                                        currentBeat += duration
                                        timings.Add(currentBeat)
                                        currentBeat += duration
                                else:
                                        currentBeat += duration * 2
                                endif
                        if note has a Q:
                                [same as D but 4 times]
                        endif
                endfor
                if currentBeat > 5:
                        return error since duration goes over the 5th beat
                endif
                return timings
        endmethod
endclass
```

Figure 26: Class object for a singular Bar, with pseudocode for finding the timings of each beat in a bar to prevent it to go over 5 beats

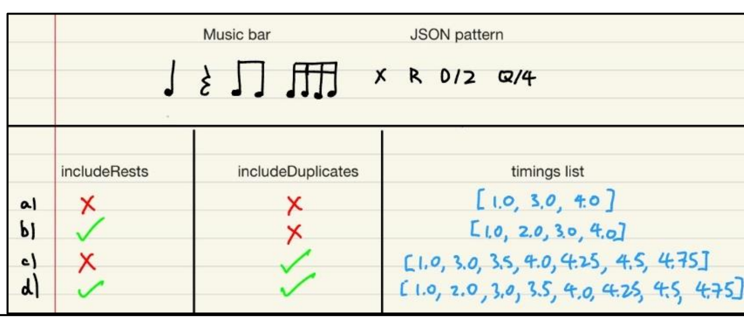


Figure 27: Visualization of the timings list output from getPatternTimings method with its Boolean values a) Unused b) Instantiating note prefabs c) Teto clap/ Player clap judgement d) Unused

Evaluation

This paper will conclude with the evaluation of the prototype game, Rithm Game, using the findings from the reviewed literature from the background section. Rather than formal user testing, the game's mechanics, feedback systems, and overall design is examined with established educational game principles, as well as their potential on introducing and supporting rhythmic sight-reading skills. The following section looks at the prototype's strengths, limitations and opportunities for further development.

The following section evaluate the game across different areas: aligning game mechanics with learning objectives, potential cognitive and educational impact with its support for musical skill development, player engagement and flow, and finally limitations with future improvements.

Aligning Game Mechanics with Learning Objectives

The game takes reference from the LM-GM model [2] to create the prototype with serious game design principles to introduce players and educate them in sight-reading. In a level, the player would read and listen to a rhythmic notation on the first measure, and on the next measure attempt to repeat the rhythm as accurately as possible. By using immediate feedback with pop up graphics and damage animation as visual cues [Figure 25], it informs the player of their tapping accuracy, which reinforces their knowledge on note durations and encourages them to self-correct. The game also has progressive difficulty for each available level – Easy, Intermediate, Hard, each having increasingly complex rhythms and tempo. This reflects the scaffolding approach [2] recommended for effective educational games.

These elements demonstrate how a turn-based game mechanic is integrated with an educational purpose to practice rhythm reading and beat synchronization, ensuring gameplay time contributes to skill development while also serving as a form of entertainment.

Potential Educational, Cognitive and Musical Skill development

Background studies have shown that rhythm training can strengthen a range of cognitive functions, including attention, working memory, and even language-related skills. [15] Based on the study by Fiveash et al. [21], rhythmic ability is known to be multidimensional: Beat perception, pattern recognition, sensorimotor synchronization, and tempo tracking. They are all linked to phonological awareness and reading development, which creates the potential to reinforce processes important for literacy and language acquisition with rhythm-based activities.

The prototype is designed to combine rhythmic perception with music to practice reading and replicating rhythmic notations. Its structure closely parallels existing educational rhythm games such as Rhythm Workers and Graveyard Symphony, which have shown positive effects on rhythm perception and music-reading abilities [19] [18]. Rhythm Workers emphasizes synchronization and auditory timing, while Graveyard Symphony focuses on improving sight-reading with interactive gameplay. This approach is mirrored in Rithm Game's focus on reading rhythmic notations. By incorporating a basic form of progressive difficulty, it reflects the LM-GM model proposed by Arnab et al. [2], demonstrating how learning can be operationalized via game mechanics where the challenges gradually match learners' developing skills.

The study with commercial rhythm game Rock Band by Kylie et al. [22] has evidence supporting these potential outcomes. The work found that extended gameplay over the nine-month period correlated with improvements in music reading and performance skills. The integration of feedback systems, progressive difficulties, and engaging properties into Rithm Game is likely to support similar benefits, supporting their music skills and related cognitive functions. However, empirical testing would be required to confirm its effectiveness and fully evaluate its impact on musical and cognitive development.

Player Engagement and Flow

With the game's real-time feedback and progressively challenging levels, it provides a motivating and rewarding learning environment that sustains interest and engagement, which matches serious games principles mentioned by Dalla Bella et al. [16]. Gamification elements such as points and levels not just create a sense of purpose and accomplishment within gameplay, it also enhances learner involvement and encourages repeated practice [3][6][17]. Rhythm games work especially well with this, as they are simple to pick up but difficult to master. Skill-based progression helps maintain the player's interest, making rhythm games well-suited for educational contexts that require structured repetition while remaining enjoyable. [17]

Other than the progressively complex levels, immediate feedback and simple controls, the pulsing of the speakers synchronized with the BPM of the song on the stage acts as a visual cue to help players stay on beat, rather than just relying on the audio. Another form of feedback is given via the attack animation onto Teto when tapping at the right time, adding a sense of responsiveness and a form of "reward" to successful actions. The choice of a simple, cartoon-like art style is picked because the research by Bai et al. [8] indicated complex graphics can distract learners and lower their learning achievements. The minimalistic design not only can let players focus better when reading music but could also enhance their emotional connection with the character. This design technique is used in Parappa the Rapper, where the Isbister [24] states "these design choices work together for me as a player, at least, to deliver a satisfying sense of accomplishment and pride".

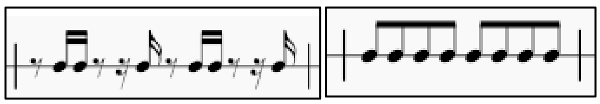
With the art style and positive feedback given during gameplay, it would be most effective in creating "flow" experiences, mentioned by Chang et al. [4], which means players stays focused, hence motivated to continue playing. With immediate auditory and visual feedback on their rhythmic accuracy similar to Rhythm Workers [18], along with levels with increasing difficulty, the prototype would keep the player engaged and encourage their learning to read and perform rhythm notations.

Limitations

A notable limitation for this project is the absence of formal testing, resulting in the educational impact and usability of the prototype remaining unknown. Despite featuring a variety of patterns for each difficulty, the game is currently limited to a single time signature of 4/4. There also isn't much option regarding the selection of song BPM, and the player is unable to adjust the tapping offset, as each individual's timing can differ. The game currently only includes three songs, each representing a different difficulty level with progressively increasing tempos: 90 BPM for easy and tutorial, 100 BPM for medium, and 120 BPM for hard. Though, it is important to note that a higher BPM does not necessarily make a bar more difficult to play. Slower tempos with syncopated or irregular rhythms could pose a challenge more than predictable, simple patterns at a higher tempo. [Figure 28]

Another technical limitation is the manual implementation of bar measures into the JSON files [Figure 21], that can only be manipulated within the Unity Engine before build. Since the game is a prototype, the levels are kept short to demonstrate the key game mechanics. However, if the game were to be deployed in an actual educational setting, it would require a larger list of bars to support progressive learning. Manual writing of the measures becomes unsustainable, as it would increase development time and the likelihood of errors. This process could get replaced with a tool to automatically place notes into a bar, but it may introduce unexpected or musically unrealistic patterns without careful oversight. The BPM also has to be stated in the same JSON file, meaning any adjustments to tempo require manual editing as well, limiting adaptive or personalized experiences from the front end.

Despite some complex patterns with the current range of note types that can make a level more challenging, it restricts the game's ability to represent what can actually appear in traditional music reading, which would limit the players' range of knowledge if the game were relied on as a tool. While some levels include difficult note combinations to increase challenge, not all of these are pedagogically beneficial, and mostly for entertainment [Figure 28, a]. Overly intricate patterns that do not reflect actual music-reading context may introduce confusion, rather than support learning.



a) b)

Figure 28: Informal playtesting with musically experienced peers revealed that a) presented a higher challenge at low BPM b) being more predictable and easier due to its regularity, regarding high or low bpm

Without a way to calibrate the offset, this could negatively impact player experience, as inconsistent input timing could cause players to miss, even when attempting to tap simple patterns. This could also confuse players and potentially frustrate them, not knowing if their timing is at fault, or the game itself. Even if there was an option to adjust the tapping offset, it would require trial and error for them to find the correct value that matches their natural tapping rhythm.

Future Work

As the prototype is demonstrated as a rhythm-based educational tool, there are several areas for future development and research.

As previously mentioned, an empirical study involving user testing would be essential to formally assess the game's use for educational purposes and player experience. This could involve collecting player performance data (scores from repeated practice over the course of a study period), qualitative feedback on engagement, clarity of gameplay and perceived learning outcomes. Similar to the study with iClef [20], recruiting varied test subjects (novice learners vs. experienced musicians) could give a good insight into how well the game acts as an educational tool across different levels.

Further enhancing the game's flexibility and accessibility would open up to more scaffolding opportunities and better support the skill of sight reading. To make the game more beginner friendly, the tutorial could include contextual pop-up explanations to introduce the main gameplay mechanic and its features like the volume bar and the tick box to disable audio cues. Other improvements that can be added include the implementation of BPM options with a slide bar with the feature to hand pick specific notes to allow for customizable practices, adding an input offset calibration feature to account for individual timing variations, and expanding more on the note types other than ones featured in Table 1 & 2.

While the game includes an animation of Teto taking damage upon a successful clap from the player, there is currently no gameplay mechanic to defeat the enemy or progress through combat. To further enhance player engagement, a system could be introduced where achieving a certain high accuracy contributes to whether the enemy is defeated or not. This can motivate players to aim for a higher score each time, hence creating a sense of reward upon completion of a level, deepening the connection between musical performance and in-game outcomes.

Conclusion

This research-through-design project explored the educational potential and the creation of a rhythm game prototype, Rithm Game, aiming to introduce enhance the musical skill of sightreading. With existing literature on the principles of serious game design with cognitive and musical development, the prototype integrates interactive feedback, audio & visual cues, and progressively challenging levels to provide an engaging learning experience.

Despite without formal user testing of the game, some peers, with and without musical experience, play tested the game informally and highlighted both its strengths and limitations. Some mentioned they had to adjust their tapping to the game's offset, suggesting the need for customizable calibration. Musically experienced peers mentioned the game would become more challenging and entertaining if the Hard level was at a lower BPM, requiring them to focus more on counting when to tap accurately. Non-musician peers preferred faster BPMs for sustained engagement, as they would lose interest when waiting for their turn or when not hitting notes properly. This reinforces the importance of flow and timely interaction in rhythm game design, while emphasizing that player preferences can vary significantly.

Overall, despite its limitations, the prototype demonstrates as a supplementary tool for learning sight reading rhythms on measures, with opportunities for refinement through user testing and additional features to further support learning, enabling more personalized learning experiences.

References

[1] Clark, D.B., Tanner-Smith, E.E. and Killingsworth, S.S., 2016. Digital games, design, and learning: A systematic review and meta-analysis. *Review of educational research*, *86*(1), pp.79-122.

[2] Arnab, S., Lim, T., Carvalho, M.B., Bellotti, F., De Freitas, S., Louchart, S., Suttie, N., Berta, R. and De Gloria, A., 2015. Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology*, *46*(2), pp.391-411.

[3] Wang, Y.H., 2023. Can gamification assist learning? A study to design and explore the uses of educational music games for adults and young learners. *Journal of Educational Computing Research*, *60*(8), pp.2015-2035.

[4] Chang, C.C., Liang, C., Chou, P.N. and Lin, G.Y., 2017. Is game-based learning better in flow experience and various types of cognitive load than non-game-based learning? Perspective from multimedia and media richness. *Computers in human behavior*, *71*, pp.218-227.

[5] Ferreira, F.H.A., Santos, L.V., Lima, R.A., Pessoa, M.M.D.A., Jayawardene, W., Anisio, R. and Pessoa, L., Donate Life! Validation of a board game about knowledge of organ and tissue donation and transplantation.

[6] Gomes, C., Figueiredo, M. and Bidarra, J., 2014. Gamification in teaching music: Case study. *International Journal on Advances in Education Research*, *1*(3), pp.56-77.

[7] Gerling, K.M., Birk, M., Mandryk, R.L. and Doucette, A., 2013, October. The effects of graphical fidelity on player experience. In *Proceedings of international conference on Making Sense of Converging Media* (pp. 229-236).

[8] Bai, H., Zhang, R., Berg Marklund, B. and Wilhelmsson, U., 2022. Game Graphics and Effective Learning: A Review of Visual Communication Research in Serious Games. In International Conferences Interfaces and Human Computer Interaction.

[9] Hargreaves, D.J., Marshall, N.A. and North, A.C., 2003. Music education in the twenty-first century: A psychological perspective. *British Journal of Music Education*, *20*(2), pp.147-163.

[10] Levitin, D.J., Grahn, J.A. and London, J., 2018. The psychology of music: Rhythm and movement. *Annual review of psychology*, *69*(1), pp.51-75.

[11] Kopiez, R. and In Lee, J., 2008. Towards a general model of skills involved in sight reading music. *Music education research*, *10*(1), pp.41-62.

[12] Gower, L. and McDowall, J., 2012. Interactive music video games and children's musical development. *British Journal of Music Education*, *29*(1), pp.91-105.

[13] Weigmann, K., 2017. Feel the beat: Music exploits our brain's ability to predict and the dopamine-reward system to instill pleasure. *EMBO reports*, *18*(3), pp.359-362.

[14] Keeler Jr, K.R., 2020. Video games in music education: the impact of video games on rhythmic performance. *Visions of Research in Music Education*, *37*(1), p.5.

[15] Bégel, V., Di Loreto, I., Seilles, A. and Dalla Bella, S., 2017. Music games: potential application and considerations for rhythmic training. *Frontiers in human neuroscience*, *11*, p.273.

[16] Dalla Bella, S., 2022. Rhythmic serious games as an inclusive tool for music-based interventions. *Annals of the New York Academy of Sciences*, *1517*(1), pp.15-24.

[17] Octaviani, A.W. and Irfansyah, I., 2021, December. Formal Game Element Analysis of Rhythm Fighting Game. In *ICON ARCCADE 2021: The 2nd International Conference on Art, Craft, Culture and Design (ICON-ARCCADE 2021)* (pp. 243-251). Atlantis Press.

[18] Bégel, V., Seilles, A. and Dalla Bella, S., 2018. Rhythm Workers: A music-based serious game for training rhythm skills. *Music & Science*, *1*, p.2059204318794369.

[19] Brett, J., Gatzidis, C. and Davis, T., 2025. Graveyard Symphony; A Study Investigating the Effectiveness of a Prototype Music Game. *ACM Games: Research and Practice*, *3*(1), pp.1-24.

[20] Barate, A., Brugaletta, A. and Ludovico, L., 2023. A Mobile Serious Game to Foster Music Sight Reading with Different Clefs. In *Proceedings of the 15th International Conference on Computer Supported Education. 1: CSME* (pp. 397-403). SCITEPRESS

[21] Fiveash, A., Bella, S.D., Bigand, E., Gordon, R.L. and Tillmann, B., 2022. You got rhythm, or more: The multidimensionality of rhythmic abilities. *Attention, Perception, & Psychophysics*, *84*(4), pp.1370-1392.

[22] Kylie, P., Michael, D., Eric, L. and Hay, K., 2011. The Nirvana effect: Tapping video games to mediate music learning and interest.

[23] Zong, L., Shannon, T., Rhythm Hell. 2023. Retrived from https://rhythmhell.itch.io/rhythm-hell

[24] Isbister, K., 2019. PaRappa the Rapper. *How to Play Video Games*, *1*, p.134.

[25] Leafo. 2016. Sight Reading Trainer. Retrieved from https://sightreading.training/

[26] ibisPaint. 2011. Retrieved from https://ibispaint.com/

[27] https://docs.unity3d.com/2022.3/Documentation/ScriptReference/AudioSource.html

[28] https://docs.unity3d.com/2022.3/Documentation/ScriptReference/AudioSource-timeSamples.html

[29] https://docs.unity3d.com/2022.3/Documentation/ScriptReference/JsonUtility.html

[30] ABC Notations. https://abcnotation.com/